Study on the Concurrent Role of Phonological Processing and Visual Perception Abilities in Word Reading in Arabic- A Follow-up Study

Arab Journal of Applied Linguistics
e-ISSN 2490-4198
Vol. 08, No. 02, 2023, 01-37

http://www.arjals.com

Smail Layes, Kamel Layes

Department of Psychology and Educational Sciences, University of El-Oued – Algeria

Abstract

The purpose of this follow-up study was to determine the specific contribution of phonological processing abilities, including phonological awareness (PA), rapid automatized naming (RAN) and verbal short-term memory (VSTM), as well as visual perception (VP), in word reading accuracy. A sample of 62 native Arabic speaking children from Grade 1 participated in study, were subdivided into typical readers (n= 42) and poor readers (n=20). Along with a diagrammatic representations test to assess visual perception, phonological processing tasks included syllable deletion, RAN objects, and pseudo-word repetition, in addition to word and pseudo-word reading tests. Participants were tested in grade 1 using the phonological and VP tasks and one year later in grade 2 using the same tasks in addition to the reading test. The main research hypotheses stipulated that typical and poor readers differ significantly in all the phonological and VP measures. It was also hypothesized that phonological and VP processing abilities contribute independently to the prediction of word reading accuracy for the entire sample. The results showed that the two groups differ significantly in PA and VSTM which were assessed in Grade 1, and in PA and VP assessed in grade 2. More importantly, hierarchical regression analyses showed that among the three phonological processing skills, PA as assessed in both grade 1 and grade 2 was the unique predictor of word reading accuracy after controlling for age and the Raven's matrices for nonverbal abstract reasoning. Visual perception also contributed significantly to the prediction of reading but only when assessed in grade 2.

The findings demonstrate the key role of both PA and VP for the early development of word reading accuracy in Arabic.

***Keywords**:* phonological processing, visual perceptual, word reading, Arabic orthography

Introduction

Over the last decades, a wide range of research has suggested the existence of strong predictors of reading abilities. The most acknowledged of these include phonological processing skills such as phonological awareness (PA), phonological memory, and rapid naming (Melby-Lervag et al., 2012), as well as visual processing skills, in particular visuo-spatial attention (Franceschini et al., 2012; Vidyasagar & Pammer, 2010) and visual memory (Mesman & Kibby, 2011). However, much less attention has been devoted to the role of visual perception in reading, although the paramount role of visual processing skills in word reading dates back to early studies (e.g., Facoetti et al., 2008; Vidyasagar & Pammer, 2010). The purpose of the current study was to examine the contribution of phonological processing abilities and visual perception in predicting word reading performance in a cohort of native Arabic speaking children.

Children who have reading difficulties are not a homogeneous group (Sleeman, et al., 2022). The term developmental dyslexia, sometimes used as a synonym of reading disability, refers to a severe difficulty in decoding (Protopapas and Parrila 2018; Snowling et al. 2019). Peterson and Pennington (2015) state that dyslexia is defined as the "low end of a normal distribution of word reading ability" (p. 285), and accordingly a cut-off point should be set up for the diagnostic. Similarly, Seidenberg (2017) states that children with dyslexia perform at the low end of a normal distribution in reading. Poor readers and children with dyslexia face the same challenges in learning to read, but those with dyslexia have more difficulty with the essential components of reading due to the severity of the deficit (Yang et al., 2022).

Based on this conceptual framework and the well-known statistical criterion for identifying children with dyslexia which consist of -1.5 SD (Wagner et al., 2020), we opted for the cut-off point -1 SD for the identification of poor readers (Catts et al., 2003). The common sets of the cut-off for reading achievement are 1 and 1.5 standard deviations (SD) below the mean for the same age (Wagner et al., 2020).

According to the "Reading Component Model", poor readers with specific difficulty in word recognition, represent one of the three subgroups of poor readers, those with specific listening comprehension difficulty and those having a mix of both difficulties, i.e., word recognition and listening comprehension (Catts et al., 2003).

Whereas inclusionary and exclusionary criteria are agreed to be the basis of the diagnosis and constantly applicable for the identification of "poor reading" and "developmental dyslexia", cut-off points remain the principal differential criterion in this process. The DSM-5 (2013) suggests that to qualify as having dyslexia, students' reading standard scores should be at least 1.5 standard deviations (SD) or more below the mean for age. In this study, we adopt a conservative approach and designate as "poor readers" children who fall below 1 SD on word and pseudoword decoding, who also meet the exclusionary criteria of developmental dyslexia as defined in DSM4 (2000).

Phonology retains a central role in current models of dyslexia as a large body of research indicate its causal role in reading development (e.g., Hulme et al., 2012). Learning to read and storage of the alphabetical system requires learning the relationship between letters and the corresponding speech sounds. According to the phonological deficit theory (Snowling, 1981), disabled readers have difficulties in representing, storing, and retrieving phonemes (Stanovich, 1986), which results in an inadequate correspondence between phonemes and graphemes, as well as reading difficulty. The phonological theory suggests poor performance in children with dyslexia on tasks requiring phonological awareness (PA), verbal phonological memory, and phonological retrieval in naming tasks (Snowling, 2000).

