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Speed of Reading Texts in Arabic and Hebrew

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Table of Contents

List of Tables

List of Figures

Abstract

We examined text reading by Arabic and Hebrew adults, together with measures of single word and nonword reading, letter naming, and visual processing. Participants read complex and simpler texts aloud and silently in their first language. Arabic speakers also performed some of the tasks in Hebrew. We measured reading speed and its relationships with component abilities. The results show that Arabic speakers read complex texts in Arabic more slowly than Hebrew readers read in Hebrew. Arabic speakers read complex texts in Hebrew more slowly than complex texts in Arabic, even though they performed the letter naming and visual tasks equivalently in the two languages. The groups reveal different patterns of relationships between the measures of components of reading and speed of reading aloud. For both, the best predictor is efficiency of reading single words, with speed of letter naming adding to the prediction in Hebrew, but not in Arabic. No variable had a significant contribution to the prediction of speed of silent reading. The results suggest that even though lower level processes such as letter and word identification may be simpler to perform in Hebrew than in Arabic, higher level processes required to comprehend a complex text, are faster in the first language of the participants. Both the characteristics of the text, such as its structural and semantic complexity, and the characteristics of the orthography play a role in the quality of reading. The relationship between the top-down and bottom-up components of reading is dynamic, and specific to orthographic factors and the sociolinguistic environment of the readers.

Speed of Reading Texts in Arabic and Hebrew

Arabic is the fourth most spoken language in the world, and is the official language of some 25 countries, with nearly 400 million speakers. It is also one of the most popular segmental scripts, used to write other languages (Persian, Urdu, and Pashto) in addition to Arabic, which are used by millions more. However, the study of how Arabic script is processed has only lately become a focus of research (Saiegh-Haddad & Joshi, 2014).

Overall, the countries in which Arabic is the major language have relatively low levels of literacy among both adults and children, even when economic measures would not predict this (Mullis, 2011; Myhill, 2014). In addition, recent findings have shown that learning to read in Arabic is more challenging than in other languages (e.g., Saiegh-Haddad, 2003, 2007; Saiegh-Haddad, Hadieh, & Ravid 2012; Assad & Eviatar, 2013, 2014). Several sources have been put forward for these patterns: The first is the diglossic situation into which Arabic speakers are born, wherein one form of Arabic is used in everyday life (Spoken Arabic: *Ammia*), and another form of Arabic (*Fusha*, also known as Literary, or Modern Standard Arabic), is universally used in the Arab world for formal communication and writing. The difference between Spoken Arabic (SA) and Modern Standard Arabic (MSA) was the prime example in Ferguson's seminal definition of diglossia (Ferguson, 1959). The second source of difficulty has been suggested to be related to the orthography of Arabic (Eviatar, Ibrahim, & Ganayim, 2004; Eviatar & Ibrahim, 2004; Ibrahim & Eviatar, 2012; Rao, Vaid, Srinivasan, & Chen, 2011), which has been shown to be processed differently from the Latin, Devanagari, and Hebrew orthographies. These are detailed separately below.

Diglossia

Arabic has two forms: spoken and written. SA is a local dialect that has no formal written form. SA is the native language of all native speakers of Arabic, while MSA is taught in school in parallel with learning to read and write. Although they share a subgroup of words, the two forms of Arabic are phonologically, morphologically, and syntactically different. For example, certain vowels exist in SA, but not in MSA; in SA words may begin with two consecutive consonants or with a consonant and a 'schwa', whereas this is illegal in MSA; the two forms utilize different inflections (such as plural markings) and different insertion rules for function words; and the two forms have different word order constraints in sentence structure. With all this, the two forms of Arabic are intertwined in everyday life: Young children are exposed to MSA via children's books and cartoons; MSA is the language in which news is reported (both written and oral) and it is the language of formal public occasions.

Saiegh-Haddad (e.g., 2007) has shown, with a series of studies, that elementary school children have a harder time decoding the phonology of letters that represent sounds that do not appear in their SA vernacular. In addition, it has been shown that although young Arab children, who have been exposed to MSA, function as bilinguals on tests of metalinguistic awareness (Eviatar & Ibrahim, 2000), this metalinguistic advantage does not carry over to advantages in the acquisition of reading (Ibrahim, Eviatar, & Aharon-Perez, 2007). Although their scores on tests of phonological awareness in kindergarten are higher than those of monolingual Hebrew speakers, their scores on tests of reading achievement in first grade are lower. These findings have been interpreted as reflecting the higher complexity of Arabic orthography as compared to Hebrew orthography.

Confusing matters even more, in a fascinating recent development, due to the prevalence of computer mediated communication, young people have begun to write SA, either in Latin, Arabic, or, in Israel, Hebrew, letters, a phenomenon known as 'Arabizi'. This ubiquitous habit is still frowned upon by older Arabic speakers, and only recently has begun to be studied (e.g. Allehaiby, 2013; Bianchi, 2012).

Orthography

Research on orthographic processing of Arabic has shown that Arabic letters are identified more slowly by Arabic readers than Hebrew and English letters by readers of those languages (Eviatar & Ibrahim, 2004). Divided visual field studies, that can examine relative cerebral hemispheric contribution to task performance, suggest that the right hemisphere may be less involved in letter (Eviatar, Ibrahim, & Ganayim, 2004) and word identification (Ibrahim & Eviatar, 2011) in Arabic than in English or in Hebrew among native readers of these three languages. It has also been shown that Arabic speakers who also know Hebrew, identify Hebrew letters faster than Arabic letters (Ibrahim, Eviatar, & Aharon-Peretz, 2002). Using the Trail Making Test, that study showed that Arabic speaking adolescents (16 year old 10th graders), who are also highly fluent in Hebrew, perform this task faster with Hebrew letters than with Arabic letters. Vowel detection experiments with 8-9 year old (3rd grade) and 11-12 year old (6th grade) readers of Arabic revealed that although neither group can read Hebrew fluently, they can detect vowels faster in the context of Hebrew words than in the context of Arabic words. In addition, even the 6th graders in this study did not show a word superiority effect in Arabic (Abdelhadi, Ibrahim, & Eviatar, 2011). We suggested that this occurs because of the visual complexity of the Arabic orthography as compared to the Hebrew orthography.

