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Orthographic Processing and Reading Comprehension Among Arabic Speaking Mainstream and LD Children

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Two cohorts of mainstream children (grades 2–5) and one cohort of children with learning disabilities (LD; grades 3–5), all Arabic speaking children in Kuwait, were given measures of reading comprehension fluency and orthographic discrimination to assess the relationship between the two. Additional measures of phonological processing (decoding and awareness), speed of processing (rapid naming) and memory (visual as well as phonological/verbal tasks) were included either because these have been found to be predictive of Arabic literacy or to provide an assessment of alternative interpretations of any influence of the orthographic task. The findings indicated that the orthographic measure predicted variability in the comprehension fluency over-and-above that predicted by the other measures in the study. This was significant in the older mainstream children (grades 4 and 5) when controlling for phonological processing, but was not in the younger grades (2 and 3) where experience text that incorporating short vowel markers is dominant. The LD group showed little evidence of an influence of phonological processing but did of orthographic processing. The findings are discussed in terms of the skills required to process Arabic literacy and potential causes of literacy learning difficulties among Arabic children.

Keywords: Arabic; orthographic processing; reading comprehension; learning disabilities; literacy; phonological processing

INTRODUCTION

Orthographic Transparency and Reading Ability

Cross linguistic research on reading and reading acquisition suggests the presence of a universal account of the cognitive processes which underlie learning to read (Snowling & Hume, 2005), with the mapping between the spoken and the printed word as a central component in the understanding of this account. Whether it is the matching of phonemes to letters (as in alphabetic orthographies such as English) or the matching of morphemes to characters (as in logographic orthographies such as Chinese), reading acquisition depends on becoming skilled with sound to symbol mapping (Goulandris, 2003; Ziegler & Goswami, 2005).

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Research mainly on alphabetic scripts has indicated that orthographic transparency is an important factor when learning to read (see discussions in, for example, Goswami, 2000; Goulandris, 2003; Katz & Frost, 1992; Landerl, Wimmer, & Frith, 1997; Leong & Joshi, 1997) and is increasingly being recognized as an important factor in determining the manifestation of literacy learning disabilities (LD; dyslexia) in individuals (Smythe, Everatt, & Salter, 2004). Transparency here refers to the association between written symbols and language sounds. A transparent script has a simple one-to-one relationship, whereas less transparent scripts, such as English, have a much more complex relationship between letters and sounds. This notion of 'orthographic depth' or the degree of isomorphism in grapheme to phoneme correspondences has been influential in explaining differences in cognitive demands when processing in different orthographies (Frost, 2005; Goswami, 2000). Therefore, the relationship between orthography and phonology is seen as an important component in literacy development and most models of skilled word identification and of the development of reading hold that word identification involves at least two types of processes: phonological and orthographic.

Although studies of English speaking children have highlighted the importance of phonological awareness and the ability to decode letters into sounds as a predictor of variability in literacy acquisition (Snowling, 2000), alternative measures related to speed of processing may be better predictors of literacy levels among children learning to read a more transparent orthography, such as German (Wimmer, 1993; Wimmer & Goswami, 1994). Previous studies investigating the role of phonological processing in Arabic have been consistent in concluding that such processes are predictive of reading levels among Arabic children and that poor Arabic readers show weak phonological decoding and low levels of phonological awareness in comparison to matched normal readers. The pattern of inter-relationships between literacy and phonological awareness is consistent with conclusions derived from English speaking cohorts (see findings in Abu-Rabia, Share, & Mansour, 2003; Al-Mannai & Everatt, 2005; Elbeheri & Everatt, 2007), suggesting that models of literacy and specific literacy difficulties based on English language data may be appropriate for application to an Arabic context. However, Arabic literacy acquisition starts by using an orthography that is relatively consistent in its mapping between letters and sounds in contrast to English and this may be predicted to lead to variations from the English-language model similar to that found with some transparent orthographies (Goswami, 2000). Consistent with this, the level of prediction of Arabic literacy provided by phonological processing skills has been less than expected from previous research in other languages (Elbeheri, Everatt, Reid, & Al-Mannai, 2006, Elbeheri & Everatt, 2007). This may be due the characteristic that the Arabic written form relates to a more general form of the Arabic language (typically referred to as Modern Standard Arabic) that is not spoken in normal day life by ordinary Arabs. The home language of most Arab children is a dialectic form and most children will be expected to acquire the general/standard form of Arabic during schooling. This diglossia (see discussions in Saiegh-Haddad, 2005) may lead to confusions between different sound forms across the local dialect and the standard Arabic that the written form represents. Indeed, Saiegh-Haddad (2005) found that phonological awareness was only indirectly related to reading fluency, whereas other measures that might focus more on a direct route to lexical access had a more direct influence. Hence, phonological processing strategies may not support acquisition as well as in other more transparent orthographies. This complication may lead to students relying on other strategies to support reading, such as focusing on salient orthographic features.