Wagner et al. (1987) proposed the Specific Ability Model, according to which phonological processing includes phonological awareness (PA), phonological memory (PM), and rapid naming (RAN) that are held to be distinct but related abilities. Consistent with the phonological processing deficit theory of developmental dyslexia (Snowling, 2002), Wagner and Torgesen (1987) have proposed that RAN tasks are an index of the speed with which phonological information can be accessed from memory and are thus best described as tapping into an aspect of phonological processing. By contrast, other studies suggest that phonological processing may be composed of several related but distinct abilities (e.g., Nelson et al., 2012; Powell et al., 2007) and, while some of these abilities may be impaired in children with dyslexia, others may remain intact (Ramus & Ahissar, 2012). The double-deficit hypothesis of dyslexia (Wolf & Bowers, 1999) posits that both rapid naming and phonological impairments can cause reading difficulties, and that individuals who have both of these deficits show greater reading impairments compared to those with a single deficit. This hypothesis also proposes a framework in which PA and Rapid Automatized Naming (RAN) are separable components of phonological ability and therefore represent distinct sources of impairment in dyslexia (Wolf et al., 2002) as they relate to different aspects of reading ability (Georgiou et al., 2009). By contrast to Wagner's position, Wolf and Bowers (1999) propose that RAN tasks index processes independently of phonology, which is the basis of the "double deficit" hypothesis in dyslexia. Regardless of the point of view one can adopts, the theoretical accounts outlined above converge on the fact that PA constitutes the pivotal component of phonological processing and recognise the independent role of the other two components in reading.

However, several indications against the generalisation of the phonological deficit in dyslexia stem from the observation that the orthographic depth variability also determines the importance of phonological factors in reading (Ziegler et al., 2010). Moreover, the contribution of phonological processing abilities in reading tends to vary across grade levels, suggesting plausible developmental changes in the relations between phonological processing during literacy development. Research also demonstrates that PA and RAN make their strongest contributions to reading ability at different developmental stages, suggesting that the impact of the phonological deficit may change during the course of development (Boets, 2014). Thus, it is of great importance for practitioners and educators to explore the predictive contribution of phonological processing skills from the beginning of literacy acquisition to determine early precursors of future literacy success.

Although developmental dyslexia is commonly described as a language-based disorder (Snowling, 2000; Peterson & Pennington, 2012), numerous studies show that reading is a complex cognitive process, in which not only phonological skills, but also visual-spatial skills are involved (Pennington, 2006; Menghini et al., 2010).

Visual perception commonly refers to active processes for locating, extracting, and analysing relevant information in the visual environment (Sortor & Kulp, 2003), and consists of several specific abilities, including form constancy, spatial relations, and visual discrimination (Auld et al., 2011). Visual perception is part of the learner's visual information processing which involves a group of perceptual and cognitive aspects necessary for extracting and organising visual information from the environment (Borsting, 2006). Visual processing is the procedure of organizing and interpreting visual information (Siok & Fletcher, 2001). It is composed of a sensory system and perception mechanisms and reflects the ability of attending to and distinguishing a figure's features and details, such as shape, orientation, colour, and size (Yang et al., 2013). Loikith (2005) states that visual perception tasks involve visual attention, as there are shifts to some spatial details requiring a purposeful activity and a visual information extraction from the visual environment.

To perform functional tasks such as reading, spelling, and writing, the learner must integrate various visual perceptual abilities, like spatial relations and visual discrimination (Retief & Heimburge, 2006; Schneck, 2005). Specifically, beginning readers need to develop good visual skills to be able to decode words (Zhou et al., 2014). Therefore, abnormal visual perception is thought to be directly associated with and often causal to reading disability (Stefanics et al., 2011; Zhao et al., 2014).

Consequently, children struggling in the visual discrimination between forms may experience difficulty to distinguish between letters in reading and spelling.

Recently, multiple researchers have linked various visual processing deficits to dyslexia, including reduced multi-character processing and visual attention for briefly presented stimuli (e.g., Hawelka et al., 2006), visual discrimination of quickly presented items (Ortiz et al., 2014), visual closure and form constancy (Germano et al., 2014), and visual search (Jones et al., 2008). More specifically, studies reported that visual perception skills predict specific academic functions, such as reading and writing (Burtner et al., 2006). Kavale and Forness (2000) conducted a meta-analysis to determine how well visual and auditory perception predicted various aspects of reading achievement. They clustered visual measures into seven types: visual discrimination, visual closure, visual spatial relationships, figure ground discrimination, visual association, visual-motor integration, and visual memory. The authors found visual memory and visual discrimination to be the best predictors of reading ability in general, and word recognition in particular, when analysing the visual measures (Kibby et al., 2015). Cheng et al. (2018) reported that three groups of children with dyslexia, dyscalculia, and association of both learning disabilities (comorbidity group), have common deficits in visual perception compared to typically developing subjects. This finding suggests that visual perception deficits are a common cognitive deficit underlying specific learning disabilities.

