Psychology, 2015, 6, 20-38
Published Online January 2015 in SciRes. http://www.scirp.org/journal/psych
http://dx.doi.org/10.4236/psych.2015.61003

Phonological and Cognitive Reading Related Skills as Predictors of Word Reading and Reading Comprehension among Arabic Dyslexic Children

Smail Layes[1,2], Robert Lalonde[1], Soulef Mecheri[2], Mohamed Rebaï[1]

[1]Normandie Université, Rouen, France
[2]Department of Psychology, University of El Oued, El Oued, Algeria
Email: smail.layes@gmail.com

Received 1 December 2014; revised 16 December 2014; accepted 1 January 2015

Abstract

The present study sought to identify cognitive reading-related skills (i.e. visual attention, rapid automatized naming and working memory) that might distinguish dyslexic Arabic children from skilled ones in 4th and 5th grades, and to examine the potential contribution of these factors to word reading and reading comprehension. Two experiments were conducted for this purpose. In Experiment 1, normal readers (N = 108) and dyslexics (23) were given a set of literacy tasks, visual attention, and rapid automatized naming. The results indicated that dyslexic children exhibited lower reading-related skills than controls. Visual attention and phonological processing were able to predict word reading. Experiment 2 was carried out on 36 dyslexic children compared to chronological-age controls. This experiment was designed to assess the relation between phonological awareness and working memory with word recognition and reading comprehension. Results showed significant differences between groups in literacy scores. In addition, inter-correlations indicated a strong relation between word recognition and reading comprehension on one hand and phonological awareness and verbal working memory on the other. Regression analyses showed that rapid naming, visual attention, and verbal working memory were significantly associated with literacy. The findings underscored the importance of cognitive skills in the acquisition of Arabic literacy and emphasized persistent difficulties in dyslexic children from multiple causes.

Keywords

Word Recognition, Phonological Awareness, Cognitive Predictors, Reading Comprehension

How to cite this paper: Layes, S., Lalonde, R., Mecheri, S., & Rebaï, M. (2015). Phonological and Cognitive Reading Related Skills as Predictors of Word Reading and Reading Comprehension among Arabic Dyslexic Children. *Psychology, 6,* 20-38.
http://dx.doi.org/10.4236/psych.2015.61003

1. Introduction

Cross-linguistic studies show that the prevalence of dyslexia differs between transparent (e.g. Arabic script) and opaque (e.g. English) orthographies (Ziegler & Goswami, 2005). An important question in deficient literacy processing is to what extent underlying cognitive mechanisms might vary as well. In European, orthographies, phonological processing (Vellutino, Fletcher, Snowling, & Scanlon, 2004) and rapid naming (Vaessen et al., 2010) have been identified as the main linguistic and cognitive predictors among typical as well as dyslexic readers. In highly transparent orthographies, vocabulary was the strongest predictor of word reading speed and accuracy (Landerl et al., 2013). Accordingly, orthographic knowledge, phonological awareness (PA), and morphological awareness contribute to the organization of reading efficiency among Arabic readers (Abu-Rabia, 2007; Taha, 2013). Yet a larger number of cognitive factors should be examined in the Arabic language.

The goal of the present study was to contribute to the growing literature on reading-related skills which might differentiate dyslexic from skilled readers in Arabic-speaking children. While researches of the most transparent orthographic have focused on word recognition as a restricted outcome to which are related the above-cited factors, we focused on phonological and cognitive factors (visual attention, rapid naming, and working memory) predicting reading comprehension.

1.2. Literature Review

1.2.1. The Role of Visual Attention on Reading

It is widely established that children with dyslexia have visual attention deficits (Stein & Walsh, 1997; Vidyasagar & Pammer, 2010), as seen in letter cancellation tasks, involving either selective attention (Casco, Tressoldi, & Dellantonio, 1998) or visual tracking (Facoetti, Paganoni, Turatto, Marzola, & Mascetti, 2000). In addition, dyslexics perform more poorly in visual search and scanning tasks (Ferretti, Mazzotti, & Brizzolara, 2008), indicating impairments in information processing accuracy and speed (Lima, Azoni, & Ciasca, 2010).

The role of visual attention on reading is particularly important because of its relationship with orthography type according to its consistency. Within this framework, some data were provided about the relation between visual attention and reading proficiency in typical Arabic readers and dyslexics (Layes, Lalonde, & Rebai, in press). The written word identification processes used by readers of opaque or transparent Semitic orthographies differ in their reliance on vowel information. Arab readers are less aware of and devote less attention to vowels relative to consonants while reading English (Hayes-Harb, 2006; Ryan & Meara, 1991), which indicates that Semitic orthographies require exceptional visuospatial processing due to the visual complexity of vowel diacritics (Abu Rabia, 2003; Share & Levin, 1999).

Franceschini, Gori, Ruffino, Pedrolli, and Facoetti (2012) showed that visuospatial attention in preschoolers predicts future reading acquisition. Poor reading children at a pre-reading stage showed inefficient serial visual search and impaired automatic orienting. Moreover, Bosse, Valdois, and Tainturier (2004) found that phonological and visual attentional processing skills were independent predictors of reading scores among dyslexic children. In addition, attentional processing skills accounted for a substantial amount of unique variance in iregular word and pseudo-word reading. However, no information has been provided about the role of visual attention in Arabic readers.

1.2.2. Rapid Automatized Naming and Reading Performance

Rapid Automatized Naming (RAN) is a key skill in learning to read for a variety of scripts (Wimmer, Mayringer, & Landerl, 2000) and proposed as a second core deficit in dyslexia (Wolf & Bowers, 1999). In a number of studies, evidence was found that dyslexic individuals are slow in digit and letter naming speed and continue to have difficulty with rapid naming over a long period (Chung, Ho, Chan, Tsang, & Lee, 2011). Several studies reported that RAN was a significant predictor of reading across orthographies (Furnes & Samuelsson, 2010; Georgiou, Parrila, & Papadopoulos, 2008) and plays an even more significant role than phonological awareness (PA) in predicting reading transparent scripts with regular letter-sound correspondence (Landerl & Wimmer, 2000; Mann & Wimmer, 2002).