In Hebrew, printed letters are forms based on variations of a square. In Arabic the complexity of letter shapes is much higher. The majority of letters are connected to their neighbors from both sides (right and left), except for six letters (ا ـد ـذ ـر ـز ـو). These are connected only from their right side (the side from which reading progresses), so that most words consist of both connected and unconnected elements. Although there are 28 letters in the Arabic alphabet, there are only 17 different basic shapes. These, in combination with dots, represent different letters (e.g. the Arabic letters representing /t/, /n/, /th/ and /b/, are represented by the following graphemes: ت, ن ,ث, ب ; the letters representing /r/ and /z/ are represented by the graphemes ر and ز ; the letters representing /f/ and /k/ are represented by the graphemes ف and ق and there are many more examples). In addition, 23 of the 28 letters in the alphabet have four shapes each: word initial or medial following a nonconnecting letter (هـ=/h/), medial when they follow a connecting letter (ـهـ=/h/), final when they follow a non-connecting letter, (ه= /h/) and final when they follow a connecting letter (ـه=/h/). Six letters have two shapes each, final and separate. Thus, the grapheme phoneme relations are quite complex in Arabic, with similar graphemes representing different phonemes, and different graphemes representing the same phoneme.

Recently, a study by Rao, Vaid, Srinivasan and Chen (2011) examined the effects of visual complexity in Urdu and Hindi. Although the spoken forms of the languages are very similar, they use very different writing systems. Urdu is written in an orthography based on a modification of Arabic script, and is read from right to left. Hindi is written in Devanagari, which is less visually complex, in which the relationship between letters and sounds is more straightforward, and is read from left to right. The authors tested the speed and accuracy of reading single words in the two languages by Urdu-Hindi bilinguals. They report 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 words were consistently slower and more error-prone than for Hindi words. The authors suggested that this is due not only to the differences in letter-sound relations in the two writing systems, but also because the orthography in which Urdu is written is visually more complex than the orthography in which Hindi is written.

The Present Study

Reading text is a complex skill that requires the reader to rapidly access and integrate information from both top-down representations such as lexical knowledge and sentence context, and bottom-up processes that decode orthographic patterns on the page. There is a consensus that the speed and fluency with which this integration occurs is crucial for the quality of text comprehension (e.g., Perfetti, 1985; Samuels, 2012). All previous studies on reading Arabic have examined single word or single sentence reading. Given the findings that diglossia affects reading acquisition, and that the orthography itself may be difficult to process, together with the low literacy rates in Arabic speaking countries, the goal of the present study was to measure reading speed, accuracy and comprehension of Arabic texts among Arabic speaking undergraduates. The measures of reading in this group were compared to reading speed, accuracy and comprehension by Hebrew speaking undergraduates. We also measured performance in letter and word identification tasks, to try to clarify the relationships between these and text reading abilities in these groups. In addition, because all the Arabic speakers were also highly functioning bilinguals, we compared their reading speed and comprehension in Arabic and in Hebrew.

The comparison with Hebrew is important because Arabic and Hebrew are both Semitic languages and share morphological, semantic, and syntactic structures (Berman, 1980; Ravid, 2003; Shimron, 2003). In both languages, the most common feature of morphology is the root and template form. Both languages are inflected, with morphemes consistently sharing common semantic, grammatical, and syntactic functions. For example, marking definiteness by the prefix *ha*– in Hebrew and the prefix *al*– in Arabic, in the same morphosyntactic conditions, such as that the noun after a direct object marker must be definite (e.g., Snyder & Barzilay, 2008). In both languages, nouns and verbs are inflected for gender and number, and verbs are also inflected for person and tense. All nouns in Arabic and Hebrew belong to one of two grammatical genders. In both languages, masculine singular nouns are typically unmarked whereas feminine singular nouns are usually identified by suffixes

(Berman, 1978; Aboul-Fetouh, 1969). It has been suggested that morphologically, Arabic is more complex than Hebrew (Ravid & Farah, 1999, 2009; Saiegh-Haddad, Hadieh, & Ravid, 2012). For example, Hebrew distinguishes only between singular and plural noun forms, whereas Arabic has inflections for singular, plural, dual, and collective nouns. The use of the bound possessive as a grammatical category is quite rare in Hebrew, being acquired with the onset of literacy (after age 6, Ravid & Berman, 2009), but extremely common in Arabic (and acquired by age 2, Isaaq, 2010).

Thus, SA and Hebrew are very close typologically, with Arabic being somewhat more complex in terms of morphology. Schwartz et al. (2016) have shown that Hebrew speaking kindergarteners who have been exposed to Arabic in bilingual educational settings reveal accelerated morphological processing in Hebrew, and have suggested that this is a result of their experience with the more complex system in Arabic. There are also similarities between Hebrew and MSA: The writing systems of the two languages are both abjads (Daniels, 1990), where letters represent mostly consonants and vowels are optional, and they are read from right to left. Both writing systems include a vowelled version, in which these are indicated as diacritics appearing above, below, and within the letters. In both languages, the diacritics are used only in children's books, poetry, and liturgical texts, while the majority of texts seen by adults are unvowelled. In both Arabic and Hebrew, children learn to read using the vowelled version of the script, and the diacritics are gradually eliminated. This occurs during 2nd grade for children learning to read Hebrew and in 4th grade for children learning to read Arabic.