However, in addition to the phonological explanation above, there are other specific reasons why orthographic processing may play an important part in Arabic literacy development. Despite the potential one-on-one correspondence between Arabic phonemes and their graphic representations, there are a number of characteristics of the written form that may over-ride the benefits of this level of transparency. First, the written forms of short vowels in Arabic are not individual, isolated letters but are diacritical markings above or below letters that represent consonants connected to the short vowel. These short vowel markers are included in vowelized forms of writing, but not in non-vowelized texts. This results in a high number of homographs in the case of non-vowelized script and a visually over-complex script when vowelized. Second, there is an overriding tendency of Arabic orthography to give precedence to morphological and syntactic clues over phonological transparency, leading to a preference for non-vowlized text, particularly after initial literacy learning school grades. Third, although the Arabic script is cursive (letters must be written connected to each other) only 22 out of the 28 letters in the alphabet connect from both sides while the remaining six connect only from one side. This orthographic feature results in two types of spaces within a text, those that occur within a word, between two-way connecting letters and one way connecting letters, and those that represent boundaries between words. Fourth, the graphical shape of each Arabic letter depends on its position in the word (initial, medial, final or isolated), with some letters having more than one standard shape of writing. Fifth, the glottal stop in Arabic, referred to as the Hamza, although a fully functioning consonant, is treated as a diacritical mark and has many different ways of writing depending on its position in the word resulting in various complex spelling conventions. Sixth, the Arabic script consists of 17 basic character forms only, with dots placed above or below various character forms making up the 28 letters of its alphabet. Dots are, therefore, extremely important and differ in their number (one, two or three) and in their position (below or above a character). Seventh, Arabic is a highly agglutinative language (i.e. one word can correspond to a whole English sentence) because negative suffixes, tense suffixes, person prefixes can all be added to the word base resulting in a highly derivational and dense morphology, which although helpful in communicating the core semantic meaning of the root embedded in various patterns, demands a lot of unpacking on the part of the reader in order to arrive at the exact meaning of an Arabic word.

The above examples of some of the challenges posed by specific linguistic features of written Arabic show that even in a language which possesses relatively regular phoneme–grapheme correspondences, there are other complexities that are likely to pose challenges for Arabic speaking readers and dyslexics alike. Therefore, the primary aim of the work reported in this paper was to assess whether orthographic processing predicts the reading of Arabic over that already identified for phonological processing, and whether this would be the same for typically developing children and those with literacy learning difficulties.

Orthographic Processing as a Predictor of Reading

Orthography is the 'system of marks that make up a printed language' (Badian, 2001) and orthographic processing has been defined broadly by Stanovich and West (1989) as 'the ability to form, store, and access orthographic representations' (p. 404). A number of researchers claim that orthographic processing skill is an additional predictor of word reading over and above phonological skills (e.g. Juel, Griffith, & Gough, 1986; Tunmer & Nesdale, 1985). Orthographic processing accounts for additional variance in word recognition, text reading and reading speed over and above that contributed by phonological processing (Barker, Torgesen, & Wagner, 1992; Stanovich, West, & Cunningham, 1991; Wagner & Barker, 1994). Bowers, Golden, Kennedy, and Young (1994) noted that some problems in oral reading fluency may result from individual differences in a child's ability to induce orthographic knowledge from the kind of exposure to print that usually is sufficient for it.

Acquisition of fluent reading skills depends on establishing a high number of orthographic representations for word recognition in long term memory (Ehri, 1992; Share & Stanovich, 1995). Badian (2005) concluded that while phonological processing skills predicted reading among the early grades, orthographic processing skills tend to predict reading, particularly reading comprehension among the later grades. Hoien (2002) reached similar results in his study of Swedish children and Adams and Bruck (1993) confirmed that even for skilled readers, visual processing of individual letters is important. Hultquist (1997) found that reading disabled adults have impaired orthographic processing skills compared to a typically achieving control group in both whole word and sub-word orthographic processing measures. In contrast, superior orthographic awareness in children with developmental dyslexia was shown in a task in which children were required to select a member of a pair which looked more like a word (Siegel, Share, & Geva, 1995) as well as word likeness and spelling recognition tasks (Stanovich & Siegel, 1994).

Despite the compelling literature that documents the importance and contribution of orthographic processing skills to reading development, there is the problem of determining when a word is read orthographically as opposed to via alphabetic decoding skills. A number of researchers have argued that measures of orthographic processing are confounded by reading achievement (Vellutino, 1994; Vellutino, Scanlon, & Tanzman, 1994), and that orthographic processing skills exceeding expectations based on an individual's phonological skills simply reflect reading experience (Harm & Seidenberg, 2004; Snowling, Bryant, & Hulme, 1996; Stanovich, Siegel, & Gottardo, 1997). In a study by Elbeheri and Everatt (2007) on the Arabic orthography, a task in which children had to decide whether two Arabic words written side-by-side were the same or different showed larger correlations with reading in a dyslexic cohort than a non-dyslexic cohort. Given that this task requires the processing of orthographic forms to perform the matching task, and that dyslexics are likely to have less reading experience than typical children, these findings argue against an experience explanation, at least for these Arabic orthography data. However, there was evidence of ceiling effects in the Elbeheri and Everatt (2007) data, meaning that further work with Arabic cohorts seems worthwhile. Therefore, an orthographic discrimination measure based on that reported by Elbeheri and Everatt (2007) was used in the work described in this paper, though ceiling effects were reduced by time-limiting task completion and hence producing a measure of fluency rather than simple accuracy.

Orthographic Processing in Arabic and Hebrew

A number of studies have indicated that the graphic characters of Arabic script constitute a specific challenge to Arabic readers and in particular to their ability to distinguish between letters. Two studies by Ibrahim, Eviatar, and Aharon-Peretz (2002) and Eviatar, Ibrahim, and Ganayim (2004) found Arabic-Israeli participants slower in processing Arabic (the participants first language) letters than Hebrew (the participants second language) letters. They concluded that this was due to the complexity of Arabic script.

A number of other studies concluded that decoding of both Arabic and Hebrew demands more visuo-spatial awareness or visual attention than decoding in English (Share & Levin, 1999; Shatil & Share, 2003). Moreover, Geva and Siegel (2000) found that English-Hebrew bilingual children made more visual letter recognition errors in Hebrew than in English. However, although vowelization (the retaining of short vowel markers) increases visual complexity, research by Abu-Rabia (1997, 1999) indicated that it led to significantly increased accuracy of performance by poor and/or skilled readers in word and text reading tasks; and similar results were obtained with skilled adult readers (Abu-Rabia, 2001).