While RAN remains a predictor of reading in transparent orthographies (Mann & Wimmer, 2002) and across grades (Furnes & Samuelsson, 2011), it appears to be time-limited in such opaque orthographies (Parrila, Kirby, & McQuarrie, 2004; Roman, Kirby, Parrila, Wade-Woolley, & Deacon, 2009). Furthermore, Vaessen et al. (2010) showed that the relation between RAN and reading seems weak among young readers but may increase later in development. Similarly, the prediction pattern of RAN shows divergent findings in Arabic-based studies. Saiegh-Haddad (2005) demonstrated that letter recoding speed was predicted by RAN in first grade native Arabic speaking children and a strong predictor of reading ability. Although RAN was associated with all literacy measures in grade (2), it failed to predict variability in literacy independently of PA. However, rapid naming in the Stroop test did not appear as an independent predictor, a finding diverging from other transparent orthographies such as German (Al Mannai, 2006). The controversy may be related to the nature of the instrument by which RAN is measured and hence requires to be explored in depth by a variety of RAN tasks. Cross-linguistic findings on the predictive pattern of RAN in reading acquisition are variable. Some studies reported that RAN predicts reading in consistent as well as inconsistent orthographies (Caravolas et al., 2012; Furnes & Samuelsson, 2011; Georgiou et al., 2008; Vaessen et al., 2010). In contrast, other researchers found associations between RAN and reading at the early stage of reading development only in consistent orthographies (Mann & Wimmer, 2002) or reported generally weak associations (Zeigler, Pech-Georgel, Dufau & Grainger, 2010).

1.2.3. Phonological Processing as a Predictor of Reading Ability across Languages

Phonological processing skills are suggested to play a crucial role in the acquisition of reading abilities (Abu-Rabia, 1995, 2001; Share, 1999) depending on the type of orthography (Siok & Fletcher, 2001). It is well established that pseudo-word identification is the benchmark test of children's phonological decoding skills (Abu-Rabia, 1995). Phonological skills seem most strongly related to literacy skills when involving the decoding of non-word reading accuracy. The reading of pseudo-words in reading-disabled children seems to be the result of deficiencies in basic phonological processing (Stanovich & Siegel, 1994). Pseudo-word reading performance is highly correlated with PA and a strong predictive factor of word reading outcomes in developing readers (Torgesen, Wagner, Rashotte, & Rose et al., 1999; Vellutino et al., 2004). Thus, pseudo-word identification is a trustworthy measure of phonological processing (Slaghuis, Twell, & Kingston, 1996) and for grapheme-to-phoneme decoding (Pugh et al., 2012). Therefore, differences between good and bad readers become more apparent in a pseudo-word decoding test because it puts more stress on phonological processing. Pseudo-word reading is the most common task in transparent systems to identify dyslexic children characterized by deficits in the phonological route (Abu Rabia & Abu-Rahmoun, 2012; Jiménez & Hernández-Valle, 2000).

Phonological awareness and/or decoding skills represent two potentially interrelated factors that contribute to reading comprehension. Phonological skills have been found to account for significant variance in reading comprehension, as reading comprehension problems are a direct consequence of the child's inability to establish or sustain a phonological representation. However, Cain, Oakhill and Bryant (2004) consider the relationship between phonology and reading comprehension may not be direct, but rather mediated by word recognition.

The pattern of cross-language predictions was also confirmed in recent studies (Furnes & Samuelsson, 2010, 2011), distinguishing between good and bad readers. Phonological processing contributed to identifying poor readers was associated with reading accuracy and speed in all orthographies and was the strongest predictor except in the highly transparent (Ziegler, Perry, Ma-Wyatt, Ladner, & Schulte-Korne, 2003). The importance of phonological processing measures as predictors of Arabic literacy levels was highlighted by AI-Mannai and Everatt (2005), who examined literacy development among grade (1) through grade (3) learners. Regression analysis indicated that pseudo-word reading was the best predictor of variability, followed by a rhyme awareness task. However, the predictive power of additional factors is insufficiently demonstrated in the Arabic-based literature.

1.2.4. The Role of Working Memory in Word Recognition and Reading Comprehension

Working memory (WM) (Gathercole, Alloway, Kirkwood, & Elliott, 2008) is involved in the executive control of all components of reading (Westby, 2004). Several studies indicate that problems in decoding and organizing phonological information are likely to cause difficulties in word storage and retrieval (Vellutino et al., 2004). Many other studies among reading-disabled children have found impaired WM (Abu-Rabia, 2003; Jeffries & Everatt, 2004), particularly in the early stages of reading (Gathercole et al., 2008). Thereby, dyslexics take a long time in processing information, especially while reading because they must connect letter patterns with corresponding associated sounds (Jeffries & Everatt, 2004).

Working memory may play an important role in reading comprehension, for example in parsing a sentence (Vukovic & Siegel, 2006). Children who have difficulty in reading comprehension may also experience difficulties in WM tasks that require the connection between storing and processing of verbal materials (Hulme &

Roodenrys, 1995). Hence, WM represents an important factor in explaining a reader's comprehension skills (Cain, Oakhill, & Bryant, 2004).

The type of relation between WM and reading comprehension is related on the type of stimuli involved. Thereby, verbal and numerical WMs were related to reading comprehension (De Beni, Palladino, Pazzaglia, & Cornoldi, 1998; Seigneuric, Ehrlich, Oakhill, & Yuill, 2000), whereas shape and pattern tasks were not (Nation, Adams, Bowyer-Crane, & Snowling, 1999; Seigneuric et al., 2000). In the present study, verbal and non-verbal stimuli were used to examine a potential orthographic effect on WM in Arabic speaking dyslexics.

In the current study, we examined the relation between a range of cognitive and phonological skills (visual attention, phonological processing, RAN, WM) as predicting factors on reading skills (word recognition and reading comprehension) in dyslexic Arabic children at the level of the 4^{th} and 5^{th} grades. In particular, we considered the importance of rapid naming in relation to all literacy measures, because RAN was found to be a powerful predictor in a number of transparent orthographies.

Based on the issues raised above, the questions are as follows:

a) How do dyslexics children perform compared to controls on word-reading and cognitive skills?

b) Do cognitive reading-related skills and PA contribute toward recognition and reading comprehension? In Experiment 1, we anticipated that dyslexic children would perform less well than controls in visual attention processing measured by a cancellation test and phonological processing measured by pseudo-word identification, indicating for each factor a unique contribution to reading real words. In Experiment 2, we predicted that PA and WM (potential predictors) as well as reading comprehension would be unequally performed by the two groups and that each factor would indicate a unique contribution to reading words and reading comprehension in the overall population.

2. Experiment One: Phonological and Cognitive Reading-Related Skills in Dyslexia

Taha (2013) reported that the complexity of visual information each written word in Arabic can carry (e.g. shapes of different letters, dots, and vowel marks) may oblige the reader to rely heavily on visual processing other phonological processing. By examining the contribution of several cognitive processing skills (phonological processing, naming, and visual processing) to the reading accuracy of isolated vowelized words among 6^{th} grade native Arabic readers, Taha (2013) found that visual processing skills predicted accuracy in reading isolated words. Abu Rabia and Sammour (2013) suggested that given the differences between English and Arabic orthographies, written word identification may differ in their degree of dependence on vowel information. In a study conducted in skilled readers, poor readers, and dyslexics, Layes et al. (in Press) investigated the relation between visual attention measured by a cancellation test and reading efficiency of unvowellized real words and pseudo-words. The dyslexic group performed similarly to poor readers in the visual attention task but differed from skilled readers. Despite unvowellisation, a low correlation was revealed between word and pseudo-word identification scores and visual attention. Introducing vowellisation in the word reading process might be sufficient to change the strength and predictive power of visual attention in regard to reading efficiency.

