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The influence of working memory on reading comprehension in vowelized versus non-vowelized Arabic

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Abstract Unlike English, short vowel sounds in Arabic are represented by diacritics rather than letters. According to the presence and absence of these vowel diacritics, the Arabic script can be considered more or less transparent in comparison with other orthographies. The purpose of this study was to investigate the contribution of working memory to vowelized and non-vowelized reading comprehension and determine whether working memory is more involved in non-vowelized than vowelized reading comprehension. Forty-nine Arabic speaking children from grade six (age 11) undertook two measures of reading comprehension (one vowelized and one non-vowelized). They were also given measures of word reading fluency, vocabulary, phonological awareness, rapid naming and listening span as a measure of working memory. The results indicated that both vowelized and non-vowelized texts were associated with the measure of working memory after controlling for vocabulary, word reading and phonological processing. Although the results are more consistent with common influences of working memory across the two orthographies, slightly larger effects of working memory on non-vowelized reading comprehension suggest that further research, potentially with younger cohorts of Arabic readers would be appropriate. The findings are discussed and future directions for research are suggested.

Keywords Working memory · Reading comprehension · Word reading · Arabic orthography

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Introduction

Reading comprehension is the process of extracting and constructing meaning from a written text. To achieve these two elements, the reader should have the ability to decode words quickly and accurately, then access the meaning of individual words, combine these words to construct meaningful units, and integrate these meaningful units to form text based knowledge, which is then linked with prior knowledge in long term memory to support understanding (Kintsch & Rawson, 2005; Perfetti, 1985). Thus, comprehending a text requires the integration of different skills/processes, starting with word-level processes and proceeding to higher language comprehension skills, which require vocabulary, syntactical knowledge and the ability to make inferences (Tunmer & Hoover, 1992). Hence, both measures of word reading (e.g., correctly pronouncing real words in isolation) and language understanding (such as vocabulary) have been found to be significant predictors of reading comprehension, including in studies of Arabic (see review in Elsheikh, 2012), which is the language of focus in the current study.

Evidence has also indicated that the contributions of word reading (or decoding) and language (linguistic) comprehension in promoting reading comprehension vary according to level of reading experience (Wilson & Rupley, 1997) but also across language/orthography potentially due to the transparency of the orthography learnt by the individual (Florit & Cain, 2011). Orthographic transparency here refers to the simplicity of the relationship between graphemes and phonemes: more transparent orthographies have a simpler relationship, such that a grapheme will represent a phoneme consistently and vice versa. Florit and Cain (2011) conducted a meta-analysis of 33 studies across a range of languages varying in orthographic transparency, including English which is considered as one of the least transparent (or more opaque) orthographies. In contrast to the findings for English readers, early learners of more transparent orthographies showed a greater influence of language comprehension than decoding accuracy (though not decoding fluency) on reading comprehension. The authors attributed this effect to the relatively rapid rate of decoding acquisition in readers of more transparent orthographies. This argument is supported by findings indicating that readers of more transparent orthographies reached ceiling levels in decoding accuracy within the first year of schooling (Seymour, Aro, & Erskine, 2003). In contrast, decoding accuracy for readers of English was found to be more important than language comprehension in the early stages of reading, and remained influential after 3–5 years of reading instruction, consistent with arguments that decoding skills in English develop more slowly than with more transparent orthographies (Moll et al., 2014; Seymour et al., 2003).