In addition to the well-established research on phonological processing, most studies on visual processing skills and word reading have been carried out at a single point in time (Zhou et al., 2014). However, both phonological and visual processing skills required for reading depend on each other during the initial period of reading development (Hautus et al, 2003), suggesting a bidirectional relationship between visual perceptual skills and learning to read in the early years (e.g., McBride-Chang et al., 2011). Therefore, a crucial element for disentangling inconsistencies on the contributions of phonological and visual abilities in developmental dyslexia could be addressed by understanding age-related changes and their predictive relationships (Goswami, 2003). Studies have shown, for example, that in more transparent orthographies, PA plays an important role in the early period of reading development until the end of kindergarten. However, PA becomes increasingly less predictive across development, and other variables contribute to the prediction of reading and writing disabilities.

Along with the vital role of phonological processing skills, the role of visual perception in reading and spelling has also been recognized in a number of studies in Latin orthographies. However, little is known about the early contribution of visual processing in reading and spelling in Arabic, and even less about its predictive relation with these literacy outcomes. Orthographies vary in their degrees of transparency and can be viewed along a continuum of orthographic depth (e.g., Seymour et al., 2003). Highly transparent languages, like Italian, are at one edge of the continuum and the languages with deep orthographies, like English, occupy the other end, due to their irregularity and the high degree of phonemes-graphemes correspondence inconsistencies. It is thought that Arabic, in its vowelised from, fits the condition of high transparent orthograph (Asadi, 2017).

To our best knowledge, the only published study having examined the role of visual perception in reading in Arabic is that of Asadi and Eviatar (2014), who investigated the influence of visual perceptual abilities, orthographic, and phonologic factors on reading skills using a set of visual perceptual skills (e.g., visual discrimination, visual spatial-relationships, etc.). The sample composed of typical readers from Grades 1, 3 and 5. The results showed that any of the visual perception skills significantly correlated with reading skills. This study being conducted on typical readers only, could not inform us on how poor/disabled readers perform on visual perception test, and more importantly, how it connects to reading in this population. To gain a better understanding of the predictive associations between reading and both phonological processing and visual perceptual skills, the present follow-up study focused on whether these factors contribute individually to promote word reading accuracy in the first and second grades, and their potential effect on spelling in Arabic.

Arabic has a unicase (lowercase) alphabet written from right to left. More notably, in the Arabic orthographic system, several letters of the alphabet are represented by similar structures distinguished only by the existence, location, and number of dots, for example: [/ شجرة/ (tree), / سحاب/ (cloud), / قبل/ (before), /فيل/ (elephant)]. Most words are derived by a joint combination of a root made up of consonants (triliteral) in a morpho-phonological pattern (Boudelaa & Marslen-Wilson, 2004). The core meaning of the word is conveyed by the root, while the pattern that can be either a sequence of short or long vowels that denote word-class information. For example, the root "ktb" means "to write", but when it is embedded in a pattern of a subject [CaCiC, katib], it gives the meaning of "writer". Given these characteristics, it is thought that compared to other alphabetic scripts, Arabic may rely more on visual-orthographic processes in lexical processing, as suggested in Abu-Rabia (1995), who found that the performance of Arabic reading disabled children on orthographic measures was as good as that of their normal counterparts matched by reading-level age.

Furthermore, children learn to read first with the transparent version that contains vowelisation marks called short vowels which are represented in the form of superscripted diacritics presented above or below consonantal letters. Around the fourth grade, short vowels are progressively removed from the text, which results in higher orthographic depth. In the absence of short vowels, and thus the lack of one part of phonological information, many words become homographic. In Arabic, homography is related to the fact that certain words can appear identical when written without short vowels, based on their consonantal form. For example, the unvowelised word (كتب) /ktb/can relate to the verb /kataba/ (wrote) or /kutub/ (books), just to cite a few. We thus hypothesize that reading and spelling in Arabic demand visual perceptual skills. In this study, we investigate the specific contribution of various phonological processing skills, namely PA, rapid automatized naming (RAN), and verbal short-term memory (VSTM), as well as visual perceptual skills in word reading and spelling of Arabic children with dyslexia in the early years (grade 1 and grade 2) of reading acquisition. Studying children's performance during this critical period, where the foundations of the decoding skills are established, enables us to examine the associations between phonological and visual perceptual skills, and to investigate their potential predictive relationships with reading and spelling.

This study investigates the relationships between phonological processing (PA, RAN and VSTM) and VP abilities on one hand, and word reading on the other hand, in a cohort of Arabic speaking children. Two main research questions guided our investigation:

1. Are there significant differences in the phonological processing and visual perception measures in typical readers and poor readers across grades?
2. To what extent phonological processing and visual perception abilities, as assessed in grade 1 and grade 2, predict word reading accuracy in all participants?