2.1. Method

2.1.1. Participants

Participants included 131 primary school children from 4^{th} and 5^{th} grades, 78 boys and 53 girls, divided into two groups: 108 normal readers, mean age 138.61 months (SD = 6.65); and 23 dyslexics, mean age 140.47 months (SD = 8.43), with no significant difference detected for age and IQ. Children were excluded from testing if there was evidence from school reports or teacher interviews indicative of major behavioral and/or learning problems except reading, or else a history of neurological disease or uncorrected visual impairment. They all studied in regular classes. All children in the dyslexic group had normal intelligence on the basis of the Coloured Progressive Matrices.

The diagnostic criteria of developmental dyslexic participants were selected on the basis of the standardization sample's mean in reading tests (APA, 2000). Therefore, a comparison group was used for determining dyslexia whose reading efficiency was below (−1) SD, because of the lack of standardized reading tests for children in Arabic. It is worth noting that Standard Arabic represents the language of education since the first grade of all the participants. However, a non-standard spoken Arabic form represents the linguistic background of the whole population.

2.1.2. Materials and Procedure

The reading test was elaborated beforehand to assess reading skills in 9 - 11-year-old children (Layes et al., in Press). A set of 80 stimuli was given (40 frequent words and 40 infrequent words). Words varied for length (disyllabic and trisyllabic) and frequency (high and low), in addition to a list of 20 pseudo-words varied for orthographic length. The two categories were further categorized as high or low frequency words based on the opinion of three primary school teachers and by consulting the Aralex lexical database for Modern Standard Arabic (Boudelaa & Marslen-Wilson, 2010). All words had a score higher than 26 (mean frequency: 31.3 per million). Participants were required to read the stimuli aloud. The number of correct responses (accuracy) and reading speed (time in sec per list) were scored.

In single word reading test, participants read 80 partially vowelized words and 40 words matched on frequency (40 frequent/40 infrequent). Each list was presented on a white sheet of A4 paper. Participants were required to read aloud the item correctly without any time limit. The score was based on the total number of words correctly read. The total internal consistency coefficient was 0.87.

Pseudo words identification task ($\alpha = 0.83$) consists of list of 20 partially vowelized pseudo-words varied for orthographic length (CVCV/CVCVC). Items were not rooted from real Arabic words which may introduce a frequency effect in identification (Layes et al, in preparation).

The *Visual attention processing* was assessed using the figure cancellation test, limited in this study to the "organized figures", one of two principal types commonly used: letter cancellation test (Geldmacher, 1996, 1998) and symbols (shapes) cancellation test (Weintraub & Mesulam, 1988). Success is determined by the number of omissions, correct responses. Non-verbal stimuli (shapes) were used to avoid presenting orthographic stimuli for dyslexic children who may render difficult the identification implementation of symbols and consequently their recognition, since letter strings may distort assessment (Hawelka & Wimmer, 2005; Zeigler et al., 2010). The figure cancellation test consisted of a sheet with pseudo-random simple geometrical figures (circle, lozenge, semicircle, square, triangle with various orientations, and rectangle in various orientations, oval). Subjects were required to cancel 60 specified target stimuli (◇) as fast as possible with no time limit. The score consists of the total number of correct responses. Split-half reliability of the cancellation test, based on correlating even items with odd items (even/odd method), showed a satisfactory reliability quotient (Guttman coefficient = 0.863).

Rapid Automatized Naming (RAN) tasks were used to assess the speed of processing in naming objects, digits and shapes. Based on the literature (Misra, Katzir, Wolf, & Poldrack, 2004; Taiba, AlBehairi, Abo Al-dyiar, Mahfoudhi, Everat, & Heinz, 2010; Wolf & Bowers, 1999), this test was elaborated for the purpose of this study. Three measures of RAN were administered: objects, digits, and shapes. Prior to timed naming, each participant was asked to name the stimuli in a practice trial to ensure familiarity. The participants were instructed as follows: "Here are some objets/digits/shapes; now, I want you to name them as quickly as you can…Start now". The time needed to name all the stimuli was the participant's score. The total internal consistency reliability had an adequate value of the Alpha Cronbach coefficient ($\alpha = 0.69$).

a) Rapid Objects Naming

Participants were asked to name as quickly as possible recurring objects (scissors, cat, book, pen, and hand) arranged semi-randomly in five rows and repeated 10 times.

b) Rapid Digit Naming

In this task, participants saw five Arabic digits (2, 4, 6, 7, and 9) each across five rows in different orders and were required to name the numerals on the list as rapidly and accurately as possible.

c) Rapid Shapes Naming

This task consists of a group of basic shapes (triangle, square, rectangle, circle, star and new moon) illustrated on a sheet. The participants were asked to name them as fast as possible. This test was based on previous studies (Wiig, Zureich, & Helen-Chan, 2000) in which repeated colors, shapes, and color-shape combinations were used to explore continuous rapid naming in children with language disorders. We avoided introducing other type of stimuli, e.g. color-shape Naming (Wolf, 1986, 1991) because it involves a supplementary cognitive load related to attention (Wiig et al., 2000).

2.1.3. Validation of the Instruments

To determine the underlying dimensions of the multi-task measurements in this study, a prior exploratory factor analysis of reading ability components was performed (**Table 1**). The dimensions of the subtests were examined by principal component analysis with Varimax rotation and factor loadings of 0.50 to 0.87 considered very ade-

Table 1. Factor loadings based on a principle components analysis for 8 measures in the preliminary study (n = 60).

Tasks	Rotated components Reading skills Factor 1	Rotated components Rapid naming Factor 2
Frequent simple words	0.872	−0.155
Frequent complex words	0.870	−0.005
Infrequent simple words	0.862	−0.050
Infrequent complex words	0.842	−0.006
Cancellation task	0.612	0.500
RAN objects	0.131	0.827
RAN digits	−0.158	0.759
RAN shapes	−0.108	0.721

quate (Hair, Black, Babin, Anderson, & Tatham, 2006). Initially, the subject-to-variable ratio is higher than (10: 1), such that there is at least 10 cases for each item in the instrument being used (Garson, 2008). The Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) was 0.827, above the recommended value of 0.6, and Bartlett's test of sphericity is significant ($p < 0.000$). Thus, the strength of the relation between variables is strong. Finally, the communalities were all above 0.5, confirming that each item shared some common variance with others. After a Varimax rotation with 8 items, the initial eigenvalues showed that the first factor (Frequent simple, Frequent complex, Infrequent simple, Infrequent complex words) explained 44% of the variance and the second factor (RAN Objects, RAN Digits and RAN Shapes) 23% of the variance.