Further influences of orthographic depth have been found in relation to the contribution of phonological processing skills to reading (for review, see Moll et al., 2014). Phonological skills enable the reader to use grapheme-to-phoneme translation strategies reliably, meaning that the reader should be able to decode words effectively. Accordingly, the development of phonological processing skills has been found to be an important component of successful reading comprehension (Chiappe & Siegel, 2006; Everatt et al., 2010). Despite the established importance of phonological processing skills to reading, such skills have been found to differ in their relationship to literacy across different languages, which may be due (as least in part) to variations in orthographic transparency (Kirby et al., 2010; Smythe et al., 2008). For example, in a cross-sectional study comparing German and American children's reading abilities between kindergarten and second grade, Mann and Wimmer (2002) found that phonological awareness was not a predictor of reading (accuracy and speed) in German, whereas it was in English. However, such variations in the phonology-literacy relationship have not followed a simple orthographic depth explanation. For example, Georgiou, Parilla and Papadopoulos (2008), in a longitudinal study following children's reading development (from grade 1 to grade 2) in Greek and English, found that phonological awareness was a significant predictor of word reading accuracy in both Greek and English; though it was a predictor of reading speed in English only. Similarly, Everatt et al. (2010) found that phonological awareness was a predictor of literacy learning in both English and comparison, more transparent, orthographies (Herero and Filipino); though the level of prediction varied across these languages. Moll et al. (2014) lend further support to the universal role of phonological awareness in predicting reading in different orthographies (from more transparent to more opaque); though they too found that the predictive power of phonological awareness was higher in English than in more transparent orthographies. Therefore, the relationship between phonological awareness and reading may be variable across languages (and with orthographic transparency), but it is the size of the relationship that varies, not whether there is a relationship or not, suggesting that with appropriately designed studies and measures, the relationship will be identified.

Differences in the level of variability in reading predicted have also been reported for rapid automatized naming; another aspect of phonological processing in many theories (see Wagner & Torgesen, 1987). Research has suggested that rapid automatized naming is a larger predictor of reading in more transparent than more opaque orthographies (e.g., Georgiou, et al., 2008; Wolf et al., 2002). Alternately, Patel, Snowling and de Jong (2004) found that rapid automatized naming was not a significant predictor of reading (accuracy and speed) in either Dutch or English, despite their difference in transparency. Moll et al. (2014), on the other hand, found that rapid automatized naming was a significant predictor of reading in both more and less transparent orthographies; and Furnes and Samuelsson (2010) found that rapid automatized naming was a stable predictor of reading speed across school years when the child was learning a transparent orthography. Overall, therefore, the findings from studies into the role of rapid naming as a predictor of reading levels have been equivocal, with the influence of orthographic transparency also been highly variable across studies.

The influence of orthographic depth on the relationship between working memory resources and reading has also proven to be difficult to establish. As originally proposed, Baddeley and Hitch's (1974) working memory model is a hierarchical tripartite model comprised of a central executive that controls two storage subsystems: one verbal, responsible for the temporary storage of sound patterns of language, such as familiar or unfamiliar words, and one visuo-spatial, responsible for holding the visual and spatial information for short time (Baddeley, 2003). Working memory has been argued to be one of the cognitive skills necessary for successful literacy development and reading comprehension (Gathercole & Alloway, 2008; Seigneuric & Ehrlich, 2005) by providing simultaneous on-line temporary storage of information that has already been processed, while supporting the processing of additional incoming information (see also De Beni, Pazzaglia, Meneghetti, & Mondoloni, 2007). Successful comprehension may depend on the efficacy of working memory central executive functions (Conway, Cowan, & Bunting, 2001) and its role in coordinating different processes, such as in integrating text with existing knowledge in long term memory, and its inhibitory functions (De Beni et al., 2007) which preventing irrelevant, distracting information from interfering with the processing of relevant information. However, the relationship between working memory and reading comprehension may be specific to the ability to manipulate and remember verbal items (Seigneuric, Ehrlich, Oakhill, & Yuill, 2000). This view has been supported by findings that verbal working memory tasks are better predictors of reading comprehension than visuo-spatial working memory tasks (Carretti, Borella, Cornoldi, & De Beni, 2009; Daneman & Carpenter, 1980).