Given the importance of phonological processing abilities in reading (e.g., Plaza, 2003), we predict that phonological processing abilities individually contribute to the prediction of reading accuracy. In addition, as visual perceptual processing is of great importance in reading Arabic due to the above-mentioned orthographic characteristics, VP would also act as a potential significant predictor of words reading accuracy.

Method

Participants

Eighty native Arabic children were primarily selected based on teacher report as having noticeable difficulties in learning to read, and have been candidates for further assessment, in addition to forty children without any clear academic difficulties. Inclusion criteria for poor readers included adequate sight and hearing, without neurological and behavioural disorders as reported by school health committees. Eighteen children were excluded from the study as they failed to meet the inclusion criteria due to having repeated their academic year or obtained a low score on the Raven Standard Progressive Matrices (Bouma et al., 1996). The final sample consists of 62 students in grade 1, who were classified into two groups based on their individual score on the composite score of word and pseudoword reading test (Layes et al, 2021; Layes et al., 2022): a typical reading group (n =42) composed of 13 females and 29 males with a mean age of 75.95 months (SD =3.01), and a poor readers group (n= 20) composed of 7 females and 13 males with a mean chronological age of 75.39 months (SD =4.28). Individuals scoring at least – 1 SD below the mean were considered as poor readers (Catts et al., 2012). Initial analyses indicated no statistically significant difference between the two groups on the Raven test (t = .202, $p > .05$) and in age (t = − .524, $p > .05$).

Educational Context

As an overview of the educational background of this study, students typically start primary school at the age of 6 years. Elementary school lasts five years from grade 1 to grade 5, and children then move on to middle school. All participants were screened for reading and IQ in their schools where teaching is mainly provided in Modern Standard Arabic. All children received an identical reading and writing instruction program based on the existing curriculum. Children and their parents were informed of the purpose of the study and their approval was obtained.

Materials and procedure

There were two testing sessions. In the first one, participants performed Raven, PA, RAN, VSTM, and visual perception tests. After 12 months, a second testing session took place for all the above-mentioned measures except for the Raven test, in addition to word and pseudo-word reading test. The tests were administered in a fixed order in the two sessions.

Raven test

The Raven Standard Progressive Matrices is a nonverbal test of reasoning ability and general intelligence. We used the shortened form (Bouma et al., 1996), comprising 36 items (sets A, B and C) and consisting of a target matrix with one missing part. The children selected from six to eight alternatives to fill the missing patch.

Phonological awareness

A syllable deletion task was used. Fifteen words were presented orally one by one and participants were instructed to verbalise the remaining part of the word after removing the specified syllable (consonant with vowel). The syllable to be deleted was either in the beginning, the middle, or the end of the word. The internal consistency of the test was fairly good (α = 0.68).

Rapid automatized naming (RAN)

An expanded version of the RAN objects task from a previous study was developed to measure lexical retrieval speed of visually presented objects (Wolf & Bowers, 1999). The RAN object task allows us to assess direct access to the phonological representations of real lexical units (i.e., entire words). Participants then named as quickly as possible recurring objects (scissors, cat, book, pen, and hand) arranged semi-randomly in eight rows and repeated 10 times. The time needed to name all of the stimuli was measured. The task was preceded by a short practice session to make sure the child named the presented pictures correctly. The test-retest reliability of the RAN task was r=.63.

Verbal short-term memory (VSTM)

We opted for the pseudo-word span test because of its attested validity in assessing phonological STM (Baddeley, 2003; Gathercole, 2006). The non–word repetition task (Stone & Brady, 1995) measures directly the ability to hold a phonological code in short-term memory and includes phonologically plausible pseudo-words. The items were presented one by one varying in length from 2 to 6 syllables. Participants repeated the pseudo-words as accurately as possible with no time limit. The test–retest reliability of this test was r=.71.

Visual perception: Diagrammatic representations test

In this test (Frick & Newcombe, 2015), stimuli were colour photographs of geometric objects and line drawings created by black line tracing of the geometric objects' borders. Representations showed pictures of 3D objects that had to be matched with 2D line drawings, or vice-versa. This test consists of 24 target items presented in letter-sized paper (21 cm / 27cm) children chose among four possible alternatives. Four-line drawings alternatives aligned horizontally below the stimulus. One of the alternatives matched the target object and three were foils were created by changing the shapes (pyramid vs cone; sphere vs hemisphere) or proportions of the depicted objects (short vs long cylinders; cubes vs cuboids). Children were presented with the target stimuli and asked to choose which of four-line drawings best matched the photograph (photo-to-drawings) (Frick & Newcombe, 2015).