When visual attention entered into the analysis, its factor loading obtained two comparable values presented in each factor: 0.61 for factor (1) and 0.50 for factor (2). Discriminative construct validity was carried out by the extreme group comparison method with a t-test to determine whether the cancellation test differentiated between groups (Streiner & Norman, 1995). The comparison showed that the 44 participants with the highest scores in the visual attention task among normal readers were higher than the 44 participants with the lowest scores (t = 34, 72; $p < 0.000$), indicating satisfactory differentiating power of the visual attention test.

2.1.4. Data Analyses

Our main analytical approach consists of a bi-variate analysis between two independent groups (*t*-test) and a multivariate one, including differences tests, partial correlation, and hierarchical analysis, allowing us to estimate phonological processing, RAN, and visual attention as potential predicting factors. The hierarchical regression analysis allows us to assess to extent of the predictive value of the cognitive skills in reading ability. It is worth noting that reading speed is only taken as an indicator apt to characterize reading performance in the two groups.

2.2. Results

2.2.1. Group Comparisons

Descriptive statistics with means and standard deviations for all measures are provided in **Table 2**.

The results of the independent-sample *t*-test indicated poorer scores by dyslexic children than controls in reading accuracy subtests (all p values < 0.001) and speed only for simple words (frequent and infrequent) as well as the total score (t (2.00) =1.99, p values < 0.05), with large effect sizes (0.34). No difference was found in reading speed for complex words (frequent and infrequent) and pseudo-words. The dyslexic group also exhibited lower scores in the cancelation task in terms of accuracy (t (2.00) = 8.73, $p < 0.001$) and speed (t (2.00) = 2.76, $p < 0.01$).

In addition, significant differences emerged with moderate effect sizes in RAN tasks for objects (t (2.00) = 2.15, $p < 0.05$) and shapes (t (2.00) = −2.16, $p < 0.05$) but not digits (**Figure 1**).

Table 2. Participant's characteristics and mean performance by group: reading accuracy and speed, cancellation, and RAN tests (standard deviations in parentheses).

Variables	Normal readers	Dyslexics			
	M (SD)	M (SD)	Difference mean	t (2.00)	Cohen's d
Age (months)	138.61 (6.65)	140.74 (8.43)	−2.128	−1.136 ns	−0.19
Raven	22.94 (3.84)	23.78 (3.83)	−0.85	−0.992 ns	−0.17
Reading word accuracy					
Total words	56.05 (21.77)	21.52 (5.40)	34.42	14.59***	2.55
Frequent simple	15.01 (3.61)	8.13 (4.60)	7.17	8.28***	1.45
Frequent complex	13.71 (3.83)	5.30 (2.14)	8.38	10.33***	1.81
Infrequent simple	15.46 (22.04)	4.17 (2.18)	11.08	2.45 **	0.42
Infrequent complex	11.86 (8.93)	3.91 (2.23)	7.77	4.22***	0.74
Pseudo words	9.91 (5.18)	2.13 (1.91)	7.61	7.05***	1.23
Reading word speed					
Frequent simple	34.98 (25.49)	33.35 (17.36)	11.39	2.08*	0.36
Frequent complex	49.22 (35.21)	37.57 (17.91)	12.222	1.65 ns	0.28
Infrequent simple	50.81 (28.67)	38.78 (14.09)	12.69	2.10*	0.36
Infrequent complex	55.49 (31.72)	46.39 (24.16)	9.74	1.41 ns	0.24
Total read words	188.51 (109.21)	156.09 (62.29)	46.05	1.99*	0.34
Pseudo words	61.37 (39.86)	47.74 (31.69)	14.66	1.68 ns	0.29
Cognitive skills					
Cancellation AC	19.69 (7.08)	11.65 (3.03)	7.98	8.73***	1.53
RAN objects	28.85 (8.07)	26.09 (5.55)	2.93	2.15*	0.37
RAN digit	27.76 (6.40)	30.09 (8.24)	−1.86	−1.02 ns	−0.17
RAN shapes	29.11 (6.75)	33.96 (10.18)	− 4.63	−2.16*	−0.37

$*p < 0.05$, $**p < 0.01$, $***p < 0.00$; n.s. = not significant.

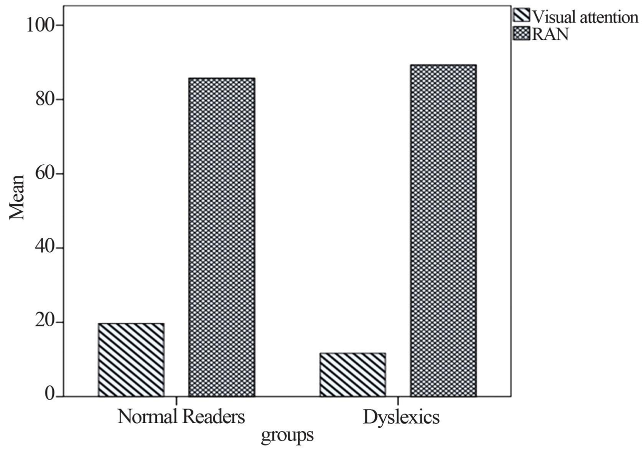

Figure 1. Mean comparison between groups in Visual attention processing and RAN.

2.2.2. Correlations between Measures

The results of correlation analyses are displayed in **Table 3** after partialling out the effects of age and IQ for the entire sample. Correlations of visual attention accuracy with all measures including pseudo-word identification were significant at the 0.05 level, except for infrequent simple words. RAN tasks were also significantly and strongly associated with word and pseudo-word reading speed (all *ps* < 0.01).

2.2.3. Predicting Reading Ability from the Cognitive Skills

Hierarchical regression analyses were performed to examine: a) the size of the relation between word reading ability as the predicted variable and the following factors: visual attention (i.e. cancellation test scores) accuracy/ speed, RAN objects/shapes/digits, and pseudo-word accuracy/speed; and b) how much each independent factor uniquely contributed to it.

As indicated in **Table 4**, pseudo-word reading accuracy and speed together explained 21% of the unique variance in total word reading accuracy and 52% of the unique variance in total word reading speed. Among cognitive factors, visual attention accuracy fairly explained the unique variance in total word reading accuracy (t = 2.28 < 0.05) and more so in word reading speed (t = 2.55 < 0.01). RAN measures did not explain any unique variance in reading accuracy.