Since verbal working memory is responsible for storing and processing verbal information, its contribution to reading comprehension might be influenced by orthographic depth, as has been hypothesised for phonological processing. Differences in transparency across orthographies may make differential demands on children's working memory: less transparent orthographies may require the involvement of executive processes due to the complexity of decoding and variations in correspondence rules. Similarly, the differential involvement of decoding and linguistic comprehension with reading experience across orthographies (Florit & Cain, 2011) may mean that the involvement of working memory processes will also be subject to variations with reading experience and orthographic depth. However, there is a relative lack of comparative studies that have focused on the role of working memory in reading across orthographies of varying transparency. Spencer and Hanley (2003) in a longitudinal cross-language study of children learning to read Welsh (more transparent) versus those learning to read English found correlations between verbal working memory and word reading in both languages in the first year of the study but only in Welsh 1 year later (see also findings in Caravolas, Volín, & Hulme, 2005). In another study by Ziegler et al. (2010), verbal working memory was correlated with reading in Dutch, Portuguese and Hungarian, though the relationship in Hungarian, the most transparent of the orthographies tested, was the largest. In contrast, Bar-Kochva and Breznitz (2014), in a longitudinal study of vowelized & non-vowelized Hebrew with grade 2–3 children, found that working memory was more involved in reading the less transparent script (i.e., the non-vowelized version of Hebrew). Other studies have found that the contribution of working memory to reading was comparable across opaque and transparent orthographies (Alptekin & Ercetin, 2010).

In summary, findings of cross-language studies suggest that orthographic depth is related to the ease and effectiveness with which children acquire their literacy skills. Orthographic depth has also been found to affect the associations between phonological skills and reading skills. However, the role of working memory on reading across orthographies has yet to be established, especially at the text level.

Arabic is an interesting language in which to study orthographic depth since, like Hebrew, it has two types of scripts: a more transparent vowelized version and a more opaque or non-vowelized version. Both scripts are identical apart from the inclusion or exclusion of markers that represent short vowel sounds in the language. Therefore, the current study investigated the influence of orthographic depth on the contribution of working memory processes to reading at the text level within the same child and basically the same task—the only difference being the inclusion or exclusion of short vowel diacritics in the reading comprehension task. In order to understand this manipulation, it is important first to discuss the specific features of short vowels diacritics in Arabic.

The Arabic orthography is based on an alphabetic writing system. However, the letters of the Arabic 'alphabet' (sometimes referred to as an abjad) represent consonants along with long vowel sounds. Short vowels in the script are represented by diacritical markers above or below an Arabic letter/consonant. These diacritics, collectively referred to as الحركات *Alharakat*, are: الفتحة *fatha* (vowel/a/), which is indicated by a small horizontal line drawn over the letter; الكسره *kasrah* (vowel/i/), which is indicated by a small horizontal line drawn under the letter; and الضمة *Dammah* (vowel/u/), which is indicated by a small و (*waw*) drawn over the letter. Inclusion of short vowel diacritics can help the reader specify a word's phonological form, allowing the reader to pronounce it correctly in isolation. Moreover, short vowels convey the meaning of the word at morphological and syntax levels (e.g., by conveying word class, such as noun or verb forms). Hence, the absence of short vowels increases opaqueness at both the lexical and phonological level. Unvowelized text can produce a large number of homographs in Arabic, potentially requiring the reader to have to process combinations of words in order to derive the meaning (and correct pronunciation) of an individual devowelized words. In such situations, the Arabic reader is heavily dependent on context to facilitate word recognition (Abu-Rabia, 2002). Studies performed on Arabic comparing the reading process on the two types of Arabic script (vowelized & non-vowelized) suggest that processing vowelized text is easier than processing non-vowelized. Abu-Rabia (2001), in a series of studies investigating the role of short vowels on reading performances, has concluded that short vowel diacritics are significant facilitators of word recognition and reading comprehension regardless of the level of reading skill or the age of the reader, possibly due to the phonological information that the short vowels carry.

Despite the potentially useful role that Arabic diacritics play in supporting decoding during reading, there are several reasons to question the strong viewpoint that including diacritics always leads to advantages for all Arabic readers, particularly those who have had several years of experience of processing non-vowelized text. First, the visual complexity of text increases when diacritics are included in text, which may slow reading down (Ibrahim, Eviatar, & Aharon-Peretz, 2002). Additionally, the different functions that these diacritics carry out at phonological, morphological and syntax levels may be a source of confusion for some Arabic readers (Mohamed, Elber, & Landerl, 2010) and may lead to misreading and misspelling (Azzam, 1993), or to slower reading (Eviatar, Ibrahim, & Ganayim, 2004). Finally, familiarity with non-vowelized text may make it harder to process vowelized text because the skills developed to process non-vowelized words are different from those used with the vowelized form of the orthography. One of these areas of differential processing may be working memory given the need to support word processing through context when words are devowelized.