The study presented here compared two groups of undergraduates (one group with Hebrew as their native language and one with Arabic as their native language) on a series of tasks that are related to reading. We examined performance on the Trail Making test and the Rapid Access Naming test, which measure processing of visual letters. Measuring performance on the Trail Making Task constitutes an attempt to replicate the results of a previous study with adolescent Arabic-Hebrew bilinguals (Ibrahim et al., 2002). We also measured accuracy and speed of single word and nonword reading, the accuracy of reading text aloud, and most importantly, speed of silent reading for comprehension. The Arabic speakers, who are highly fluent bilinguals, performed the tasks in both Arabic (all of the materials were in MSA) and in Hebrew. All of the participants were university students, and most of the texts were taken from the Psychometric Entrance Test (PET), which is used as an entrance exam for universities in Israel. All of the participants had passed the exam with grades high enough to allow them to enter the university. All of the texts were unvowelled, and were presented in both languages. Our hypothesis is that all other things being equal, texts in Arabic would be read more slowly than texts in Hebrew. In addition, given previous findings with children in which phonological abilities predicted reading in Hebrew better than reading in Arabic (Ibrahim et al., 2007), and adults, in which differential hemispheric involvement was found in letter and word identification between readers of Hebrew and of Arabic (Eviatar et al., 2004; Ibrahim & Eviatar, 2012), we examined the correlations between letter and word identification tasks and text reading in the two language groups.

Method

Participants

The participants were 125 students from the University of Haifa. The students were recruited by advertising on campus, and were undergraduates whose native language was either Hebrew or Arabic, and had no learning disabilities. Six participants were excluded after data collection (1 was dysgraphic, 2 had lived for a significant time abroad, and 3 for technical reasons). Of the remaining 119 participants, 58 were native Hebrew speakers (33 females) and 61 were native Arabic speakers (48 females). All received monetary compensation: 60 NIS for the Hebrew speakers and 80 NIS for the Arabic speakers (because they also did some of the tasks in Hebrew).

Materials

Some of the tasks were performed with paper and pencil, and some were computerized. For Arabic, we used Yagut XB font, which is clearer than the one provided by the regular Office software, and seemed the most similar to the David font used for the Hebrew texts. The tasks used are listed below, with a brief description.

Demographics Questionnaire

This questionnaire was composed of 30 questions, examining demographic information and reading habits. The results of comparing the two groups on these variables are shown in Table 1.

Table 1. Distribution of responses to demographic questions and tests of differences between the two language groups

		Arabic	Hebrew	Overall	Significant difference
Parent income	Low	24	8	32	$\chi^2(2, N=112)=13.37$ $p<.01$
	Medium	18	34	52	
	High	16	12	28	
Years of schooling (Mother)	8	7	0	7	$\chi^2(4, N = 118) = 28.16$ $p < .01$
	10	14	2	16	
	12	17	26	43	
	15	20	13	33	
	20	3	16	19	
Years of schooling (Father)	8	1	0	1	$\chi^2(4, N = 118) = 14.94$ $p < .01$
	10	17	5	22	
	12	18	27	45	
	15	23	16	39	
	20	2	9	11	
Number of books in childhood house	0-25	12	3	15	n.s.
	26-100	18	17	35	
	101-200	17	17	34	
	More than 200	14	19	33	
Frequency of book read to participant during childhood	Did not read	2	1	3	$\chi^2(3, N = 101) = 12.40$, $p = .01$
	1-2 a month	7	11	18	
	1-2 a week	27	12	39	
	Almost every day	13	28	41	
Number of books read annually (not for school)	0	12	4	16	n.s.
	About 4	26	22	48	
	About 20	4	3	7	
	About 50	19	29	48	
Number of minutes spent reading daily	1-15	12	10	22	n.s.
	16-30	13	14	27	
	31-45	9	11	20	
	46-60	9	11	20	
	More than 60	16	12	28	
Participation in a "fast reading" course	Yes	16	2	18	$\chi^2(1, 119) = 12.02$, $p < .01$
	No	45	56	101	

It can be seen that although the two groups differ on several key demographic variables related to exposure to reading in childhood, these differences did not seem to carry over to adulthood.

Nonverbal Intelligence

Raven's Colored Progressive Matrices (RCPM; Raven, 1995): The test comprises 36 multiple choice items in which participants must choose a match to a given design. The accuracy of responses was measured. The test measures nonverbal reasoning and has been used to estimate nonverbal intelligence. The internal validity of the test has been reported to range from .80 to .90 (Strauss et al., 2006). The test was done using the original hard copy cards of the task.

Visual Processing of Letters

Trail Making Test (part B) (Reitan, 1971): The test measures processing of visual information, short term memory and cognitive flexibility. Participants are presented with the numbers 1-13 and the first 13 letters of the alphabet and asked to connect them in alternating serial order (1-A-2-B-3-C etc.). The Hebrew speakers performed the test in Hebrew and the Arabic speakers performed it twice, once in each language. The time to complete the task was measured. This is a paper and pencil task.

Rapid Access Naming (RAN): The test consists of a sequence of 50 letters that are arranged in 5 rows of 10. The task requires participants to name the letters as fast as they can. The Hebrew speakers performed the test in Hebrew and the Arabic speakers performed in both languages. The stimuli were presented on a page and we measured the time taken to name all the letters.

Single Word and Nonword Reading

Each stimulus was presented in the center of the computer screen for 6 seconds, and participants were asked to name it, and then press the space bar to proceed to the next trial. The accuracy of the responses was recorded by the experimenter, and the mean speed of reading was computed using a computer program that measured the time from the presentation of the word until the utterance ended. The mean time and accuracy for reading each word was computed for each participant.

Nonwords: In each language, we created a list of 35 nonsense words that followed the phonotactic constraints of both Hebrew and Arabic. The stimuli were created to sound as much alike in the two languages as possible. The nonwords were presented in vowelled form, such that all the information necessary for accessing their phonological form was available. Cronbach‘s alpha measures for the nonword task were .95 for Arabic and .97 for Hebrew.