The results of the hierarchical regression analysis indicate that higher scores on pseudo-word decoding accuracy and speed, cancellation accuracy, and RAN object scores contributed to higher scores on single word reading accuracy and speed. All *ps* of *F* were < 0.001, except for cancellation accuracy (<0.05). However, cancellation speed, RAN shapes, and digits did not contribute significantly to predicting word reading abilities for either

Table 3. Partial correlation coefficients controlling for age and Raven between word reading accuracy and speed, cancellation and RAN tasks.

Variables	TRW	FW	IW	PW	RS	CT	RAN.O	RAN.S	RAN.D
Total Words	-	0.37***	0.93***	0.35***	0.17*	0.21**	0.10	−0.06	0.09
Frequent Words		-	0.013	0.64***	−0.110	0.40***	0.07	−0.16	−0.15
Infrequent Words			-	0.13	0.22**	0.07	0.08	−0.001	0.16*
Pseudo Words				-	−0.05	0.51***	0.05	0.10	0.11
Reading Speed					-	0.29***	0.34***	0.21**	0.26***
Cancellation Task						-	0.42***	0.17*	0.20**
RAN Objects							-	0.46***	0.42***
RAN Shapes								-	0.39***
RAN Digits									-

*p < 0.05; **p < 0.01; ***p < 0.001 (2-tailed).

Table 4. Summary of hierarchical regression analysis predicting word reading.

Variables	Word reading			
	ß	*t*	*F change*	*Total R^2*
Pseudo words accuracy	0.36	4.63 ***	17.96***	0.218
Pseudo words speed	0.32	4.10 ***		
Cancellation accuracy	0.23	2.28*	3.61*	0.053
RAN objects	0.15	1.53	1.74	0.039
RAN shapes	−0.17	−1.69		
RAN digits	0.10	1.04		

*p < 0.05, **p < 0.01, ***p < 0.00.

accuracy or speed.

2.3. Discussion

In accordance with previous studies (e.g. Neuhaus & Swank, 2002; Visser, Boden, & Giaschi, 2004), children with dyslexia differ from normal readers in wordrecognition, RAN, visual attention, and phonological processing. Phonological processing in Arabic serves as a predictor in reading proficiency (Abu-Rabia, 2004; Abu-Rabia, Share, & Mansour, 2003; Al Mannai, & Everatt, 2005; Elbeheri & Everatt, 2007; Elbeheri et al., 2006) as in English-speaking cohorts. The slower word reading speed in dyslexic subjects is similar to that of a previous study (Layes et al, in Press), indicating the existence of an information processing deficit as claimed by Breznitz (2008), who presented the "asynchrony phenomenon" as a means of explaining dyslexia as a "speed of processing gap" (pp. 11-30) in word decoding. The dyslexic group also exhibited lower scores than controls on the cancellation test, results that corroborate findings of visual attention deficits in dyslexia (Stein & Walsh, 1997; Vidyasagar & Pammer, 1999), with their reaction times affected by size effects in serial processing (Casco et al., 1998; Iles, Walsh, & Richardson, 2000; Shalev & Tsal, 2003). Although a strong correlation was found between visual processing and the reading of frequent words, this was less so with infrequent words. In contrast, visual attention was strongly correlated with pseudo-word identification, which links phonological processing and orthographic structure (Taha, 2013). Both Arabic and Hebrew scripts make heavy demands on the visuo-spatial processing of letters, roots, affixes, and short vowels posted on and/or under the letters (Abu-rabia, 2001, 2003; Share & Levin, 1999).

Intergroup differences in RAN tasks are in accordance with previous studies on transparent orthographies (Lopez-Escribano & Katzir, 2008). RAN results showed strong associations with word recognition and pseudo-word speed, so that the impact of serial processing seems to be attributed to the simultaneous activation of visual and phonological representations (Protopapas & Altani, 2013). Our findings agree with those of RAN tasks in shallow orthographies (Katzir et al., 2006; Kirby, Georgiou, Martinussen, & Parrila, 2010), likely due to shared components (Protopapas, Altani, & Georgiou, 2013). The predictive pattern of word reading speed was also highly spotlighted by pseudo-word accuracy and speed, cancellation accuracy, and speed measures. However, RAN did not show predictive power for reading accuracy and speed. The contribution of RAN in explaining individual differences in reading performance was relatively smaller than pseudo-word and cancellation tests, in agreement with findings of Ziegler, Pech-Georgel, Dufau and Grainger (2010) on a shallow orthography in Finnish children. The correlation between RAN (shapes and digits) and the reading of frequent words inspires further investigations of this type. It seems increasingly necessary to identify other factors that predict reading ability, including one of the most studied in opaque orthographic systems: working memory.

3. Experiment Two: Phonological Awareness, Working Memory, and Reading Comprehension in Dyslexics

Verbal working memory (VWM) has been shown to be closely related with severe reading difficulties in early stages of development and serves as a predictor of reading ability (Cutting, Materek, Cole, Levine, & Mahone, 2009; Gathercole et al., 2006). Despite a growing body of knowledge about the influence of WM on Arabic reading (Abu-Rabia et al., 2003; Abu-Rabia & Taha, 2004; Abu-Rabia & Abu-Rahmoun, 2012), much less is known about how this factor works with others, particularly in relation with PA and reading comprehension. The latter represents a complex process involving several subcomponents and abilities that vary between readers (Sweet & Snow, 2003). These reading abilities are typically related to lower-level reading accuracy and fluency and higher-level comprehension-related linguistic and cognitive abilities (Pazzaglia, Cornoldi, & Tessoldi, 1993). Both levels are essential for successful reading. Starting from the 3rd year, children are gradually introduced to non-vowelized Arabic texts and consequently phonological processing may be needed to supplement WM processes for reading comprehension (Elbeheri, Everatt, Mahfoudhi, Abu Al-Diyar, & Taibah, 2011). It is widely accepted that a WM deficit is one of the most important factors underlying phonological deficiencies. If an individual cannot hold an unfamiliar word in short-term memory long enough to repeat it, segmenting the word poses an immediate challenge (Nicolson & Fawcett, 1994).

The aim of the second study was to investigate the extent to which WM and PA are related to word recognition and reading comprehension**.** We anticipated that dyslexic children would show poorer performances in PA and WM. Verbal WM has been found to be a strong predictor of reading comprehension and single word decoding in Arabic children of grade 6 or higher while phonological processing has more power in predicting literacy in earlier grades (Abu Rabia et al., 2012; Al Mannai & Everatt, 2005). We looked at the contribution of WM and PA on reading comprehension and word recognition at 4th and 5th grades.