In the other half of the trials, the task direction was reversed such that children saw a line drawing as target stimulus at the top of the page and were asked to choose the best matching photograph among four alternatives i.e., drawing-to-photos (Frick & Newcombe, 2015). The following visual perception aspects could be identified in the Diagrammatic Representations test: visual discrimination and form consistency (visual form constancy). The test showed excellent internal consistency in the original version, with a Guttman's split-half coefficient of .85.

Word and pseudo-word reading test

A list of 80 fully vowelised words varying in frequency (high and low) and length (di-syllabic and tri-syllabic) was presented and read aloud. In addition, 40 pseudowords, controlled for orthographic length, were used. Participants were asked to read aloud and accurately all the items printed on A4 sheet without a time limit. The score was the total number of words or pseudowords read accurately. The internal consistency reliability of the test was high ($\alpha = 0.89$).

Procedure

Before testing commenced, parents, teachers, and school administrators were informed about test procedures. All tests were administered individually in quiet room at their school during regular school hours during three sessions. The first session took about 40 min and covered the Raven and word- and pseudoword-reading tests. The second session took about 30 min and covered the phonological tests, whereas the third session was devoted to the visual perception test. All written tests were presented fully vowelized and instructions were given in spoken Arabic to ensure full comprehensibility. All tests were preceded by two practice items to ensure that children understood task demands, except for word-reading accuracy.

Results

A one-way multivariate analysis of variance (MANOVA) was conducted to determine possible differences on PA, RAN, VSTM and visual perception as dependent variables with Group (typical/poor readers) included as the fixed factor. For the dependent variables assessed in grade 1, the omnibus effect was significant [Wilks' Lambda = 0.84, F (4.57) = 2.72, $p < .05$, partial η^2= 0.161]. Follow-up univariate analyses (ANOVAs) showed differences on the group factor in PA [F (1, 60) = 7.53, p < .01, partial η^2= 0.11] and VSTM [F (1,60) = 3.72, p < .05, partial η^2= 0.06]. In addition, for the same dependent variables assessed in grade 2, the omnibus effect for Group was significant [Wilks' Lambda= 0.64, F (4.57) = 7. 96, $p < .001$, partial η^2= 0.35]. Follow-up univariate analyses (ANOVAs) showed differences on the group factor in PA [F (1, 60) = 14.77, p < .001, partial η^2= 0.20] and visual perception (F (1,60) = 23.10, p < .001, partial η^2= 0.27].

Furthermore, to determine the extent to which the two groups made changes in the phonological and visual perception abilities over grades, paired t-test analyses were performed comparing the two times of measurement (grade1 / grade2) for each group separately (Table 1). Results revealed significant improvements in grade 2 over grade 1 in both phonological processing and visual perception abilities for typical readers (all $p < 0.01$). However, for poor readers, improvements were measurable in the three phonological processing abilities only (all $p < 0.01$), not in visual perception.

Table1

Differences between Grade 1 and Grade 2 in all measures by group of readers.

Measures	Typical readers (n= 42)				Poor readers (n=20)			
	Grade1 M (SD)	Grade 2 M (SD)	Mean Differen	t-value	Grade1 M (SD)	Grade 2 M (SD)	Mean Difference	t-value
PA	6.04 (6.48)	14.12 (3.48)	−8.07	−8.38 ***	1.80 (2.64)	10.35 (4.64)	−8.55	−7.69***
VSTM	7.02 (1.52)	7.80 (1.60)	−.78	−2.46**	6.05 (1.73)	7.90 (2.07)	−1.85	−3.31**
RAN	44.53 (15.10)	33.35 (8.97)	11.17	4.62***	41.60 (6.74)	36.09 (5.68)	5.50	3.80**
VP	17.80 (2.89)	19.90 (1.78)	−2.09	−3.92***	17.60 (2.34)	17.70 (1.71)	− .10	− .20 ns

Note. PA = phonological awareness; RAN = rapid naming; VSTM= verbal short-term memory; VP = visual perception

** $p < .01$; *** = p < .001 ; ns= non-significant

Two hierarchical regression analyses were run to examine the potential predictive relations between PA, RAN, VSTM, and visual perception as predictors and word reading accuracy as predicted variable for the entire sample in each Grade. The results showed that for phonological processing skills, PA assessed in grade 1 (Table 2) was the only factor to account for a substantial amount of unique variance in word reading accuracy (18 %). As assessed in grade 2 (Table 3), the contribution of PA in reading accuracy increased dramatically (37 %). The predictive role of VP in reading was noticeable only when assessed in grade 2 (6%).

Table 2

Hierarchical regression models for the prediction of reading accuracy for the entire sample in Grade 1.