Single Words: The stimuli for this task were constructed in two stages. First we compiled a list of 35 common words in Arabic. Two different lists in Hebrew were derived from the list in Arabic. The first, the *phonemic list*, was composed of Hebrew words that sound similar to the Arabic words (same number of syllables, same pattern of CVC structure). The second, the *semantic list*, was composed of translations of the

Arabic words. Arabic speakers read the Arabic list, and Hebrew speakers read both of the lists in Hebrew. Cronbach's alpha measures for the words in the Arabic task was .97. In Hebrew, alpha for the phonemic list was .97 and for the semantic list was .98. The frequency of the words in Arabic was estimated using the corpus from http://corpus.leeds.ac.uk/list.htm, but only 27 of the 35 words were found there. The frequency of the words in Hebrew was estimated using a corpus containing 644 texts (approximately 1 million words) from various sources. The average frequencies of the lists were: Arabic=21.20 per million; Hebrew phonetic list= 21.05 per million; Hebrew semantic=24.94 per million. Comparisons of the frequencies revealed that the frequency of the words in the Hebrew phonetic list were not significantly different from the frequencies of the words in the Arabic list, $p>.9$. However the frequencies of the words in the Hebrew semantic list were higher than those in the Arabic list, $p=.08$, and significantly higher than the Hebrew phonetic list, $p=.03$.

Text Reading

We used six different texts. Four texts were taken from previous versions of the PET in Hebrew and in Arabic. The texts in Hebrew were shown to be of equal difficulty using a computerized analysis (NiteRater, 2007). The texts in Arabic were matched to the texts in Hebrew as much as possible in content and length. Two texts were taken from the PISA 2006 administration - a well-known international standardized assessment of reading, math and science literacy for 15 year olds. Since the texts were meant for 15 year olds, we expected them to be somewhat easier than the PET texts. Slight editing was done on the Arabic versions, to suit them for the Israeli Palestinian sample. The correlations between the reading times of the PET texts and the PISA texts were .863 for Hebrew readers and .645 for Arabic readers.

Overall, the texts in Arabic were longer than the texts in Hebrew. Table 2 shows the topic and the number of words in each of the six texts in Arabic and in Hebrew. In order to equate the measure of reading speed across the different texts, for each participant, the time taken to read each text was divided by the number of words in the text and then multiplied by 200, producing a measure that represents reading speed for 200 words.

Table 2. Length of matched texts in Hebrew and Arabic

Topic (source)	Number of words in Hebrew	Number of words in Arabic
Linguistics (PET)	183	205
Learning (PET)	211	242
Brain (PET)	225	250
Emotions (PET)	179	207
Influenza (PISA)	182	210
Ethics (PISA)	205	227
Mean	198	224

The texts were counterbalanced across the groups. Each group was divided randomly into two sub-groups, and the specific texts were assigned so that each text appeared in each condition (reading aloud or silently) for each group. The Hebrew speakers read two texts each, one aloud and one silently, and the Arabic speakers read four texts each, one aloud and one silently in each language. The silent reading task included a comprehension question to induce motivation for serious reading

Procedure

The participants were tested individually in a quiet room on campus. The experiment took approximately 40 – 60 minutes, at the end of which, the participants received payment and were debriefed. All of the participants completed the tasks in the following order:

Demographic questionnaire (in the native language, L1)

Single non-word naming (in L1)

Single word naming (in L1)

Reading aloud: PET text (in L1)

Reading aloud: of PISA text (in L1)

Reading silently: PET text (in L1)

Reading silently: PISA text (in L1)

Arabic speakers only:

Reading aloud: PET text (in Hebrew, their L2)

Reading aloud: PISA text (in L2)

Reading silently: PET text (in L2)

Raven's Colored Progressive Matrices Trail Making Test

Rapid Access Naming (RAN) Test

Results

The scores of the two groups were compared for each of the measures. Recall that for some of the tasks, the Arabic speakers, who are bilingual, performed the tasks in both Arabic and in Hebrew. This allowed us to compare the two groups when both performed the task in their native language, when both performed the task in Hebrew, and also a within-subject comparison in the Arabic speaking group, comparing their performance in Arabic and in Hebrew. Table 3 summarizes the main results from these analyses.

Nonverbal Intelligence

The scores of the two groups on the test of nonverbal intelligence, the Raven's Progressive Matrixes test (Hebrew speakers=32.67 SD=2.60; Arabic speakers= 32.49, SD=2.23) revealed that they were not significantly different from each other, $t_{(117)}=-0.41$, $p=.68$.

Visual Processing of Letters

A. Trail Making test:

Both groups in L1: Comparison of the groups when both performed the task in L1 revealed that there was no significant difference between the groups in accuracy ($p=.10$), but the Hebrew speakers performed the task significantly faster (M=57.91s, SD=24.13) than the Arabic speakers (M=71.79s, SD=24.86), $t_{(117)}=3.99$, $p<.001$.

Both groups in Hebrew: Recall that here the Arabic speakers performed the task in their L2. The comparisons revealed that there was no difference between the groups in accuracy ($p=.26$), but the Hebrew speakers performed the task significantly faster (M=57.91s, SD=24.13) than the Arabic speakers (M=74.52s, SD=18.34), $t_{(117)}=4.24$, $p<.001$.

Arabic speakers in Hebrew and Arabic: As can be seen from the means reported above, the performance of the Arabic speakers was equivalent in the two languages ($p=.39$). The correlation between performance in the two languages was medium sized and significant, $r=.38$, $p<.005$.

B. Rapid Access Naming test

Both groups in their L1: Comparison of the two groups performing in L1 revealed that Hebrew speakers (M=12.62s, SD=2.02) performed significantly faster than Arabic speakers (M= 14.05s, SD=2.29), $t_{(117)}=3.59$, $p<.001$.

Both groups in Hebrew: We compared the mean of the Hebrew speakers (reported above) to that of the Arabic speakers performing the task in their L2, (M=13.85s, SD=2.23). This difference was also significant, $t_{(117)}=3.15$, $p<.001$.