3.1. Method

3.1.1. Participants

The dyslexic children (n = 36) were diagnosed in their school, 11 females and 25 males, in the 4th and 5th grade. Their mean chronological age was 131.72 months (SD = 6.49). The additional criterion was their performance on general ability tests (**Table 5**). The dyslexic group showed adequate performance on the Raven Standardized Matrices test. The age-matched group, composed of 20 students from grade 4 and 5, 5 females and 15 males, were screened on the general ability test. Their mean age in months 125.80 months (SD = 3.86).

3.1.2. Measures and Procedure

Reading tasks were the same described in experiment one.

Phonological awareness was measured by the phoneme elisiontask (internal consistency coefficient, α = 0.91), which included 10 word pairs: consonant clusters, as all Arabic words are triliteral (three lettered) consonantal roots. The words were disyllabic (CVCVC), and were spoken in standard Arabic. Based on the auditory pathway, participants were asked to remove the first phoneme of each word and then use a new combination. Some training was given in three practice trials to make sure that the participants understood the task.

Reading comprehension was assessed by an adapted version of the "sentences comprehension" subtest of Khomsi's LMC-R test (1999) was used. The participants were required to point at one of four pictures corresponding to the read sentence. Participants were instructed to respond to the 15 items as quickly and as accurately as possible without any time limit. The internal consistency coefficient, α = 0.83). The sentences were in ascending order of syntactic difficulty (structural length). For each item, the sentence was presented with pictures on the same sheet. We first introduced a free practice trial on one sheet containing one phrase and 4 illustrations. If that was well accomplished, we invited the participant to start the test; otherwise, we added another practice trial. The child was first asked to read the sentence and then indicate the picture that best matched with its meaning. A score of "0" was given for incorrect responses (the first response given by the participant if there was no immediate correction) and a "1" for correct responses. The maximal score is 15.

Working Memory was assessed using two tasks (verbal and symbolic) were taken from the WRAML-2 test (Sheslow & Adams, 2003) designed to evaluate children and adults (ages 5 - 90 years). The WRAML2 is a relia-

Table 5. Participant's characteristics and mean performance of all measures by group.

Variables	Normal readers N = 20	Dyslexics N = 36		
	M (SD)	M (SD)	Difference mean	*t* (2.00)
Age (months)	125.80 (3.86)	131.72 (6.49)	5.39	4.32***
Raven	20.95 (5.39)	20.41 (3.96)	0.53	0.42 ns
Total reading words	72.75 (10.62)	52.47 (9.94)	20.27	7.13***
Frequent words	36.45 (6.41)	27.50 (4.86)	8.95	5.88***
Infrequent words	36.30 (4.69)	26.27 (5.44)	10.02	6.92***
Pseudo words	17.95 (3.31)	11.05 (2.77)	6.89	8.30***
Phonological awareness	15.50 (4.16)	10.33 (4.67)	5.16	4.11***
Read comprehension	13.00 (1.84)	10.48 (2.00)	2.51	4.61***
Speed reading words	301.00 (224.54)	719.19 (338.58)	418.19	4.94***
Verbal W.M accuracy	6.90 (1.55)	3.21 (2.50)	3.68	6.79***
Symbolic W.M accuracy	3.38 (1.32)	2.93 (1.26)	0.44	1.25 ns

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; n.s. = not significant.

ble, norm-referenced test that has been nationally standardized to assess a wide range of clinical issues.

Verbal Working Memory task

During verbal WM task, the participant heard lists of nouns (10 series) representing animals and non-animals and, immediately thereafter, recalled the animals in a reorganized order from the smallest to the largest. The test-retest reliability coefficient was 0.53 and the Guttman split-half coefficient (0.633). The scoring was as follows: all names mentioned in the correct order: 1 point, an error in the ranking order: 0.5 point, an omission of a name but in a correct order: 0.5 point, an error in order and omission: 0 point.

Symbolic Working Memory task

The symbolic WM task measures how well a person actively operates on and retains symbols, including numbers (1 to 9) and shapes (star, dot, triangle, circle, arrow, cube, crescent, line, and square). Participants first heard a list of 4 than 5 items out loud (the processing component) and remembered the digits and shapes in each list (the storage component), in the same order of presentation using only finger pointing. The comparison of two extreme groups showed that the 18 participants with the highest scores in the visual attention task were better than the 18 participants with the lowest scores ($t = 24.44$; $p < 0.000$), indicating a satisfactory differentiating power. Split-half reliability of this task showed a satisfactory reliability quotient (Guttmanco efficient = 0.445).

3.2. Results

Descriptive data are shown in **Table 5**. An unexpected difference in age was revealed between the two groups, likely due to the number of dyslexic subjects in grade 5. As expected, children with dyslexia showed impairments in literacy measures, PA accuracy and speed, and reading comprehension accuracy.

3.2.1. Group Comparisons

There were differences between dyslexics and controls in reading accuracy (t (2.00), all p values < 0.001) and speed only for simple words (frequent and infrequent) and the total score (t (2.00), p values < 0.05), with large effect sizes (0.34). However, no difference occurred in reading speed for complex words (frequent and infrequent) and pseudo-words. The dyslexic group also exhibited lower scores in the cancellation task for accuracy (t (2.00) = 8.73, $p < 0.001$) and speed (t (2.00) = 2.76, $p < 0.01$) (**Figure 2** and **Figure 3**).

3.2.2. Correlations between Reading Abilities, PA, and WM

Table 6 shows inter-correlations among all measures after partialling out the effects of age and IQ for the entire sample. All correlations were significant at the 0.001 level. Word reading, reading comprehension, and PA were significantly associated with verbal WM. Correlations of visual attention with all measures including pseudo-word identification were significant at least at the 0.05 level except for infrequent simple words. RAN tasks were likewise strongly associated with word and pseudo-word reading speed (all ps < 0.01).

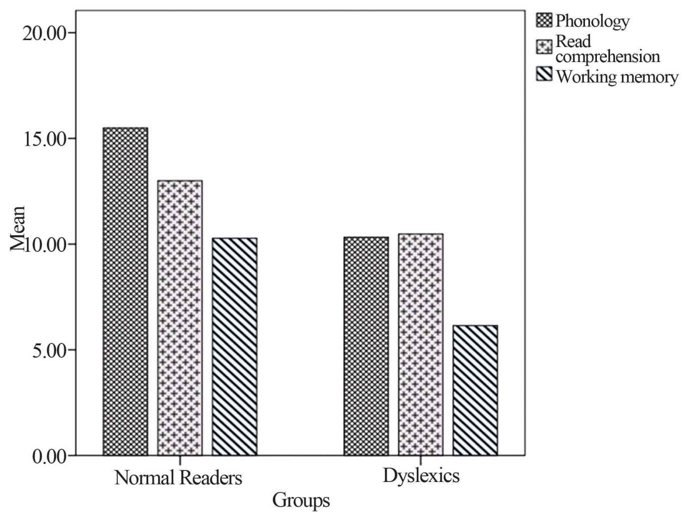

Figure 2. PA, reading comprehension and WM by group.