	Predictors	Reading Accuracy					
		B	*SE*	Β	R^2	ΔR^2	*F*
Model 1	Age	−0.218	0.643	−.045	0.003	0.003	0.092
	Raven	−0.415	1.351	−.040			
Model 2	Age	−0.180	0.603	−.037	0.186	0.182	4,182**
	Raven	0.072	1.276	.007			
	PA	1.055*	0.439	.311			
	RAN	0.101	0.185	.067			
	VSTM	2.536	1.536	.213			
Model 3	Age	−0.192	0.621	−.039	0.186	0.000	0.009
	Raven	0.066	1.290	.006			
	PA	1.038*	0.479	.306			
	RAN	0.098	0.189	.065			
	VSTM	2.585	1.636	.217			
	VP	−0.092	0.982	−.013			

Note. SE = standard error; PA = phonological awareness; RAN = rapid naming; VSTM= verbal short-term memory; VP = visual perception
* $p < .05$. ** $p < .01$.

Table 3

Hierarchical regression models for the prediction of reading accuracy for the entire sample in Grade 2.

	Predictors	Reading Accuracy					
		B	*SE*	Β	R^2	ΔR^2	*F*
Model 1	Age	−0.218	0.643	−.045	0.003	0.003	0.092
	Raven	−0.415	1.351	−.040			
Model 2	Age	−0.444	0.530	−.091	0.375	0.372	11.09***
	Raven	−0.003	1.134	.000			
	PA	2.709***	0.502	.582			
	RAN	−0.366	0.279	−.146			
	VSTM	−0.137	1.293	−.012			
Model 3	Age	−0.313	0.509	−.064	0.440	0.066	6.453**
	Raven	0.360	1.092	.035			
	PA	2.097***	0.537	.451			
	RAN	−0.323	0.267	−.129			
	VSTM	−1.002	1.281	−.084			
	VP	2.898**	1.141	.299			

Note. SE = standard error; PA = phonological awareness; RAN = rapid naming; VSTM= verbal short-term memory; VP = visual perception
* $p < .05$. ** $p < .01$. *** $p < .001$

Furthermore, a logistic regression analysis was performed to test whether phonological and visual perception assessed in Grade 1 and Grade 2 separately affect the likelihood that participants belong to one of the readers groups after controlling for Age and Raven (see Table 4). The factors were entered in the model in the same order for both grades as follows: PA, RAN and VSTM were entered first, followed by VP (second). The logistic regression model for Grade 1 was statistically significant for the first set step [$\chi^2(3) = 13.13$, $p < .01$], where phonological processing abilities were entered. This model explained 26.4 % of the variance (Nagelkerke R^2) and correctly classified 63 % of the cases. The logistic regression model was not statistically significant when VP was entered (step 2) [$\chi^2(1) = 14.02$, $p > .05$]. The logistic regression model for Grade 2 was statistically significant for the first set step [$\chi^2(3) = 13.03$, $p < .001$], where phonological processing abilities were entered first. This model explained 26.3 % of the variance (Nagelkerke R^2) and correctly classified 72.6 % of the cases. The logistic regression model was also statistically significant when VP was entered (step 2) [$\chi^2(1) = 13.15$, $p < .001$]. This model explained 47.7 % of the variance (Nagelkerke R^2) and correctly classified 77.4 % of cases.

Table 4

Summary of logistic regression analyses predicting the likelihood of group of readers in grade 1 and grade 2

Measures of Grade 1	*B*	*SE*	Wald's	*p*	OR	95% CI
Step 1						
(Constant)	4.039	2.037	3.930	.047	56.764	
PA	−.197	.089	4.949	**.026**	.821	[.690 − .977]
RAN	−.047	.029	2.698	.100	.954	[.901−1.009]
VSTM	−.309	.196	2.493	.114	.734	[.501−1.077]
Step 2						
(Constant)	4.831	2.948	2.685	.101	125.321	
VP	−.047	.125	.142	.707	.954	[.746−1.219]

Measure of Grade 2	*B*	*SE*	Wald's	*p*	OR	95% CI
Step 1						
(Constant)	1.409	2.543	.307	.580	4.092	
PA	−.250	.081	9.418	**.002**	.779	[.664 − .914]
RAN	.013	.040	.112	.738	1.013	[.937−1.096]
VSTM	.068	.194	.123	.726	1.070	[.732−1.566]
Step 2						
(Constant)	11.840	4.386	7.288	.007	1387.2	
VP	−.725	.237	9.368	**.002**	.484	[.305 −.771]

Note. SE = standard error; PA = phonological awareness; RAN = rapid naming; VSTM= verbal short-term memory; VP = visual perception; In bold = statistically significant *p* values.

Discussion

This study examined the individual contributions of phonological processing abilities (PA, RAN, and VSTM) and visual perception in reading accuracy in Arabic poor readers as compared to their peers who are typical readers. The results are summarized as follows. First, one-way MANOVA showed significant multivariate effects of the Group on PA assessed in Grade 1 and PA and visual perception assessed in Grade 2. These results highlight the fact that individuals with reading disability present not only with phonological impairments but also difficulties in processing visual stimuli. The dual phonological and visual impairments suggest that reading disability is a compound condition characterized by deficits in different cognitive mechanisms that underpin reading performance (Provazza et al., 2019). Accurate word recognition requires the use of visual decoding based on familiar letter sequences or graphic configuration and orthographic patterns (order of letters), while phonological skills (sounds represented) are necessary to develop proficient word recognition (Lachmann & Geyer, 2003).