Arabic speakers in Hebrew and Arabic: The within-subject comparison for the Arabic speakers performing the task in L1 and L2 yielded no significant difference ($p=.45$). It is notable that the actual time taken to perform this task in L1, Arabic (14.05s) is slightly longer than it is in L2, Hebrew (M=13.85s). The correlation between performance in the two languages was high, $r=.60$, $p<.0001$.

C. Summary:

Although there were no differences between the groups in accuracy, all the measures of RT revealed that Hebrew speakers performed the tasks faster than Arabic speakers, and that the performance speed of Arabic speakers in Arabic (L1) and in Hebrew (L2) was equivalent and positively correlated in the two languages.

Single Word and Nonword Reading

These tests were performed by the groups only in L1. We compared RT (in seconds), percentage of errors, and the Inverse Efficiency Score (IES), which is the ratio of RT to accuracy (1- percentage of errors). Because three comparisons were done for each dependent variable, we used the Bonferroni correction, yielding an alpha of .0167.

A. Nonword reading: There were no differences between the groups in RT, (Arabic speakers: M=2,178ms, SD=450; Hebrew speakers: M=2,297ms, SD=521; $p=.21$), or in percentage of errors (Arabic speakers: M=15.39%, SD=7.2%; Hebrew speakers: M=11.93%, SD=12.2%; $t_{(117)}=1.89$; $p=.06$); and no difference in IES (Arabic speakers: M=23.01, SD=5.3; Hebrew speakers: M=24.12, SD=6.1; $p=.31$).

B. <u>Single word reading, phonemic equivalent list</u>: No differences were found between the groups in RT, (Arabic speakers: M=1,454ms, SD=358; Hebrew speakers: M=1,451ms, SD=428; p=.93); there was a significant advantage for the Hebrew readers in percentage of errors (Arabic speakers: M=8.1%, SD=5.0%; Hebrew speakers: M=2.2%, SD=2.9%; $t_{(117)}$=7.86, p<.001); and no difference in IES (Arabic speakers: M=15.89, SD=3.7; Hebrew speakers: M=14.63, SD=4.3; p=.6). Recall that the frequencies of the words in the two lists were equivalent.

C. <u>Single word reading, semantic equivalent list</u>: There was no difference between the groups in RT, (Arabic speakers: M=1,454ms SD=358; Hebrew speakers: M=1,327ms, SD=384, $t_{(117)}$=1.87; p=.06), but a significant advantage for the Hebrew readers in percentage of errors (Arabic speakers: M=8.1%, SD=5; Hebrew speakers: M=3.5%, SD=2.6; $t_{(117)}$=5.84, p<.001). The Inverse Efficiency score also resulted in a significant difference (Arabic speakers: M=15.89, SD=3.7; Hebrew speakers: M=13.75, SD=3.8; $t_{(117)}$=2.93, p=.004). Recall that the frequency of the words in the Hebrew semantic list was higher than that of the Arabic list. For the Hebrew speakers, performance on the two lists (phonetic and semantic) was highly correlated, r=.89, p<.001.

Table 3. Descriptive and inferential statistics for comparing the performance of the two language groups

		Arabic Speakers (N=61)		Hebrew Speakers (N=58)			
Test	Measure	Mean	SD	Mean	SD	$t_{(117)}$	Sig
Raven	# correct	32.49	2.23	32.67	2.60	-0.41	>0.68
Trail Making (L1)	Time (seconds)	71.79	24.86	57.91	24.13	3.09	<.001
	% correct	97.44	4.68	98.62	2.76	-1.66	0.1
Trail Making (Hebrew)	Time (seconds)	74.52	18.34	57.91	24.13	4.24	<.001
	% correct	97.84	4.54	98.62	2.76	-1.13	0.26
RAN (L1)	Time (seconds)	14.05	2.29	12.62	2.02	3.59	<.001
RAN (Hebrew)	Time (seconds)	13.85	2.23	12.62	2.02	3.15	<.001
Nonwords reading	Time (ms)	2178	450	2297	521	-0.29	0.21
	% errors	15.39	7.20	11.93	12.20	1.89	0.06
	IES	23.01	5.30	24.12	6.10	-0.77	0.31
Single word reading, phonemic	Time (ms)	1454	358	1451	428	0.05	0.95
	% errors	8.10	5	2.20	2.90	7.86	<.001
	IES	15.89	3.70	14.63	4.30	1.83	0.18
Single word reading, semantic	Time (ms)	1454	358	1327	384	1.87	0.06
	% errors	8.10	5	3.50	2.60	5.84	<.001
	IES	15.89	3.70	13.75	3.80	2.93	0.004