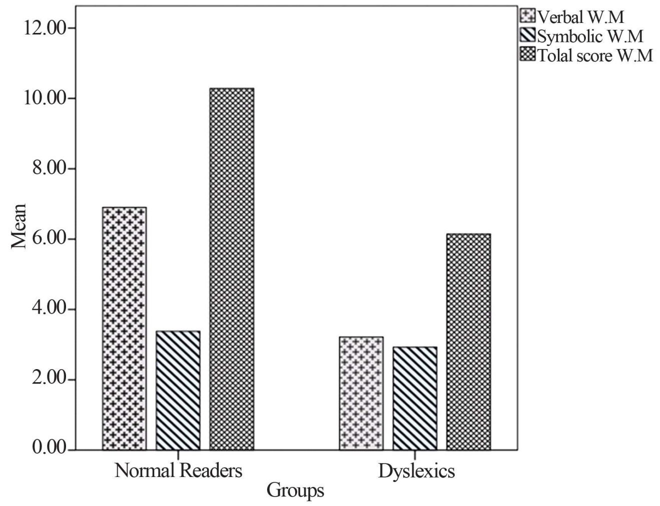

Figure 3. Performance by group in verbal and symbolic WM.

Table 6. Partial correlations controlling for age between literacy, PA, reading comprehension and WM measures.

Variables	TRW	FW	IW	PW	PA	RC	VWM	SWM
Total Words	-	.085***	0.77***	0.79***	0.52***	0.64***	0.51***	−0.05
Frequent Words		-	0.67***	0.82***	0.60***	0.65***	0.59***	0.17
Infrequent Words			-	0.72***	0.64***	0.73***	0.59***	0.08
Pseudo Words				-	0.54***	0.63***	0.58***	0.14
Phonological Awareness					-	0.45***	0.46***	0.06
Reading Comprehension						-	0.38***	0.17
Verbal W. Memory							-	0.12
Symbolic W. Memory								-

***p < 0.00 (2-tailed).

3.2.3. Predicting Word Recognition and Reading Comprehension from PA and WM

The control variables of age and IQ were first entered into each regression analysis followed by PA and verbal WM. Reading comprehension and word recognition were then entered as predicting factors of one or the other. As shown in **Table 7**, PA and WM skills explained significant variables in word reading ability (all F changes < 0.00): PA (R^2 = 0.30); verbal WM (R^2 = 0.42). Verbal WM predicted higher scores on word recognition (t = 3.04 < 0.000) but not on reading comprehension. PA explained significant variables in reading comprehension (R^2 = 0.28) but not WM. In contrast, age and IQ were not associated with word reading (R^2 = 0.03) and reading comprehension (R^2 = 0.09). Reading comprehension strongly predicted word recognition and vice-versa (F changes < 0.000).

3.3. Discussion

The second experiment was conducted to examine the contribution of PA and WM as predictors of reading efficiency. Verbal WM was correlated with literacy, PA, and reading comprehension. A result corroborates a previous Arabic study with preschool children (Zayed, Roehrig, Arrastia-Lloyd, & Gilgil, 2013). Individuals with dyslexia are not efficient in converting letters into a phonological form, which may inhibit their ability to learn the reading of new words (Jeffries & Everatt, 2004). It has been proposed that WM has an impact on children's phonological sensitivity and reading skills. Thus, the interplay between the two reflects a common physiological substrate (Jeffries & Everatt, 2003, 2004; Oakhill & Kyle, 2000).

Table 7. Summary of hierarchical regression analysis predicting reading words and reading comprehension (n = 56).

Variables	Word reading				Reading comprehension			
	ß	*t*	*F change*	*Total* R^2	*ß*	*t*	*F change*	*Total* R^2
Step 1								
Age + IQ	−0.07/0.30	−1.05/0.70	1.02	0.037	−0.01/0.07	−1.68/1.13	2.66	0.091
P.A	1.53	4.46	19.96***	0.304	0.21	3.75	14.66***	0.285
V.W.M	1.99	3.04	8.55**	0.320	0.18	1.63	2.08	0.340
S. W.M	−1.40	−1.18	5.00**		0.21	1.04		
Step 2								
V. W.M	2.86	4.62	10.79***	0.324	0.18	1.63	5.54**	0.254
S.W.M	1.26	−1.07	8.35**	0.420	0.21	1.04	6.52**	0.340
P.A	1.04	2.89			0.16	2.55		

$^{**}p < 0.01$, $^{***}p < 0.00$.

A significant correlation was also detected between verbal WM and reading comprehension, that requires the processing and storage of words and sentences. Thus, the relation between a word and a sentence is likely to be predictive of reading comprehension because both require linguistic skills (Seigneuric, et al., 2000). Verbal WM was a strong predictor of word reading and reading comprehension when entered before PA but after PA, it was a significant predictor only of word reading, in line with previous studies indicating its fundamental contribution in reading comprehension (Alloway & Alloway, 2010; Carretti, Borella, Cornoldi, & De Beni, 2009).

Verbal WM is direct predictor when entered first in the equation but contributes beyond phonological skills in reading comprehension, in agreement with recent research in developmental dyslexia (Frost, Madsbjerg, Niedersøe, Olofsson, & Sorensen, 2005). This may be explained by the function of executive processing, which distributes appropriate attentional resources to the phonological loop during PA tasks (Navarro, Aguilar, Alcalde, Ruiz, Marchena, & Menacho, 2011). Thus, PA may be contingent on the capacity of verbal WM to store the target word and locate the phoneme to be deleted.

WM and PA explain variability in word reading, just as the former accounted for a significant proportion of variance in word recognition ability (Cain et al., 2004), underlying its importance in explaining reading comprehension in children from 7 to 11 years of age (Vukovic & Siegel, 2006). This finding corroborates many others showing a link between WM and reading comprehension (Alloway & Alloway, 2010; Cartwright, 2012). Opaque orthographies particularly require cognitive flexibility relative to transparent ones (Ziegler & Goswami, 2005).

4. General Discussion

The present study contributes to establish literacy and cognitive measures that characterize Arabic speaking children with and without dyslexia. The dyslexic group performed less well than controls on a wide range of literacy, phonological, and cognitive skills. In particular, dyslexic children were poorer than controls in PA, reading comprehension, rapid naming, visual attention, and WM. Regression analyses showed that rapid naming, visual attention, and WM were associated with word reading and reading comprehension, extending previous work on multiple cognitive deficits that underlie reading mechanisms (Shaywitz & Shaywitz, 2005; Wolf & Katzir-Cohen, 2001).