Second, paired t-tests presented in Table 1, showed significant differences between the first and the second grades in all the measures of phonological processing for both groups of readers. However, while typical readers demonstrated a significant increase in visual perception performance from grade 1 to grade 2, poor readers did not. These findings indicate that visual perception may be one of the main early factors that differentiate poor readers form typical readers. This is congruent with findings by Frick and Newcombe (2015) showing that children gain an increasing understanding of diagrammatic representations between 4 and 8 years of age, with the most noticeable increase in performance between 5 and 6 years around the time of school entry (Frick & Newcombe, 2015). It has been also reported that there is typically age dependence in the development of visual perception components, with faster rate development occurring between age 5 and age 6 (Bezrukikh & Terebova, 2009). Remarkably, and similar to typical readers, poor readers also exhibited a noticeable improvement in PA across grades. One plausible explanation is that poor readers heavily rely on phonological information for word identification (Ericson, 1997), and as a result, phonological processing may witness some improvement during reading instruction.

Third, the results of hierarchical regression analyses (Table 2 and Table 3) showed that PA assessed in Grade 1 and Grade 2 accounted for a substantial amount of unique variance in word reading for each grade separately, demonstrating its key role from an early stage of reading development. PA predictive power also increased significantly over the two assessment sessions, consistent with previous findings in studies targeting PA in Arabic where the contribution of PA was relatively consistent up to the fifth grade (e.g., Ibrahim et al., 2017). In contrast to the argument that reading development in consistent orthographies imposes less demands on PA than reading development in inconsistent orthographies (e.g., Babayigit & Stainthorp, 2007; Mann & Wimmer, 2002), our study demonstrates that PA predicted word reading in Arabic from the beginning of reading instruction until grade 2. Our results also revealed that, when assessed in grade 2, visual perception accounted for unique variance in word reading accuracy, indicating that the contribution of visual perception turned out more influential in Garde 2. Based on the significant predictive role of visual perception in reading accuracy, our results provide evidence that children who read Arabic are sensitive to the internal visual characteristics of words. For an effective letter encoding within words, visual perceptual discrimination seems to be vital for processing internal configurations of Arabic letters varying in their position within the word. This is supported by an event-related potential study by Khateb et al. (2003) reporting that the differentiation of written Arabic words starts early and depends on intensive visual discrimination processes. One explanation is that Arabic orthography forces readers to develop automatic and sophisticated visual discriminations, especially when words share the same phonology (Taha & Khateb, 2013).

Our findings that visual perceptual and phonological awareness contributed significantly to the prediction of word reading corroborate those reported in older populations of children who read Arabic. For example, Taha (2013) examined the role of phonological and visual processing, RAN, and morphological awareness in reading and decoding abilities among typical and poor readers. The results indicated that visual perception and visual search along with phonological processing skills play an important role in reading among both typical and poor readers. This suggests that children reading Arabic rely predominantly on the analytical (phonological and morphological) strategy in reading words before they become proficient in recognizing words holistically (orthographic) (Coltheart et al., 2001). This reliance on the phonological component is based on learning the associations between letters and diacritical marks with their corresponding sounds. The current findings also extend previous data in showing the importance of visual processing skills in addition to phonological skills in children with developmental dyslexia from the early stage of systematic reading acquisition irrespective of the transparency of the language. In a similar vein, Provazza et al. (2019) explored the nature of phonological and visual processing, and the extent to which both visual decoding and visual perceptual processing were used in developmental dyslexia. The authors administered a series of non-reading tasks tapping both domains. The results showed that individuals with developmental dyslexia performed worse than typical readers in phonological and visual tasks. Similarly, Bellocchi et al. (2017) in their longitudinal study showed that PA and visual perception skills predicted reading abilities outcomes one year later. Weak visual perception and impaired processing of simultaneous visual stimuli could also be associated with difficulty learning reading words and spelling (Schneck, 2009).

Overall, our study provides evidence on early underlying deficits in PA, together with visual perceptual abnormalities as potential main factors of reading disability in Arabic. The results demonstrate that among phonological processing skills, PA is the strongest early predictor of word reading accuracy. This finding corroborates with previous Arabic based studies which reported that PA has been repetitively found as a strong predictor of word reading in typical readers and children with dyslexia (Layes et al., 2021; Tibi, 2010). These finding provide further evidence for the crucial role of phonological representations in the development of reading.