There is a general agreement that phonological processing skills play an important role in developing reading skills in vowelized and non-vowelized Arabic; and tasks assessing phonological processing skills, especially phonological awareness, are found to be significant predictors of reading skills (Elbeheri & Everatt, 2007). Similar to English, the data on Arabic have indicated differences in the contribution of phonological awareness and rapid naming to reading skills. Results argue for the influence of rapid naming to be more evident in the early stages of reading when children are exposed primarily to vowelized scripts, with this role decreasing in later stages of reading development when children are exposed to non-vowelized scripts (Taibah & Haynes, 2011). In contrast, the phonological awareness skills, especially measures of phoneme deletion, have been found to play an important role in reading regardless of the type of the script and the stage of reading development (Al-Mannai & Everatt, 2005; Elbeheri & Everatt, 2007).

Little work has been conducted to explore the impact of vowelization on the contribution of working memory to reading in Arabic, and what data there are show inconsistent results. Whereas some studies have found that working memory measures did not contribute significantly to reading comprehension in vowelized and non-vowelized text (Al-Rashidi, 2010; Elsheikh, 2012), others have found a relationship between Arabic literacy levels and working memory skills (Abu-Rabia, Share, & Mansour, 2003) and Al-Menaye (2009) found a relationship between working memory and reading comprehension for non-vowelized but not vowelized texts. Hence, although studies have confirmed the influence of vowelization on reading performance, and the role of phonological skills in reading vowelized and non-vowelized text, the contribution of working memory to reading in Arabic is still debatable. The current study, therefore, aims to investigate further the relationship between working memory and reading in Arabic by comparing the comprehension of vowelized versus non-vowelized Arabic texts, and contrasting the potential contribution of working memory against measures that have been shown to be influential on Arabic reading comprehension (i.e., phonological processing, vocabulary and word reading fluency).

Method

Forty-nine children from grade 6 (on average 11 years old) in a Kuwaiti government mainstream intermediate school for boys participated. The school was typical of intermediate schools in Kuwait at the time of testing, and was chosen due to it been known to one of the researchers and because of the willingness of staff to help with organising classroom activities around the research. Based on interviews with teachers, parents and children, Arabic was the spoken main language of home and school for all of the children, though English was a taught subject in the school consistent with the Kuwaiti government curriculum of the day. School records and teacher/parent interviews suggested that none of the children tested had reported evidence of difficulties with literacy learning or any other learning-related disability. All children at the grade level in the school were asked to participate and, therefore, lack of parent/child informed consent was the only criteria for exclusion from the study.

Procedures and measures

Measures were based on those used in previous research on both Arabic and English, and included standardized tests used with the permission of the test authors. All measures were piloted on same grade students independent of those tested in the present study prior to the work reported. Pilot work on groups of children similar to those in this study ensured that the procedures were manageable, intelligible and easy to interpret. Testing was performed either in small groups or individually, and was conducted in a quiet room away from distractions and supervised by the researcher. When group testing was undertaken, children were not allowed to talk or see each other's work. Each task was preceded by instructions, together with one or more worked examples of the task required. Items and instructions were presented in standard Arabic (the normal language of the classroom) and practice items were used to ensure understanding.

Listening span

This task assessed both the retention and the processing of linguistic information. The rationale for using listening span as a measure of working memory was that studies of Arabic have shown that digit span measures are not sensitive to working memory processes involved in reading comprehension (see Al-Menaye, 2009; Al-Rashidi, 2010; Elsheikh, 2012). Furthermore, this research has shown greater levels of prediction of comprehension by listening span versus digit span measures. This listening task was similar to the reading span task originally developed by Daneman and Carpenter (1980), given that such tasks have been associated with reading levels in previous studies of English (see Pickering & Gathercole, 2001) and that similar tasks have been used in research on Arabic (see Al-Menaye, 2009; Al-Rashidi, 2010; Elsheikh, 2012). In the present task, the assessor spoke a short sentence in Arabic to the child who was asked to state whether the sentence was true or false. Half of the sentences spoken were non-sense sentences: for example, in English "ice is hot" in contrast to a true sentence such as "scissors are used to cut paper." After hearing all the sentences in a trial, the child was required to recall the final word of each sentence in the order in which they had been presented—a nod from the assessor indicated when this second part of the task was required. After four individual sentences, the task moved to recalling the last words every two sentences. After a further four trials, recall occurred after three sentences. This increase in the number of last words retained continued until the individual failed to recall all four trials in a block, with the score being the number of trials recalled correctly. Hence, simultaneous processing and retention of information was necessary, consistent with the hypothesised function of the working memory system. This Arabic measure has reasonable reliability levels (α = .75) and has been shown to be associated with other measures of memory consistent with English language working memory batteries (Pickering & Gathercole, 2001) and current models of working memory (see Abu Al-Diyar, Everatt, Elbeheri, & Mahfoudhi, 2015).