However, almost all of the reported studies of Arabic have been conducted on students from 10th and 11th grades or above. (For a more comprehensive review of orthographic processing in Arabic than space allows this paper, see Hansen, 2008.) Generally, in the Arab World, students are expected to read without diacritical marks from grade 4 onwards and, as such, studies focusing on earlier grades rather than on older children and adults may be more informative of the acquisition of literacy skills under vowelized and non-vowelized conditions. Therefore the current work can be considered unique and arguably more sensitive to the specific linguistic nature of written Arabic in that it focuses on early grades of Arabic literacy learning among predominantly monolingual Arabic speakers and on the influence of orthographic features on reading comprehension fluency.

Therefore, the studies reported in this paper were designed specifically to assess the contribution of orthographic processing to Arabic comprehension over-and-above that provided by other skills. These other areas of processing were selected as they have been found to be predictive of literacy levels in previous studies of Arabic (as covered in the introduction). Measures of these skills were chosen in order to assess alternative interpretations of any relationship between the orthographic measure and Arabic reading comprehension by entering them into regression analyses prior to the orthographic measure. Additional measures of phonological processing were non-word reading (phonological decoding), sound deletion (phonological awareness), non-word repetition (phonological memory) and rapid naming (fluent access of a phonological form). This range of phonological measures makes it unlikely that any unique variability in comprehension explained by the orthographic measure is due to some aspect of phonological processing. The inclusion of the non-word reading measure makes it unlikely that any unique variability is due purely to translating written units into sound forms. The range of memory measures included means that unique variability cannot purely be due to processes involved solely in visual memory, or the storage of alphanumeric names, verbal word forms or meaningful verbal text.

Comprehension fluency was the specific predictor variable targeted as this provides an assessment of both fluency of reading processes and understanding. Fluency of reading has been considered a better measure of individual differences in reading levels when a relatively transparent orthography is learnt. The mainstream school years of grades 2–5 were targeted for investigation since this is the period when there is likely to be a move from experiencing mainly vowelized to non-vowelized text. The initial grade of formal schooling was not assessed due to the aim of the current work to focus on comprehension and many children in Kuwait will not have had formal teaching in literacy prior to school entry. Beyond grade 5, children move out of the primary stage of schooling and would be expected to have reasonable literacy skills that can allow them to access additional curriculum areas via literacy. Therefore, the grades targeted were the period of formal mainstream instruction.

A second aim of the present work was to determine whether the orthographic measures used in the current work could be used with Arabic children with LD. The term LD in Kuwait refers to children who have an intelligence quotient (IQ) within or above the average range (i.e. an IQ of 85 or more) but who show evidence of persistent problems in educational achievement, primarily in the areas of literacy. Informed assessment procedures, including early identification, are vital for the effective outcome of intervention procedures used with LD children (e.g. Torgesen, 2002, 2005), whereas a failure to recognize difficulties can lead to negative consequences (Elbeheri, Everatt, & Al-Malki, 2009). The present study, therefore, sought to determine the influence of orthographic processing on comprehension within a group of Kuwaiti LD children. Such a poor literacy ability group can determine also the likelihood of the orthographic effects being due to experience, since these LD children will have had less reading experience than their typically developing peers. As with the mainstream data, the primary year levels were targeted; though, due to the lack of identification of children in grades 1 and 2 at the time of testing, children in grades 3–5 were selected. Again measures of reading comprehension and orthographic discrimination were augmented by tasks requiring phonological decoding, phonological awareness, short-term verbal memory and rapid naming, as well as a spelling task to assess wider literacy skills.

METHOD

Participants

The study tested two cohorts (A and B; see Table 1) of grades 2–5 children from mainstream schools for boys or for girls (Kuwaiti government schools are single-sex). All schools followed the standard Kuwaiti national curriculum. None of these children had evidence of reported learning/behavioural difficulties (determined by school reports) and all were first language Arabic speakers (based on teacher interviews and background information about the school population). No further exclusion criteria were used except guardian consent and completion of all tasks. The latter exclusion criteria led to over half of grade 2 children from cohort B being excluded from analyses since they could not, or would not, attempt the comprehension fluency task. A handful of cohort B grade 3 children were excluded from the data analyses for the same reason. For the schools used to obtained cohort A, there were far fewer cases of this exclusion criteria being implemented. These findings are representative of the fact that many children in Kuwaiti schools are only just able to perform reading comprehension tasks by grade 2; hence, the variability in excluded cases across cohorts A and B. Given that a large proportion of these children were boys, overall there are fewer males in cohort B.

Two cohorts of mainstream children were tested to allow the study to split tests across the cohorts and avoid over-testing young primary-age school children. The first

Table 1. Numbers of children in each grade for cohorts A and B, with male:female numbers in brackets

	Grade 2	Grade 3	Grade 4	Grade 5	Total
Cohort A	45 (21:24)	52 (28:24)	57 (30:27)	50 (24:26)	204 (103:101)
Cohort B	18 (8:10)	38 (14:24)	44 (20:24)	48 (23:25)	148 (65:83)
Cohort C (LD)	—	9 (8:1)	10 (7:3)	16 (13:3)	35 (28:7)

cohort (cohort A) was tested mainly on phonological skills, whereas the second cohort (cohort B) was tested mainly on memory measures. However, both samples completed measures of comprehension fluency (the dependent variable, DV, in the study) and orthographic processing (the primary focus of the work). Due to the use of a fluency measure as the DV, both cohorts were also tested on measures of rapid naming to take speed of processing influences into account in both sets of data.

Children in grades 3, 4 and 5 of a Kuwaiti special school comprised the LD sample in the study (cohort C in Table 1). This special school followed the same Government educational curriculum as that for mainstream schools, though with smaller class sizes (less than 6 and often one-to-one) and with special teaching methods designed for the children. As with the mainstream samples, all LD children had Arabic as their first language and the only exclusion criteria used was that testing could not be completed, either due to consent to participate, or continue, not being given by guardians or the children themselves, or due to illness/personal reasons that kept the children from attending school during the period of testing. There were more boys than girls in the special school and the number of children in each year group varied due to identification rates across grades and the policy of the education system to return children to mainstream as soon as deemed appropriate.