4.1. The Role of Phonological Processing, Visual Attention and RAN on Reading Efficiency

The most marked differences were evident in PA and RAN. These findings are in agreement with those between reading-disabled children and normal Arabic readers on a range of reading and cognitive measures (Abu-Rabia, 2003, 2007; Abu-Rabia & Siegel, 2001), indicating that interpersonal differences in reading abilities can be explained mainly through differences in phonological processes. This claim is based on the manipulation deficit of the phonological code by dyslexic children who demonstrated serious failures on reading pseudo-words and persistent difficulties in phonological processing (Facoetti, Turatto, Lorusso & Mascetti, 2000), whereas normal readers reached best levels, suggesting that Arabic dyslexics are less sensitive to language sound structure than controls. These results are similar to reading-disabled characteristics reported in other studies (e.g. Ben-Dror, Frost, & Bentin, 1995). Moreover, a number of studies in Arabic orthography showed significant effects of phonology on reading accuracy and reading comprehension (Abu-Rabia, 2001; Abu-Rabia & Siegel, 2002). The importance of phonological processing is also established by regression analyses which indicated that pseudo-word reading and PA were the best predictors of variability in word-level literacy and reading comprehension. This was noted by Al-Mannaiand Everatt (2005), who examined predictors of literacy development from grade 1 through grade 3 Arabic-speaking learners.

Although differences between dyslexics and controls were significant in RAN tasks (objects and shapes), RAN was not related to reading words unless we partialed out group as a variable. However, RAN measures strongly predicted reading speed, in agreement with previous findings (Torgesen, Wagner,&Rashotte, 1994; Torgesen, Wagner, Rashotte, Alexander, & Conway, 1997). SinceRAN is time-based. Scores are likely due to shared features, namely rapid visual-verbal associations between printed symbols and their phonological identities. Our findings are consistent with those indicating that a rapid naming deficit seems to be one of the main characteristics of dyslexic children in a transparent orthography (Georgiou, Papadopoulos, Zarouna, & Parrila, 2012). Though color and object RAN tasks were not predictive of reading performance in normal readers after the first or second grade, letter and digit RAN continued to predict performance until at least the age of 18, suggesting that good readers automate letter and digit naming after grade 1, whereas poor readers do not.

One of the theories to explanting the relation between RAN and reading speed is that both reflect orthographic processing (Bowers & Newby-Clark, 2002; Manis, Seidenberg, & Doi, 1999). According to this view, efficient orthographic processing depends on an accurate integration of visual information about letter sequences in the words. In particular, participants with shorter RAN object naming times had better visual attention. Indeed, several researcher workers have argued that RAN deficits in children with dyslexia reflect lower-level visual processing deficits that are amplified when the tasks require integration of more than one set of sub-processes (Stainthorp, Stuart, Powell, Quinlan, & Garwood, 2010; Stein, Talcott, & Walsh, 2000). Similarly, it has been claimed that Arabic scripts make heavy demands on the visuo-spatial processing of letters, roots, affixes, and short vowels posted on and/or under letters (Abu-Rabia, 2001; Share & Levin, 1999).

As demonstrated in various studies on visual attention in children performing cancellation tasks (Hawelka & Wimmer, 2005; Iles et al., 2000; Taroyan, Nicolson, & Fawcett, 2007), it has been suggested that children with developmental dyslexia have slower information processing speed (Huang & Wang, 2009). Hari and Renvall (2001) explained these characteristics by the theory of "slugging attentional shifting", in which the processing of a stimulus sequence is hindered by slow attentional capture and increased reaction time. According to these authors, the link between visual attention and reading achievements does not necessarily provide an argument in favor of the attentional hypothesis of dyslexia.

4.2. The Role of WM in Word Recognition and Reading Comprehension

Our results show that word reading, reading comprehension, and PA were significantly associated with verbal WM. In addition, regression analysis indicated that PA and WM skills explained significant variables in word reading ability. Furthermore, verbal WM contributed to the prediction of higher scores on word recognition and reading comprehension when entered before PA. These findings are consistent with those of Seigneuric et al. (2000) who established that verbal and numerical WM tasks revealed unique variance in the reading comprehension of normal subjects. More recently, Georgiou, Das and Hayward (2008) revealed that PA and rapid naming provide unique variance beyond the effects of WM as a predictor of reading.

The link between WM and reading comprehension is likely related to computing semantic and syntactic relations among successive words, phrases, and sentences, to construct a coherent overall representation. Nation et al., (1999) found that good and poor comprehenders differed in verbal WM and thus the latter may have specific problems in tasks that placed an emphasis on semantic processing. It is assumed that WM enables an individual to hold the constituent sounds and phonological codes in a short-term store until recognized as a word or sentence and its meaning extracted from long-term memory. In the opinion of Oakhill, Yuill and Garnham (2011), WM resources are specialized for language processing. WM and PA are underlying factors which contribute to reading comprehension even when word reading ability is taken into account. Thus, WM resources seem to be an important and specific determinant of children's word reading ability and reading comprehension (Swanson & Berninger, 1995).

5. Limitations and Future Directions

Reading-related skills are subject to development during schooling and might influence differently reading mastery. The interrelation with the age factor might be examined by adding a control group matched for reading level. A second limitation of the present study is the lack of standardized tests of reading and phonological processing in Arabic-speaking children. Such tests would be helpful in identifying deficits without the need to compare with reading-level controls. In addition, our data are limited to primary schools. Thus, we do not know the extent to which the variability of the individuals' profile changes over time and if students identified as having dyslexia will continue to have problems later which strategies are used to cope with heir handicap.

6. Implications and Conclusion

Despite these limitations, the present study offers new insights into Arabic speaking children diagnosed with dyslexia, demonstrating continuing problems in cognitive related reading skills beyond the early years of reading instruction, namely rapid naming, verbal WM, morphological awareness, and visual attention. The present findings support the hypothesis that dyslexia is persistent and multifactorial.

It seems worthwhile to understand the compensatory strategies used to attain academic success. Kirby, Georgiou, Martinussen and Parrila (2010) identified two methods for grasping how university students cope with their reading deficit in the face of their academic work, i.e., self-report questionnaires and observational methods in which strategies are observed or inferred from performance. In early intervention implications (Breznitz, 2008), it is also valuable to conceive a program, inexistent hitherto in Arabic, in an attempt to train dyslexic children to process phonological and orthographic information for speeding up information processing. The present study highlights the role of PA on literacy achievement, so that PA training may be used to ascertain its impact at the lexical level and linguistic-related skills such as morphological awareness.

Acknowledgements

We wish to thank the children, who participated in this study and their parents for their consent, well as school professionals for their valuable contribution.

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