Reading comprehension

Two parallel measures of reading comprehension were used, one incorporating vowelized text and the other non-vowelized text. Pilot work led to five vowelized (i.e., all marks were included) and five non-vowelized (i.e., short vowel diacritics not included) passages of increasing length and complexity (determined by using vocabulary from lower to high school grade textbooks). With each passage a number of comprehension questions asked the child about the content of the passage. Passages were derived from previous work on Arabic reading comprehension (Al-Menaye, 2009; Al-Rashidi, 2010) and have been shown to have good levels of reliability (see Elbeheri et al., 2013, who report alpha coefficients of .94, and significant correlations with measures of literacy, including other measures of reading comprehension). Passages were paired, in order to be allocated across the two conditions, and revised by teachers of Arabic to ensure that these pairs were matched for genre, length and general level of difficulty and that all passages were appropriate for the age range of the children in the study. Pilot work with these revised pairs of passages showed good reliability scores (alphas greater than .70). For roughly half of the participants, one of the paired passages was used in the vowelized condition, with the rest of the children experiencing the same passage in its non-vowelized form. In this way, each child experienced both vowelized and non-vowelized texts, but the versions of the task were controlled to make them as similar as possible. For each passage, the child read the passage quietly to themselves at their normal speed. They were told that they would be asked questions about the passage when they finished reading. After the child indicated that they had read the passage, the assessor read out each comprehension question in turn allowing time for the child to answer prior to moving to the next question. The child answered each question by choosing the correct answer from multiple choices. There were six comprehension questions for each passage and these comprised three literal and three inferential questions. Literal questions focused on answers presented directly in the text. Inferential questions required general understanding of the main ideas in the text and making inferences based on the text and background knowledge. For example, if the passage stated "The Dead sea is a salt lake boarded by Jordan to the east and Israel and Palestinian territories to the west," then a literal question would be "The dead sea is a … (canal–lake–ocean–port)" and an inferential question would ask, "The writer of this text is a … (priest–artist–geographer–poet)." The number of questions answered correctly was calculated so that the task produced two measures of comprehension: one score out of 30 for the vowelized condition and a second score out of 30 for the non-vowelized condition.

Word reading fluency

A list of 30 fully vowelized words in Arabic was presented to the child to read aloud. Words were clearly presented in plain type-font, in black ink on white paper. Six rows of words were presented, with five words per row. Words were taken from the reading texts used by government schools and increased in complexity by considering vocabulary examples in the textbooks, word length and pattern complexity. Examples of relatively simple items are رَكَبَ and بَيْتٍ, whereas more complex items are بِمَواقِعِها and وَالِاستْيعابَ. This sort of task has been used regularly in studies of Arabic word reading (e.g., Al-Mannai & Everatt, 2005) and the present task has shown good level of reliability (alpha greater than .90) and correlations with other measures of Arabic literacy (see Elbeheri et al., 2013). The child was asked to read out loud and clearly each word on the stimulus card so that the tester could hear their response. Children were required to start with the row of words at the top of the page (less complex, more familiar words) and to move down the page so that words of increasing grade level were encountered as they progressed. Responses were noted as correct or incorrect by the tester. The number of words read correctly and the time taken to read all the words was recorded. The number of correct words was divided by the time taken to produce a measure of fluency (i.e., words correct per second).