Measures

Measures were developed based on previous relevant literature and pilot testing conducted with Arabic children independent of those reported in the studies in this paper. All measures were preceded by instructions with detailed examples, and were presented in Arabic in a form familiar to the Kuwaiti samples tested (i.e. the local Arabic dialect was used as necessary to ensure understanding).

Reading Comprehension Fluency (All Cohorts)

This task (shortened to comprehension fluency) comprised 50 incomplete Arabic sentences. Participants were required to complete each sentence with a correct word chosen from four alternatives (an English example would be: 'We tell the time with a …' 'pen-picture-clock-book'). The children were given 180 seconds to complete as many sentences as possible, with the number correct in this time giving an indication of speeded comprehension.

Orthographic Discrimination (all cohorts)

Two tests of orthographic discrimination were used, one which comprised real Arabic words and one that comprised non-words derived from Arabic written words. Each set contained 50 pairs of words/non-words. Each pair was made up of letter strings that were identical or differed by one character only (minimal pairs). Participants were required to distinguish between the identical and different pairs by either inserting a tick or a cross next to the identical or different pair, respectively, or, in the case of the LD cohort, by circling the identical pairs. Participants were given 60 seconds to complete as many as possible. The number of correct responses in 60 seconds was the measure for this task.

Rapid Naming (All Cohorts)

For cohort A, two naming tasks were used: naming drawings of familiar objects (3 repetitions of 12 objects) and naming individual letters (3 repetitions of 12 letters).

For cohort B, these same two tasks were also used, but a digit naming task was also included (with six repetitions of six digits). For cohort C, only one naming task was used, which comprised 50 line drawings of familiar objects (repetitions of 10 different drawings). Familiarity of names was ensured prior to testing. All tasks involved the child been given a sheet of paper on which the items were positioned in rows and the child was asked to name all the items as quickly but as accurately as possible. The time taken to name all the items was recorded and any non-correctly naming errors meant that 1 second was added to the time. Each task was performed twice, with the first trial being used as practice, due to the use of several naming tasks, and times on the second trial being used as the measure.

Spelling Choice (Cohort A)

In this task, the child was presented with a set of three Arabic letter strings, only one of which was spelled correctly. The other two letter strings were not Arabic words but could be sounded-out using Arabic grapheme–phoneme conversion rules (i.e. these were non-words). Each of the two incorrect spellings differed from the correct spelling by one character, which differed in each case, and sounded similar (though not identical) to the correct word. The child's task was to indicate the correctly spelled word. There was a total of 56 items in the task.

Spelling to Dictation (LD Cohort C)

A spelling-to-dictation test was given to the LD children—such procedures would have been familiar to this cohort. The task consisted of a passage of connected Arabic text, 57 words in length that was meaningful to the children tested but which included words at a higher reading level than grade 4. The researcher read out the passage at a pace determined by pilot work, with suitable gaps in speech to allow the children to write what was dictated, but also to allow context to support word recognition. After dictation, papers on which the children had written were collected and the number of words spelled correctly was used as the measure for this task.

Non-word Reading (Cohorts A and C)

This task comprised 25 non-meaningful Arabic letter strings that followed Arabic translation rules (i.e. from written form to language sound) allowing an appropriate pronunciation to be formed. Non-words were derived from real words, but with letters exchanged or re-arranged to remain consistent with the Arabic orthography. The child was given a sheet of paper on which the non-words were typed and asked to read each one out loud. All non-words contained diacritic marks to ensure that only one pronunciation was legitimate. The number of non-words read correctly was used as a measure of non-word reading accuracy. For the mainstream children (cohort A), a stop-watch was used to measure the time taken to name all of the non-words in order to calculate non-word reading fluency, which was determined by the number of non-words read correctly per minute. Given evidence of word-level literacy problems evident among the LD group, the fluency measure was not deemed necessary as these children were unlikely to show ceiling effects.

Sound Deletion (Cohorts A and C)

For the mainstream children, this test comprised 20 Arabic words being presented verbally to the children one at a time with an instruction to delete a sound from the word and produce the remaining verbal form (an English example would be 'Say DOG without the /d/ sound' with a correct response being/og/). The position of the deleted sound was varied between the beginning, middle and end of the word. The number of items pronounced correctly by the child was used as the measure for this task.

A similar task was used with the LD cohort, though this comprised 30 Arabic words, with the first 10 items requiring the first sound to be deleted, the next 10 requiring the final sound to be deleted and the final 10 requiring a middle sound to be deleted. These were blocked to avoid over-taxing these LD children. Again, the number correct was used as the measure for this task.

Non-word Repetition (Cohorts A and C)

This test involved the child being asked to repeat a non-word pronounced by the tester. For the mainstream cohort, 20 non-words were used and for the LD cohort 25 non-words were used. In both cases, the non-words used in the test had no meaning in Arabic but were based on Arabic sound forms so as to be consistent with the language used by the Kuwaiti children. Non-words increased in pronunciation length over the course of the test. Each non-word was pronounced clearly by the tester, followed by a pause to allow the child to repeat the item. The number of non-words repeated correctly was used as the measure for this test.

Forward Digit Span (Cohort B)

Each participant was verbally presented with a sequence of digits and was required to repeat the sequence. Sequences started with two digits and increased by one digit every three items up to a total of 8 digits. The number of trials repeated correctly (i.e. in the required order) was used as the measure for this task.

Backward Digit Span (Cohorts B and C)

The procedures were the same as in the forward digit span task except that the children were required to repeat the digits in the reverse order to that presented.

Immediate and Delayed Recall (Cohort B)

In this task, the child was verbally presented with 15 unrelated Arabic words at a standard pace of roughly one every second. For the immediate recall task, the child was asked to say all the words from the list that they could remember. For the delayed recall task, roughly 5 minutes after presentation, the child was again asked to say all the words from the list that they could remember. In both cases, the number of words recalled correctly was used as the measure for the task.