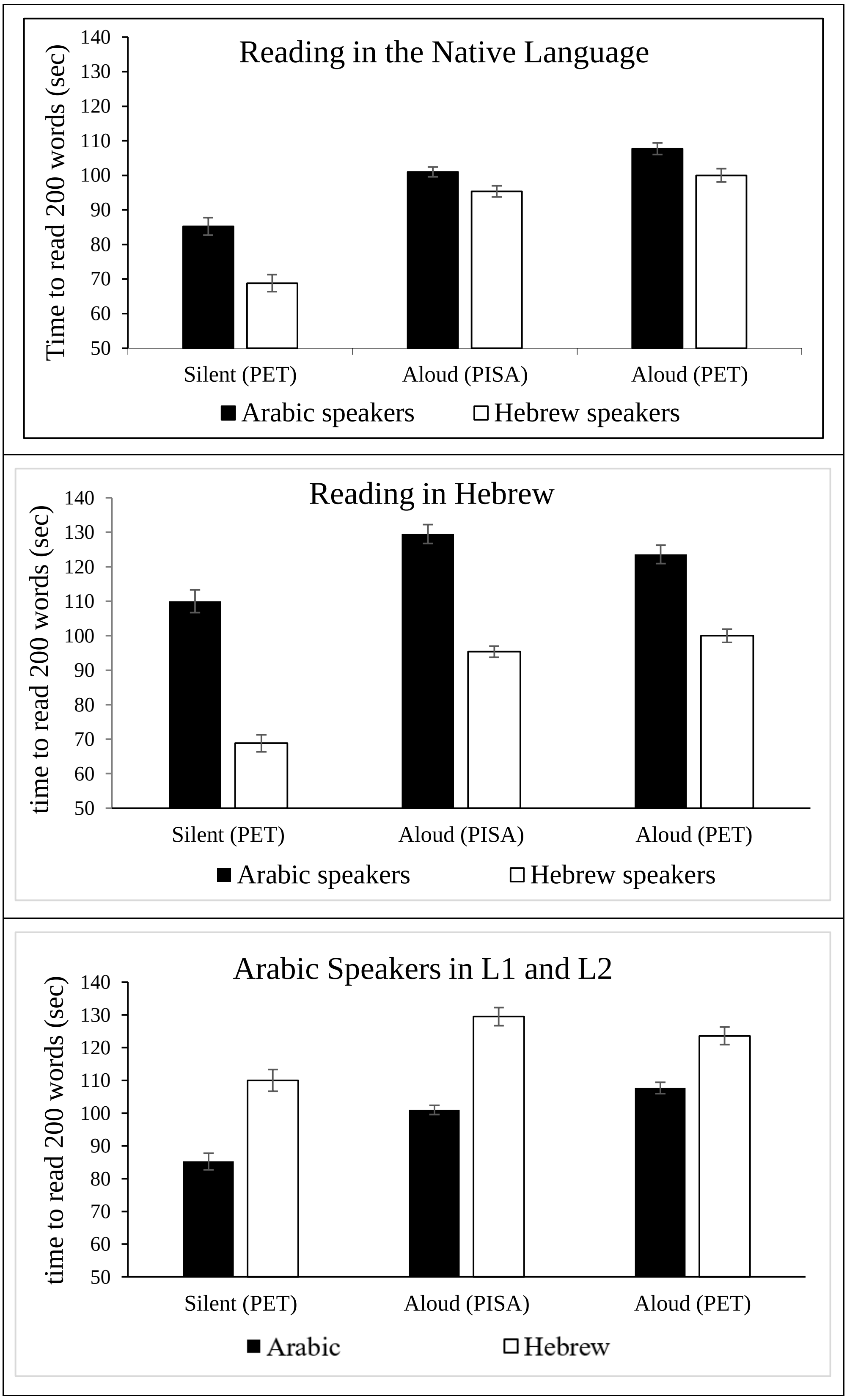
Text Reading

Recall that the texts in Arabic were a bit longer than the equivalent texts in Hebrew. In order to overcome this, the text reading time of each participant was divided by the number of words in the text, and multiplied by 200, yielding a dependent measure that estimates the time taken to read 200 words. There were three main reading tasks: Reading silently (PET texts), reading aloud the easier PISA texts, and reading aloud the more difficult PET text. The Hebrew speakers performed all the tests in Hebrew, their L1, and the Arabic speakers performed each test in Arabic and in Hebrew. This allowed us to compute three main comparisons between the groups: Reading in their native language; reading in Hebrew, and for Arabic speakers, reading in Arabic vs. reading in Hebrew. For each of these conditions we compared the groups reading silently, reading aloud the easier text and reading aloud from the more difficult text. We made 9 comparisons, so that the Bonferroni adjustment yielded an alpha of .0056. The mean reading times for each of these comparisons are shown in Figure 1, and the inferential statistics are shown in Table 4.

Table 4. Descriptive and inferential statistics for the comparisons of reading speed for texts.

Contrast	Task	Means (SD) in sec	Between subjects t statistic df=117
Each group in their native language	Silent reading (PET)	Arabic speakers=85 (20) Hebrew speakers=69 (19)	4.67, p<.0001
	Reading Aloud (PISA)	Arabic speakers=101 (11) Hebrew speakers=95 (12)	2.65, ns
	Reading Aloud (PET)	Arabic speakers=108 (13) Hebrew speakers=100 (15)	2.98, p=.0038
Both groups reading in Hebrew	Silent reading (PET)	Arabic speakers=110 (26) Hebrew speakers=69 (19)	9.89, p<.0001
	Reading Aloud (PISA)	Arabic speakers=130 (22) Hebrew speakers=95 (12)	10.52, p<.0001
	Reading Aloud (PET)	Arabic speakers=123 (21) Hebrew speakers=100 (15)	7.13, p<.0001
			Within-subject t-test df=60
Arabic Speakers reading in Arabic vs. in Hebrew	Silent reading (PET)	Arabic text= 85 (20) Hebrew text=110 (26)	-8.72, p<.0001
	Reading Aloud (PISA)	Arabic text= 101 (11) Hebrew text=130 (22)	-9.92, p<.0001
	Reading Aloud (PET)	Arabic text= 108 (13) Hebrew text=123 (21)	-5.10, p<.0001

Figure 1: Reading speed of the participants groups in each of the conditions



At the end of the silent reading condition, the participants were required to answer a comprehension question about the text. No significant differences were observed for the accuracy of the responses (p=.74). Arabic speakers responded with 80%

(SD=4.0%) and Hebrew speakers with 83% (SD=3.8%) accuracy. For Arabic speakers, there were no correlations between speed of reading in the two languages (for the PET texts, r=.03; for the PISA texts, r=.15).

Correlations between text reading and word and letter identification

One of the goals of the study was to examine the relationships between the components of reading, such as letter and word identification, and speed of text reading. To this end, we examined the relationship between measures of letter and word identification in each of the groups separately (Table 5). Because six correlations were computed, we used the Bonferroni correction which yielded an alpha of .008.