Phoneme deletion

This measure was used to assess the ability to recognize sounds within words (i.e., phonological awareness). The test comprised 30 real words from which a sound was to be deleted. Sounds were deleted from the first (say "cat" without the sound represented by "c"), middle (say "king" without "n") or final (say "push" without "sh") position within a word. The number of items pronounced correctly out of 30 was used as the measure for this task. Again, this sort of task has been used regularly in work investigating Arabic reading ability (Al-Menaye, 2009; Elsheikh, 2012; Al-Mannai & Everatt, 2005), and has been found to show good levels of reliability (alphas greater than .85) and to be related to other measures of phonological processing (see Taibah et al., 2011).

Rapid naming

This measure was used to assess children's ability to retrieve a phonological code from long-term memory. The test items comprised of an array of letters in their stand-alone shapes (4 repetitions of 10 familiar letters). Familiarity with letter names was ensured prior to testing by showing each Arabic letter individually to the child and asking them to name the letter. Letters were presented as black type font on white paper and were presented on a single line but with 2 spaces between each letter. Children were asked to start with the right-hand letter and read each item from right-to-left following their normal reading practice. The number of seconds spent in naming the array was the score of the task. Such rapid naming tasks have been frequently used in studies of Arabic (Taibah & Haynes, 2011), and have shown good correlations with other measures of rapid naming ($r > .65$ with rapid object naming) and phonological processing (see Taibah et al., 2011).

Vocabulary

This measure assessed the children's knowledge of word meanings. The child was given 40 separate sentences with one word underlined in each. At the end of each sentence a phrase provided a potential meaning of the underlined word and the child was asked to judge whether this phrase explained the meaning of the underlined word or not. For example, an English translation of an item would be, "Ahmed **designed** an interesting programme on his computer; the underlined word means 'insist on'" with the answer being no. The task was based on Nation (2001) and this Arabic version was developed from curriculum textbooks used in schools in Kuwait (these are government-produced textbooks that are used by all government mainstream schools in the country). A vocabulary for each grade level is provided in these textbooks and the current items were taken from these vocabularies, with items starting at the grade level of the children in the current study and progressing to higher grade levels. Previous research using such a task (Elsheikh, 2012) and pilot work to the current study shows that this measure has reasonable reliability (alphas greater than .70). The number of correct responses was the score for the task.

Results

The results of the study can be found in the following tables. In Table 1, descriptive statistics for the measures are presented. First order correlations (Pearson coefficients) between all the measures are then presented in Table 2. Finally, regression analyses are presented in Tables 3 and 4.

As shown in Table 1, children's performance in non-vowelized reading comprehension was better than their performance in vowelized reading comprehension. A related samples *t* test revealed that this difference between the two forms of reading comprehension was significant ($t_{(48)} = 3.88$, $p < .01$).

Pearson correlation coefficients were calculated primarily to determine the relationship between comprehension measures and the other measures in the study. As shown in Table 2, the two forms of comprehension measures (vowelized and non-vowelized) were correlated with each other, and they were correlated with all measures used in the study except the rapid naming measure. The other measure of primary interest was the working memory measure (listening span) and this was significantly ($p < .05$) correlated with all measures used in the study, including the two reading comprehension measures; though the correlation with non-vowelized reading comprehension was larger than that for the corresponding vowelized text analysis.

In order to determine specific, unique influences of working memory on reading comprehension, linear regression analyses were performed for each type of reading comprehension measure. One set of regression analyses used vowelized reading

Table 1 Descriptive statistics: means and standard deviations with minimum and maximum scores

Variables	Mean	SD	Minimum	Maximum
Vowelized reading comprehension	21.18	6.10	8.00	30.00
Non-vowelized reading comprehension	23.35	4.80	11.00	30.00
Vocabulary	28.49	5.33	15.00	37.00
Word reading fluency	0.60	0.31	0.16	1.69
Phonological awareness	22.61	4.38	13.00	29.00
Rapid naming	21.10	6.48	13.00	40.00
Listening span	7.30	1.54	5.00	11.00

Table 2 Correlations between the comprehension measures and the other measures used in the study