Visual (Abstract Shape) Memory (Cohort B)

A set of abstract forms was produced for this test. None of the forms had a meaning in the language of the child but comprised combinations of squares, circles, triangles, multi-sided shapes, stars and arrows, some of which were filled and others empty. In each trial, two or three of these forms were presented for 5 seconds. A second later, the identical number of forms was presented, but this time one of the forms was varied in some way (e.g. a square in the form might be shaded when it was empty in the previous version, or an arrow would be pointing in a different direction). The child's task was to indicate the form that was different across the two presentations. The number of trials correct out of a total of 20 was the measure for this task.

Sentence Repetition (Cohort B)
A total of 18 Arabic phrases/sentences were prepared for this test. All were meaningful in the language and described an object or an event. The first 3 items comprised two word phrases, the following 2 were four-word phrases, the next 3 items contained 6–9 words each, the next 7 items were between 10 and 20 words in length and the final 3 items were 22–27 words long. The phrase/sentence was spoken to the child and they were asked to repeat as much of the phrase/sentence as they could. The number of words repeated correctly for each item was recorded and combined to produce the measure for this task.

RESULTS

Means, standard deviations and min–max scores for each of the measures in the study are presented in Table 2 (the subscripts a, b and c being used for the different cohorts). Relationships between the variables were calculated as partial correlations controlling for grade and sex of the child (Table 3).

Overall, these data indicate good relationships between the orthographic discrimination measures and comprehension fluency in all cohorts. The version of the orthographic discrimination task that comprised pairs of real words showed larger partial correlation values than most measures except the non-word reading and spelling choice tasks in cohort A. In addition, regression analyses using the comprehension fluency measure as the DV and entering all other variables prior to the orthographic discrimination measure indicated that such orthographic measures predicted significant unique levels of variability in comprehension fluency over-and-above that explained by the measures of spelling to dictation, non-word reading (phonological decoding), sound deletion (phonological awareness), non-word repetition (phonological memory) and rapid naming (speed of processing or fluent access of phonological forms) (Table 4).

For cohort A, further regression analyses were performed that entailed splitting the children into two groups, one comprising grades 2 and 3 and the other incorporating grades 4 and 5. This was to assess the influence of the orthographic task, in contrast with the phonological-related tasks, on comprehension fluency in the two early grades versus the later primary grades. The results of these regression analyses for the two grade levels are presented in Table 5 (subscript i for grades 2 and 3, and subscript ii for grades 4 and 5). These results indicated that for the second and third grades, the orthographic task did not predict significant levels of comprehension fluency over that predicted by the phonological measures, whereas it did for the fourth and fifth grades.

DISCUSSION

The results indicated relationships between the orthographic tasks and the Arabic reading comprehension measure that were not explained by the influence of phonological or memory processes. However, the results indicated that the unique prediction of comprehension provided by the orthographic tasks over-and-above that provided by phonological processing was more apparent in grades 4 and 5 mainstream children than grades 2 and 3 mainstream children. The same unique influence of orthography on comprehension was found in the LD children. The results of these studies provided further evidence of the influence of orthographic processing on Arabic reading. However,

Table 2. Means and standard deviations (SD), with minimum and maximum scores in square brackets produced by the (a) Cohort A, (b) Cohort B and (c) LD group

	Grade 2	Grade 3	Grade 4	Grade 5
(a)				
Comprehension fluency	6.80 (5.99) [0–23]	11.96 (8.09) [0–30]	17.16 (7.69) [0–39]	24.22 (9.70) [5–44]
Spelling choice	26.71 (6.88) [0–40]	29.85 (8.98) [0–48]	34.93 (8.85) [17–52]	37.76 (8.95) [19–51]
Non-word reading accuracy	16.09 (6.60) [2–25]	16.83 (6.49) [0–25]	17.86 (5.37) [3–25]	19.36 (4.24) [8–25]
Non-word reading fluency	7.28 (5.31) [0.67–24.23]	8.89 (5.96) [0.00–24.64]	9.92 (6.37) [0.59–28.80]	12.93 (6.77) [2.73–35.38]
Sound deletion	10.60 (3.00) [0–17]	11.27 (2.73) [4–19]	12.47 (3.45) [0–19]	13.78 (2.89) [8–19]
Non-word repetition	10.64 (2.97) [5–17]	10.90 (3.68) [4–17]	11.30 (3.32) [2–17]	12.32 (2.68) [5–17]
Rapid naming of objects	82.09 (15.17) [52–119]	76.31 (17.13) [46–133]	71.47 (18.36) [42–146]	67.28 (14.01) [44–101]
Rapid naming of letters	62.78 (19.35) [35–113]	58.71 (26.05) [31–169]	55.54 (19.31) [28–102]	43.24 (10.51) [25–72]
Orthographic discrimination of words	11.80 (3.40) [5–22]	14.67 (4.87) [6–29]	17.93 (4.92) [7–32]	20.82 (5.05) [8–33]
Orthographic discrimination of non-words	9.20 (2.96) [4–18]	11.31 (3.35) [6–20]	13.39 (3.57) [7–23]	15.58 (4.19) [8–29]
(b)				
Compre fluency	8.39 (5.85) [0–22]	10.95 (6.35) [1–25]	15.27 (7.70) [2–39]	17.35 (9.65) [1–40]
RapNam letters	56.89 (13.71) [41–93]	56.87 (15.82) [35–95]	48.43 (11.92) [29–81]	49.06 (16.97) [28–113]
RapNam digits	55.78 (8.64) [41–70]	48.37 (9.18) [36–72]	44.45 (11.46) [29–81]	42.58 (10.85) [28–79]
RapNam objects	90.17 (20.19) [64–131]	77.53 (16.98) [47–121]	71.20 (15.56) [45–122]	71.60 (15.94) [47–117]
Immediate recall	6.22 (1.99) [2–10]	5.79 (2.04) [3–14]	6.43 (1.87) [3–11]	7.08 (2.22) [4–14]
Delayed recall	5.67 (2.57) [2–14]	5.13 (1.71) [2–11]	5.45 (1.58) [2–9]	6.42 (2.74) [2–14]
Visual memory	12.56 (2.81) [8–19]	12.92 (2.27) [9–18]	13.36 (2.27) [6–19]	14.27 (2.28) [9–18]
Forward digit span	11.17 (1.86) [8–14]	12.53 (2.93) [7–19]	12.39 (3.16) [8–20]	12.44 (2.84) [6–19]
Backward digit span	4.94 (1.89) [0–9]	5.55 (1.72) [0–10]	6.23 (1.93) [3–12]	6.31 (2.15) [3–11]
Sentence repetition	52.44 (14.04) [23–78]	54.66 (14.53) [27–96]	61.93 (13.09) [38–93]	62.23 (16.55) [32–99]
Ortho words	11.28 (4.18) [5–23]	12.79 (3.96) [3–23]	15.14 (3.87) [7–27]	17.04 (4.91) [7–28]
Ortho non-words	8.61 (2.45) [4–14]	9.79 (3.07) [3–18]	11.86 (2.80) [7–20]	12.81 (4.01) [4–23]
(c)				
Comprehension fluency		8.00 (5.00) [2–17]	10.30 (5.42) [3–18]	14.19 (6.82) [4–24]
Spelling to dictation		34.44 (11.02) [17–50]	32.00 (11.80) [15–49]	37.44 (10.33) [14–56]