Table 5: Correlations between letter and word identification by group

Arabic speakers (in L1, N=61)	**RAN (time)**	**Trails (IES)**	**Single word reading (IES)**
Trails (IES)	.17, ns		
Single words (IES)	-.04, ns	.07, ns	
Nonwords (IES)	-.09, ns	-.03, ns	.70, p<.0001
Hebrew speakers (in L1, N=58)	**RAN (time)**	**Trails (IES)**	**Single word reading of the phonemic list (IES)**
Trails (IES)	.30, p=.02		
Single words (IES)	.17, ns	.16, ns	
Nonwords (IES)	.09, ns	-.03, ns	.23, p=.09

*IES is the Inverse Efficiency Score= time/accuracy

It can be seen that the major difference between the groups is the correlation between the efficiency of reading real words and nonwords. In Arabic, this correlation is high and significant, whereas in Hebrew it is low and not significant. These correlation coefficients are significantly different from each other, z=3.33, p<.0001.

We are interested in examining the relationships between the components of reading (letter and word identification) and the measures of text reading. Because we computed 12 correlations, we used the Bonferroni correction, which yielded an alpha of .004. Table 6 shows these relationships in the two groups.

Table 6: Correlations between letter and word identification and reading efficiency of text by group

Arabic speakers (in L1, N=61)	RAN (time)	Trails (IES)	Nonword reading (IES)	Single word reading (IES)
PET text reading aloud (IES)	.06, ns	-.13, ns	.26, p=.039	.33, p=.009
PISA reading aloud (IES)	.03, ns	-.08, ns	.19, ns	.37, p<.004
PET silent reading (time)	.13, ns	-.004, ns	.04, ns	.15, ns
Hebrew speakers (in L1, N=58)	**RAN**	**Trails Test**	**Nonword reading (IES)**	**Single word reading (IES)**
PET text reading aloud (IES)	.42, p<.004	.28, p<.05	.02, ns	.49, p<.0001
PISA reading aloud (IES)	.45, p<.004	.29, p<.05	.02, ns	.51, p<.0001
PET silent reading (time)	.10, ns	.02, ns	.001, ns	.13, ns

*IES is the Inverse Efficiency Score= time/accuracy

Interestingly, it can be seen that in both groups, speed of reading silently is not correlated with any of the measures of reading components. In the patterns of relationships with the reading aloud tasks, we again see a difference between the groups. For Arabic speakers, only the relationship between reading single words and text reading is significant, whereas for Hebrew speakers, Rapid Access Naming is also significantly related to speed of reading aloud. It can also be seen that performance on the Trails test is somewhat related to reading speed in Hebrew, but not at all in Arabic.

We computed stepwise regression analyses for all the reading tasks. The results reflect the same pattern as the correlations above. For Arabic speakers, only the IES for reading single words had a significant contribution to the variance in IES of reading text aloud of both the more difficult PET text, $F(1,59)=7.31$, $p<.01$, $R_p^2=.11$, and of the easier PISA text, $F(1,59)=9.53$, $p<.005$, $R_p^2=.14$. For Hebrew readers, the best model for the PET text included word reading ($R_p^2=.24$) and letter recognition (RAN, $R_p^2=.12$), $F(2,52)=14.99$, $P<.0001$, $R_p^2=.37$. For the PISA text, the best model included these two variables, (word reading of the phonemic list, $R_p^2=.27$; RAN, $R_p^2=.15$) with a slight addition of the Raven score ($R_p^{2=}.04$), $F(3,51)=14.52$, $p<.0001$,

R_p^2=.46. Thus, in both groups, the best predictor is efficiency of reading single words, with speed of letter naming adding to the prediction in Hebrew, but not in Arabic. None of the variables had a significant contribution to the prediction of speed of silent reading.

Discussion

The results reported here confirm that Arabic speakers read texts in Arabic more slowly than Hebrew speakers read equivalent texts in Hebrew. They do not confirm that Arabic speakers read Hebrew *faster* than they read Arabic. The two language groups were well matched on nonverbal IQ and in the frequency of reading in adulthood. The tests of letter recognition replicate previous findings, showing that whereas there is no difference in accuracy of performance of these tasks, Hebrew speakers perform them faster in Hebrew than Arabic speakers perform them in Arabic. In addition, it is noteworthy that when the tasks that were performed by the Arabic speakers in both languages, their performance in Hebrew, a language they began to learn in school in second grade (age 7-8), did not significantly differ from their performance in Arabic. These results replicate previous findings from our lab (e.g., Ibrahim et al., 2002) and support the hypothesis that letters in Arabic are harder to recognize than letters in Hebrew.

The tests of single word reading revealed that when the words in the two languages are matched for word-frequency (the Hebrew phonetic list and the Arabic list), there was no difference in speed (the difference between the groups was 3ms) or efficiency of reading, but the Arabic speakers made slightly more errors. When the Hebrew list comprised translations of the Arabic words, we found a significant advantage in efficiency, and a trend in RT (p=.06, the mean difference between the groups was 127ms), for the readers of Hebrew over the readers of Arabic. We believe that this is also a reflection of the effects of frequency (recall that the frequency of the Hebrew words was marginally higher than that of the Arabic words). How can the Hebrew and Arabic translation equivalents be different in frequency? We speculate that this may be due to the diglossia in Arabic society. Frequently used words in Hebrew are the same in spoken and written forms, but in Arabic, the written forms are different from the spoken forms, and this may result in differential frequency effects.

In tests of text reading, Arabic speakers consistently read more slowly in Arabic than Hebrew speakers read in Hebrew, except in the condition using the easier text (from the PISA 2006 exam for 15 year olds). One of the hypotheses raised by extrapolating from previous results with single letters and words, had been that Arabic speakers will read texts in Hebrew faster than in Arabic. This hypothesis was not supported. In this study participants read complex Arabic texts faster than complex Hebrew texts, even though in the tasks requiring letter recognition (the Trail Making Test and the RAN) they performed equivalently in the two languages. This finding underscores the importance of ecological validity in making generalizations about reading. Although the access of meaning from print must involve letter and word recognition, it is clear that text comprehension requires additional processes that result in different data patterns.