	Vowel reading comp	Non-vowel reading comp	Vocab	Word reading fluency	Phono aware	Rapid naming
Non-vowelized reading comp	*.770*					
Vocabulary	*.660*	*.631*				
Word reading fluency	*.530*	*.591*	*.472*			
Phonological awareness	*.499*	*.521*	*.403*	**.325**		
Rapid naming	−.163	−.216	−.001	−.226	−.168	
Listening span	*.503*	*.556*	**.346**	*.430*	**.280**	*−.365*

Values in italics are significant at .01 level; bold correlations are significant at the .05 level

comprehension as the DV; the other used non-vowelized reading comprehension as the DV. Two hierarchical regressions were performed for each DV. In Tables 3 and 4, analyses designated by ‘I’ entered vocabulary as the first predictor variable, followed by word reading fluency, phoneme deletion and rapid naming, and finally listening span. In the analyses designated by ‘II’, the same enter procedure was followed except that the alternate measure of reading comprehension was entered as the first step in the regression. Final beta values were calculated to assess associations with reading comprehension after controlling for all other variables in the final model. These regression analyses provided evidence for the potential influence of working memory on Arabic reading comprehension, firstly controlling for vocabulary, word reading and phonological processing (including phonological awareness and rapid naming), and then, in addition, taking into account potential associations between working memory and the alternative form of the orthography.

In the analyses not including the alternative comprehension measures (‘I’ in Tables 3 and 4), listening span predicted approximately 4–5% of additional variability in reading comprehension over that explained by vocabulary, word reading and phonological processing. For the non-vowelized text analysis, the final

Table 3 Regression analysis to investigate working memory in vowelized reading comprehension

	(I) Excluding Non-vowelized Reading comprehension		(II) Including Non-vowelized Reading comprehension	
	R2 change	Final beta	R2 change	Final beta
(Non-vowelized comprehension)			.59 ($F_{(1,47)} = 68.24$, $p < .01$)	.45 ($p < .01$)
Vocabulary	.44 ($F_{(1,47)} = 36.34$, $p < .01$)	.42 ($p < .01$)	.05 ($F_{(1,46)} = 6.54$, $p = .01$)	.27 ($p = .03$)
Word reading	.06 ($F_{(1,46)} = 5.61$, $p = .02$)	.17 ($p = .18$)	<.01 ($F_{(1,45)} = .44, p = .51$)	.06 ($p = .63$)
Phonological processing	.05 ($F_{(2,44)} = 2.53$, $p = .09$)	.22[a] ($p = .06$)	<.01 ($F_{(2,43)} = .53, p = .59$)	.11[a] ($p = .32$)
Listening span	.04 ($F_{(1,43)} = 3.63$ $p = .06$)	.23 ($p = .06$)	<.01 ($F_{(1,42)} = .84$ $p = .36$)	.11 ($p = .36$)

[a] Beta is for the phonological deletion task as the rapid naming task produced values around zero

Table 4 Regression analysis to investigate working memory in non-vowelized reading comprehension

	(I) Excluding Vowelized Reading comprehension		(II) Including Vowelized Reading comprehension	
	R2 change	Final beta	R2 change	Final beta
(Vowelized comprehension)			.59 ($F_{(1,47)} = 68.24$, $p < .01$)	.41 ($p < .01$)
Vocabulary	.40 ($F_{(1,47)} = 31.08$, $p < .01$)	.33 ($p < .01$)	.03 ($F_{(1,46)} = 3.23, p = .08$)	.16 ($p = .18$)
Word reading	.11 ($F_{(1,46)} = 10.32$, $p < .01$)	.24 ($p = .04$)	.04 ($F_{(1,45)} = 4.58, p = .04$)	.17 ($p = .12$)
Phonological processing	.07 ($F_{(2,44)} = 3.51, p = .04$)	.23[a] ($p = .03$)	.02 ($F_{(2,43)} = 1.40, p = .25$)	.14[a] ($p = .16$)
Listening span	.05 ($F_{(1,43)} = 5.54$ $p = .02$)	.26 ($p = .02$)	.02 ($F_{(1,42)} = 2.60$ $p = .11$)	.17 ($p = .11$)

[a] Beta is for the phonological deletion task as the rapid naming task produced values around zero

beta score for listening span was significant (beta = .26, $p = .02$), and it approached significance for the corresponding vowelized text analysis (beta = .23, $p = .06$). When the alternative reading comprehension measures was included in the regressions, the level of variability explained by all measures reduced. For listening span, this reduction was to near zero when vowelized reading comprehension was the DV, though it was still about 2% of non-vowelized reading comprehension.