Table 2. Continued

	Grade 2	Grade 3	Grade 4	Grade 5
Non-word reading accuracy		11.33 (5.27) [4–20]	14.70 (7.70) [4–24]	18.81 (4.20) [12–25]
Sound deletion		17.44 (6.25) [7–27]	18.80 (7.38) [0–27]	22.19 (3.76) [15–28]
Rapid naming of objects		63.56 (16.61) [42–86]	69.40 (24.45) [35–111]	60.44 (17.90) [29–93]
Non-word repetition		18.00 (4.53) [11–24]	20.60 (2.83) [15–24]	20.44 (2.37) [15–23]
Backward digit span		4.44 (1.59) [3–7]	5.10 (3.78) [2–15]	6.06 (3.07) [1–12]
Orthographic discrimination of words		18.33 (3.50) [13–22]	25.70 (12.37) [6–48]	26.06 (11.55) [10–50]
Orthographic discrimination of non-words		14.44 (3.36) [9–19]	25.20 (14.90) [7–48]	25.25 (11.49) [14–50]

the data were relatively unique in assessing this influence in a reading comprehension fluency measure and showing that scores on the orthographic task were predictive over-and-above the level of prediction provided by tasks involving a range of phonological and memory processes. Indeed, this unique relationship argues against several alternative explanations for the relationship between orthographic processing and reading comprehension. The relationship is unlikely to be due to phonological processing (including phonological decoding, awareness and memory), speed of processing (as assessed by the rapid naming tasks), nor to commonalities with various memory processes (i.e. those processes involved in visual memory, memory for digit names, long-/short-term recall of words or the retention of meaningful verbal text), since tasks involving these processes were entered into regression analyses prior to the orthographic tasks. The most likely explanation, therefore, is that the relationship is based on the ability to discriminate orthographic forms within Arabic written words.

In a task similar to that reported in the current work, Elbeheri and Everatt (2007) required children to decide whether two Arabic words written side-by-side were the same or different. In contrast to the present data, Elbeheri and Everatt found larger correlations between their orthographic measure and reading for a dyslexic cohort than those found with a non-dyslexic cohort. This disparity may have been due to ceiling effects in the orthographic task accuracy measure used by Elbeheri and Everatt and/or their reading test measuring accuracy of responding to isolated words as well as text comprehension questions. When fluency measures are used in the current study, correlations in the mainstream cohort are similar to those found in the LD cohort (all partial correlations were between 0.4 and 0.6)—and the regression analyses argue for significant increases in reading comprehension variability explained by the orthographic measures across all cohort. Given that fluent access is often considered the main reason for the development of an orthographic lexicon (or an orthographic route), the findings of the present study can be argued to be more representative of the influence of orthographic processing on Arabic literacy. In addition, the lack of evidence for a difference in the reading-orthography relationship between the mainstream and LD

Table 3. Partial correlations (controlling for grade and sex) for the measures completed by (a) cohort A, (b) cohort B and (c) LD group

	Com flu	Spell	NW acc	NW flu	Sou del	NW rep	RN obj	RN let	Orth wrd
(a)									
Spelling choice	0.570								
Non-word accuracy	0.574	0.519							
Non-word fluency	0.584	0.499	0.719						
Sound deletion	0.508	0.460	0.451	0.442					
Non-word repetition	0.390	0.182	0.220	0.193	0.346				
RapNam objects	−0.437	−0.336	−0.364	−0.323	−0.380	−0.222			
RapNam letters	−0.296	−0.273	−0.327	−0.343	−0.134	−0.016	0.459		
Ortho words	0.568	0.416	0.357	0.353	0.321	0.285	−0.326	−0.242	
Ortho non-words	0.497	0.410	0.208	0.219	0.236	0.213	−0.286	−0.240	0.708