The correlations between the components of reading suggest that single words are recognized in different ways in Hebrew and Arabic. In Arabic, we found a high significant correlation (r=.70) between reading nonwords and real words, whereas in Hebrew this correlation is low and not significant (r=.23). These correlations are significantly different from each other. We can interpret this finding as reflecting the utilization of similar processes in reading words and nonwords in Arabic, but different processes in reading words and nonwords in Hebrew. These data converge with those reported by Abdelhadi, Ibrahim and Eviatar (2011), who showed that in a diacritic detection task, 6th graders did not show a word superiority effect in Arabic. This is a well known finding that letters (or components of words) are identified faster in real words than in nonwords (for a review see Baron, 2014). In the current study, this was true of both language groups: the difference in RT between reading nonwords and words was 724ms (SD=291) for Arabic speakers, and 846ms (SD=452) for Hebrew speakers. The difference between these means is high, but not significant (p=.0778). Thus, it may be the case that naming times of nonwords and real words in Arabic are highly correlated because they depend on similar decoding and encoding processes, where the phonological form of the stimulus is assembled via grapheme-phoneme rules (Coltheart et al., 2001). It may be the case that reading nonwords and real words in Hebrew are not correlated because nonwords must be assembled (they have never before been encountered), and words are recognized by an addressed mechanism that locates the words in an orthographic lexicon.

The hypothesis that the process of reading text aloud may be structured differently in the two languages is supported by our findings of different relationships among the tasks that tap the components of reading (letter and word identification) and speed of reading aloud. For Hebrew speakers, although there were no significant correlations between the measures of letter name accessibility (the Rapid Access Naming test) and word recognition themselves, both were significantly related to the speed of reading aloud. Above we suggested that the phonological forms of words in Hebrew were accessed via addressed phonology. Thus, a process which accesses stored representations (the names of letters and the phonological forms of words) may be tapped also when Hebrew readers read text aloud. For Arabic speakers, the measures of letter recognition (RAN) were not related to word identification, or to reading aloud. The measures of word reading are the only component that is related to reading aloud. Above we suggested that word naming in Arabic requires conversion from graphemes to phonemes, which are then assembled to produce the phonological form of the word. The process of assembling phonological forms, even when they have been encountered previously, is almost always slower than recognition of familiar forms in the orthographic lexicon (Coltheart et al., 2001). If readers of Arabic rely more on an assembling process, and readers of Hebrew rely more on an addressing process, this may explain part of the differences in reading speed.

An alternative explanation for the differences in speed in reading aloud in Hebrew and Arabic is based on differences in quantitative rather than qualitative aspects of word recognition. This is based on the finding by Frost (1995), that in Hebrew, word naming tasks, that require explicit phonological information, reveal a monotonic relationship between response time and the amount of vowel information and phonological ambiguity of the stimuli. He suggested that the insertion of missing vowel information (recall that Hebrew is an abjad with optional vowelization) and phonological disambiguation are sub-served by lexical information. Thus, word naming in Hebrew includes both assembled and an addressed processes. Because Arabic is also an abjad and these ambiguities occur also, we may assume that word naming in Arabic is also a hybrid process with both addressed and assembled components. However, there are reasons for both processes to be slower in Arabic than in Hebrew. The grapheme-phoneme conversion component may be slower because Arabic letters are visually more complex and take longer to recognize (e.g., Assad & Eviatar, 2013). The top-down lexical component may be slower because Arabic speakers are reading a language somewhat different from the one they speak. Thus, both orthographic complexity and diglossia can contribute to the slowness of reading aloud in Arabic as compared to Hebrew.

It is important to note that in both groups, none of the measures of reading components were correlated with reading silently. Frost (1995) also reported that assembled phonology effects did not occur for a lexical decision task in Hebrew, because words can be recognized without access to the complete phonological form. This, together with our findings, suggests that there is a large difference between the phonological aspects of reading aloud versus reading silently. An important limitation of this study is that the results cannot speak to processing differences in silent reading in the two languages, except to show that this is slower in Arabic than in Hebrew, when other factors are held constant.

The results of the current study have both practical and theoretical implications. In terms of practice, the results suggest that timed reading comprehension tests must take the characteristics of the orthography in which the text is written into account. Equivalent texts in different orthographies seem to make different demands on the reading faculty, that have less to do with individual differences between people, and more to do with differences between the orthographies.

In terms of theory, the study reveals that data patterns shown when individuals read single words or detect letters, do not necessarily generalize to data patterns when individuals read complex texts for comprehension. It is notable that the only condition in which the two groups, each reading in their native language, did not show a difference in reading speed, was in the condition for reading the PISA text. These texts were simpler than the other texts and here the two groups, who were equivalent in general ability, in the amount of reading they do as adults, and in their comprehension of the texts, were not different from each other. When the texts were more complex, the Arabic speakers read more slowly than the Hebrew speakers, but still read the texts in Arabic faster than the text in Hebrew.

The first finding, that Arabic is read more slowly by its speakers than Hebrew is read by its speakers, was predicted, and converges with the data from studies using simpler stimuli (e.g., Eviatar & Ibrahim, 2004). The second finding, that Arabic speakers read these complex texts in Arabic more quickly than they do in Hebrew was not predicted.

It suggests that even though lower level, bottom-up processes, such as letter and word identification, may be simpler to perform in Hebrew than in Arabic, higher level, top-down processes, such as those required to comprehend a complex text, are faster in the first language of the participants. The interplay between these types of processes is the main target of our exploration of reading. The results suggest that both the characteristics of the text, such as its structural and semantic complexity, and the characteristics of the orthography play a role in the quality of reading. This is not a novel finding. What is novel in the study's results is that this relationship between the top-down and bottom-up components of reading is dynamic, and specific to orthographic factors and to the sociolinguistic environment of the readers (such as diglossia). This is important because we controlled for the individual differences that are usually controlled for, such as general ability and amount of reading, and still found different patterns in the two languages.

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