Discussion

The present study investigated the contribution of working memory to vowelized and non-vowelized reading comprehension performance of Arabic speaking sixth graders. It aimed to determine whether working memory is more involved in non-vowelized than vowelized reading comprehension. As with previous studies, findings indicated that word reading fluency, phonological awareness and vocabulary were significant predictors of Arabic reading comprehension (Al-Menaye, 2009; Al-Rashidi, 2010), suggestive of underlying commonalities in reading comprehension development across both Arabic and English (Elbeheri & Everatt, 2007).

The results were inconsistent with previous findings (Abu Rabia, 2001) in that sixth graders' performance in reading comprehension was better when reading non-vowelized text than vowelized text. One possible explanation is that despite the useful role that Arabic diacritics play in enhancing reading/decoding accuracy, they could be a source of difficulty. This difficulty may be an outcome of the visual-graphic complexity that diacritics add to the Arabic script or to the different functions that such diacritics carry when reading Arabic (Azam, 1993; Mohamed et al., 2010). Furthermore, learning experience and educational function may determine the effects of diacritics with some readers: better performance in the non-vowelized condition may reflect the degree of curricular exposure. Around grade 3, children are exposed to non-vowelized script and by grade 6 they are likely to have adapted to the general absence of vowelization, using familiarity and direct access recognition processes to read more opaque text. A main purpose of including vowel diacritics in Arabic scripts after initial years of schooling is to differentiate homographs or to ensure correct pronunciation (such as in religious texts). Accordingly, when a sixth grader is exposed to a vowelized text, the student is likely to think that the diacritics are included in order to pronounce the word correctly. Hence, when diacritics are included, the learner's main concern is to detect each letter with its diacritic, and this sequential letter-by-letter processing may lead to less efficiency in reading, particularly in reading comprehension.

The results indicated that working memory performance was associated with Arabic reading comprehension regardless of the form of script (vowelized versus non-vowelized). Furthermore, associations were maintained after controlling vocabulary, word reading and phonological measures. This would argue for working memory to play a role in written word processing beyond the level of single word recognition. The commonality of processing across the two forms of orthography is consistent with the reduction in reading comprehension explained when the alternative text form was controlled in the regression analyses. However, in each of the analyses reported, the involvement of working memory was slightly larger for non-vowelized text than vowelized text—a small and non-significant difference between the levels of relationship (given the relatively small differences in r-values and beta scores, a much larger sample would be required to show statistical significance, hence the cautious conclusion), but one which future research, with larger samples, may confirm.

While this study's findings add to and reinforce the research base on Arabic literacy, it was restricted to sixth graders. Studies following Arabic children from grade 1 to grade 6 in different cultural contexts will be central to exploring how predictors of reading for vowelized versus non-vowelized text change as Arabic learners develop their reading and language skills. In the first 3 years of the Kuwaiti curriculum, for example, textbooks comprise mainly vowelized words and in the following 3 years, the children encounter mainly non-vowelized texts. During this transition, the influence of working memory on reading is likely to vary based on the child's learning as well as familiarity and exposure to vowelized versus non-vowelized texts. Given the transparency of Arabic orthography in the early grade school years, working memory's influence may be marginal and restricted to early reading comprehension skills, and in supporting basic decoding and spelling processes. By grade four, increased working memory involvement may be needed specifically to support reading of devowelized text with its larger number of homophones and the reliance on context to support decoding (consistent with Al-Menaye, 2009). By grade six, learners' years of experience with practice reading non-vowelized orthography may lead to devowelized text processes being used independent of orthography, as found in the current study. During this period from grade 3–6, the more complex vocabulary, syntax and discourse of later grade school texts may pose greater demands on working memory. In addition, the variations in visual and orthographic complexity of vowelized versus non-vowelized text may also tap visual and/or phonological working memory. Clearly, future research is needed (potentially longitudinal in nature) to further specify the role, and perhaps changing role, of working memory in reading and comprehending Arabic text.

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