	Com flu	RN let	RN dig	RN obj	Vis mem	Imm rec	Del rec	For DS	Bac DS	Sen rep	Orth wrd
(b)											
RapNam letters	−0.414										
RapNam digits	−0.472	0.599									
RapNam objects	−0.475	0.463	0.633								
Visual memory	0.288	−0.108	−0.149	−0.169							
Immed recall	0.227	−0.078	−0.115	−0.279	0.073						
Delayed recall	0.230	−0.150	−0.125	−0.232	0.066	0.602					
Forward digit span	0.391	−0.099	−0.219	−0.137	0.075	0.028	−0.004				
Backward digit span	0.320	0.001	−0.132	−0.230	0.103	0.248	0.186	0.252			
Sentence repetition	0.463	−0.177	−0.149	−0.319	0.202	0.247	0.292	0.515	0.371		
Ortho words	0.599	−0.250	−0.343	−0.264	0.198	0.133	0.234	0.174	0.185	0.279	
Ortho non-words	0.415	−0.222	−0.238	−0.149	0.172	0.122	0.173	0.165	0.238	0.202	0.642

Table 3. Continued

	Com flu	Spel	NW acc	Sou del	Rap nam	NW rep	Bac DS	Orth wrd
(c)								
Spelling	0.562							
Non-word accuracy	0.578	0.571						
Sound deletion	0.266	0.571	0.410					
Rapid Naming	−0.350	−0.089	−0.226	0.060				
Non-word repetition	0.163	0.089	0.542	0.154	−0.237			
Backward digit span	0.094	−0.095	0.028	−0.071	0.113	−0.125		
Ortho words	0.422	0.428	0.414	0.305	0.057	0.189	−0.245	
Ortho non-words	0.483	0.408	0.357	0.271	0.114	0.194	−0.111	0.919

Table 4. Results of a regression analysis to investigate predictors of Comprehension Fluency amongst (a) cohort A, (b) cohort B and (c) LD children

	Variables	R^2	R^2change	Sig R^2 change	Final beta
(a)					
1	Grade and sex	0.409	0.409	$F(2, 201) = 69.67$, $p < 0.001$	Grade: 0.23 Sex: 0.08
2	Spelling choice	0.601	0.192	$F(1, 200) = 96.29$, $p < 0.001$	Spell: 0.14
3	NW accuracy and NW fluency	0.684	0.082	$F(2, 198) = 25.75$, $p < 0.001$	Accuracy: 0.11 Fluency: 0.17
4	Sound deletion	0.701	0.017	$F(1, 197) = 11.33$, $p = 0.001$	Deletion: 0.09
5	Non-word repetition	0.725	0.024	$F(1, 196) = 16.92$, $p < 0.001$	NWrep: 0.13
6	RapNam obj and RapNam let	0.735	0.010	$F(2, 194) = 3.68$, $p = 0.027$	Objects: −0.08 Letters: <0.001
7	Ortho discrim	0.772	0.038	$F(2, 192) = 15.82$, $p < 0.001$	Words: 0.16 Non-words: 0.15
(b)					
1	Grade and sex	0.241	0.241	$F(2, 145) = 23.04$, $p < 0.001$	Grade: 0.03 Sex: 0.16
2	RapNam objects, letters & digits	0.463	0.222	$F(3, 142) = 19.57$, $p < 0.001$	Objects: −0.14 Letters: −0.15 Digits: −0.05
3	Visual memory	0.493	0.030	$F(1, 141) = 8.24$, $p = 0.005$	Visual: 0.11
4	Immediate and delayed recall	0.505	0.013	$F(2, 139) = 1.77$, $p = 0.174$	Immed: 0.06 Delayed: −0.02
5	Forward/Backward digit span	0.586	0.081	$F(2, 137) = 13.39$, $p < 0.001$	Forward: 0.16 Backward: 0.09
6	Sentence repetition	0.598	0.011	$F(1, 136) = 3.88$, $p = 0.051$	Sentence: 0.10
7	Ortho discrim	0.692	0.094	$F(2, 134) = 20.50$, $p < 0.001$	Words: 0.40 Non-words: −0.02
(c)					
1	Grade and sex	0.178	0.178	$F(2, 32) = 3.46$, $p = 0.044$	Grade: 0.04 Sex: 0.23
2	Spelling	0.437	0.260	$F(1, 31) = 14.30$, $p = 0.001$	Spell: 0.22
3	Non-word reading	0.518	0.081	$F(1, 30) = 5.02$, $p = 0.033$	NWread: 44
4	Sound deletion	0.527	0.009	$F(1, 29) < 1$	Deletion: −0.04
5	Non-word repetition Backward digit span	0.541	0.014	$F(2, 27) < 1$	NWrep: −0.20 RevSpan: 0.08
6	Rapid Naming	0.594	0.052	$F(1, 26) = 3.35$, $p = 0.079$	RapNam: −0.33
7	Ortho discrim	0.696	0.102	$F(2, 24) = 4.03$, $p = 0.031$	Words: −0.42 Non-words: 0.73

cohorts suggests that this relationship is not simply due to exposure to literacy, given poorer literacy levels in the LD cohort.

The data, therefore, argue for orthographic processing to play a role in Arabic reading comprehension. Sharah-Yames and Share (2008) have argued that the acquisition of orthographic knowledge, whether represented in localist (e.g. Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001) or distributed architectures (e.g. Plaut, McClelland, Seidenberg, & Patterson, 1996), is one of the cornerstones of literacy. The mainstream data obtained from the Arabic speaking cohorts tested in the present work seem consistent with this perspective. They argue for an influence of orthography that is independent of phonological processing following some level of reading experience (i.e. associated with higher grade levels and higher scores on the literacy measures); although this effect in Arabic could be due to increased experience of non-vowelized text around grades 3–4 and, therefore, could

Table 5. Results of a regression analysis to investigate predictors of Comprehension Fluency among (a) cohort A grades 2 and 3 and (b) cohort A grades 4 and 5

	Variables	R^2	R^2change	Sig R^2 change	Final beta
(a)					
1	Grade and sex	0.134	0.134	$F(2, 94) = 7.28$, $p = 0.001$	Grade: 0.20 Sex: 0.11
2	Spelling choice	0.433	0.299	$F(1, 93) = 49.04$, $p < 0.001$	Spell: 0.18
3	NW accuracy and NW fluency	0.607	0.174	$F(2, 91) = 20.12$, $p < 0.001$	Accuracy: 0.25 Fluency: 0.22
4	Sound deletion	0.617	0.010	$F(1, 90) = 2.26$, $p = 0.136$	Deletion: 0.04
5	Non-word repetition	0.645	0.028	$F(1, 89) = 7.14$, $p = 0.009$	NWrep: 0.16
6	RapNam obj and RapNam let	0.648	0.003	$F(2, 87) < 1$	Objects: −0.07 Letters: 0.002
7	Ortho discrim	0.658	0.010	$F(2, 85) = 1.19$, $p = 0.310$	Words: 0.12 Non-words: 0.01
(b)					
1	Grade and sex	0.202	0.202	$F(2, 104) = 13.16$, $p < 0.001$	Grade: 0.12 Sex: 0.07
2	Spelling choice	0.459	0.257	$F(1, 103) = 49.06$, $p < 0.001$	Spell: 0.14
3	NW accuracy and NW fluency	0.531	0.072	$F(2, 101) = 7.73$, $p = 0.001$	Accuracy: −0.05 Fluency: 0.21
4	Sound deletion	0.576	0.045	$F(1, 100) = 10.65$, $p = 0.002$	Deletion: 0.20
5	Non-word repetition	0.609	0.033	$F(1, 99) = 8.37$, $p = 0.005$	NWrep: 0.11
6	RapNam obj and RapNam let	0.638	0.029	$F(2, 97) = 3.86$, $p = 0.024$	Objects: −0.08 Letters: 0.005
7	Ortho discrim	0.742	0.104	$F(2, 95) = 19.03$, $p < 0.001$	Words: 0.24 Non-words: 0.23

be a specific feature of an Arabic (or a Semitic) orthography. A greater influence of orthographic processing over-and-above phonological processing could be related to diglossia in Arabic. Saiegh-Haddad (2007) has argued that differences between the spoken form of Arabic experienced by the pre-school child (i.e. a local dialect) and the standard form of Arabic used in education and writing (i.e. MSA) disrupts the construction of phonological representations of MSA. This may lead to less reliance on such phonological representations to support literacy acquisition and, hence, to the use of alternative processes (such as those involving orthographic skills); although this influence might be expected to decrease with exposure to MSA. Alternatively, the complexity of the orthography (Ibrahim *et al.*, 2002) may require more precise orthographic processing skills and, hence, to those with better skills in this area progressing in literacy learning at a faster rate. Clearly, further research is needed to determine the precise influence of vowelization, orthographic complexity and diglossia.

The finding that the influence of orthographic processing is explained by phonological processing measures in the younger cohort but not in the older groups is consistent with several models of reading acquisition that were developed for orthographies other than Arabic, as well as data obtained from longitudinal studies of English languages children. For example, the work of Badian (1995) is consistent with the conclusion of an initial influence of phonology on reading development followed by an emerging influence of orthographic processing. Additionally, Share (1995) has argued that repeated learning builds up orthographic representations which, in turn, lead to the development of a sight word vocabulary, and the processes needed to access such visual word representations, resulting in the child becoming a fluent reader. Share has proposed also that reading development progresses from greater reliance on phonological decoding skills to greater reliance on orthographic decoding skills as the reader becomes more competent. Perfetti (1992) also argued for the importance of both phonological and orthographic processing, explaining that a skilled orthographic word recognition system involves having fully specified and autonomous internal representations. Direct access to these representations should allow resources to be used in the ultimate task of deriving meaning from text (Castles & Nation, 2008).

However, the data that seem less consistent with the perspective outlined above were the LD data. In the present study, the LD children showed an influence of orthographic processing that was independent of phonological processing despite learning difficulties associated with literacy acquisition. The lack of an influence of phonological awareness in the LD analyses was consistent with the interpretation of deficits in phonological skills leading to literacy learning difficulties (Snowling, 2000; Stanovich, 1988); a finding that has been found across several languages (Goulandris, 2003; Smythe *et al.*, 2004), including Arabic (Abu-Rabia *et al.*, 2003; Al-Mannai & Everatt, 2005; Elbeheri & Everatt, 2007). Therefore, the LD children may be reliant on (or at least primarily influenced by) orthographic processing from the start of literacy development. If this is the case, then a level of independence in the development of phonological and orthographic processing has to be hypothesized, rather than considering that phonological skills provide the basis on which orthographic processing develops. This would seem to be more consistent with a basic dual route model in which the two routes develop independently (compare Coltheart *et al.*, 2001; Plaut *et al.*, 1996). However, further research is needed to specify the area of deficit within these Arabic-speaking children and to determine how this relates to normal development of Arabic literacy skills (see discussions in Elbeheri, Everatt, Mahfoudhi, & Abu Al-Diyar, 2009).

Overall, the data argue for an influence of orthographic processing on comprehension fluency in Arabic. This influence can be explained by variability in phonological skills in the younger typically developing children targeted by the present work but not in those in grades 4–5. This may be due to a normal developmental process whereby orthographic processing is dependent on a certain level of phonological skill. Once phonological decoding is reliable, an orthographic lexicon can be developed and units within that lexicon specified. Alternatively, grades 3 or 4 is the point when these Arabic children are likely to experience text that is non-vowelized and it may be that this leads to more dependency on orthographic processing over phonological decoding; hence, when non-vowelized text is the dominant form, the better reader is the one with additional reading skills to those associated with a phonological decoding strategy. Further research is needed to determine whether the reasonable large influence of orthographic processing on comprehension identified in the present paper are specific to Arabic (i.e. they are due to the increased experience of non-vowelized text) or whether they are a universal developmental effect that manifests in Arabic more than in other languages, such as English, due to the orthographic complexity of Arabic. Such further work should inform both theories of Arabic literacy development as well as views about reading and writing across orthographies.

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