Our result showing the significant predictive role of VP in reading from grade 2 indicates that its contribution seems to increase early. This finding is consistent with prior studies indicating that low performance in visual perception is a fundamental mechanism of reading disability (Zhao et al., 2014). During the earlier stage of learning to read, children examine written words by a sequential decoding, in which PA and visual processing are required for letter-sound associations. As children improve their reading skills, they start to recognize words wholistically by relying on orthographic strategies (Giovagnoli et al., 2016). Furthermore, although PA accounted for the larger amount of variance in word reading than VP, phonological deficits can stem from more fundamental deficits in visual perceptual processing (Stefanics et al., 2011; Vidyasagar & Pammer, 2010). Emerging evidence from studies on children with dyslexia indicates that phonological problems and reading impairments arise from poor visual perception processing such as detection of letter-strings (Zhao et al., 2014).

This could be related to the role of the visual magnocellular pathway known as the neural substrate of visual perception in reading (Stein & Walsh, 1997).

A practical implication of our findings is that providing phonological processing training along with visual perception experiences for pre-schoolers may contribute to overcoming reading difficulties. A visual perceptual processing-based intervention program targeting reading letters and words could be effective for poor readers (Fusco et al., 2014). From a clinical perspective, the results of this study have important implications as they show that reading develops partly by interacting relationships between phonological and visual perceptual processing. It would be advantageous to assess visual perceptual skills for reading early as part of a larger screening strategies for learning disabilities such as dyslexia. Thus, both PA and visual perception are relevant aspects for identifying children at risk for dyslexia and related reading disabilities.

Limitations

A number of limitations have to be reported in the current study. First, it is recommended that the identification and the classification of the readers should be accomplished using a standardised reading test. However, due to the lack of standardized Arabic reading test, our identification procedure may lack of accuracy. Second, our results demonstrating the crucial importance of both PA and VP abilities in reading in Arabic children from 2nd grade, could not be generalised to children of all ages from the elementary school. Future cross-sectional or longitudinal studies should involve children with larger scale of age group to examine the potential changes in the relationships between the different variables across ages / grades. Such studies should also apply more rigorous criteria selection of participants that include children with dyslexia. Another limitation relates to the visual perceptual ability which has been assessed using a single measure (Diagrammatic Representation test) which is thought to primarily evaluate visual perception discrimination, whereas VP includes different aspects such as visual spatial relationships. Future studies should consider more measures to assess the compound visual perception processes. Another limitation is related to the lack of data about the oral language abilities of the participants, such as vocabulary, as potential factors impacting reading performance.

Disclosure: This research did not receive any funding from any agency in the public, commercial, or not-for-profit sectors.

References

APA (2000). *Diagnostic and Statistical Manual of Mental Disorders (DSM-IV TR)*. American Psychiatric Association, Washington DC.

Asadi, I. (2017). Reading Arabic with the diacritics for short vowels: vowelised but not necessarily easy to read. *Writing Systems Research*, *9* (2), 137-147.

Auld, M., Boyd, R., Moseley, G., & Johnston, L. (2011). Tactile assessment in children with cerebral palsy: a clinimetric review. *Physical Occupation Therapeutics & Pediatry*, 31, 413-439

Bellocchi, S., Muneaux, M., Huau, A., Lévêque, Y., Jover, M., & Ducrot, S. (2017). Exploring the link between visual perception, visual-motor integration, and reading in normal developing and impaired children using DTVP-2. *Dyslexia, 23*, 296-315.

Bezrukikh, M.M., & Terebova, N.N. (2009). Characteristics of the development of visual perception in five- to seven-year-old children. *Human Physiology,* 35**,** 684–689.

Boets, B. (2014). Dyslexia: Reconciling controversies within an integrative developmental perspective. *Trends in Cognitive Sciences*, 18, 501–503.

Boudelaa, S., & Marslen-Wilson, W. D. (2004). Abstract morphemes and lexical representation: The CV-Skeleton in Arabic. *Cognition, 92*(3), 271–303.

Burtner, P., Dukeminier, A., Ben, L., Qualls, C., & Scott, K. (2006). Visual perceptual skills and related school functions in children with hemiplegic cerebral palsy. *New Zealand Journal of Occupational Therapy*, 53, 24–29.

Catts, H. W., Compton, D., Tomblin, J. B., & Bridges, M. S. (2012). Prevalence and nature of late-emerging poor readers. *Journal of educational psychology*, *104*(1), 10.1037/a0025323. https://doi.org/10.1037/a0025323

Cheng, D., Xiao, Q., Chen, Q., Cui J., & Zhou, X. (2018). Dyslexia and dyscalculia are characterized by common visual perception deficits, *Developmental Neuropsychology*, 43, 497-507.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review*, 108, 204-256.

Facoetti, A., Ruffino, M., Peru, A., Paganoni, P., & Chelazzi, L. (2008). Sluggish engagement and disengagement of non-spatial attention in dyslexic children. *Cortex*, *44*(9), 1221–1233.

Franceschini, S., Gori, S., Ruffino, M., Pedrolli, K., & Facoetti, A. (2012). A causal link between visual spatial attention and reading acquisition. *Current Biology*, 22(9), 814–819.

Frick, A., & Newcombe, N.S. (2015). Young children's perception of diagrammatic representations. *Spatial Cognition & Computation*, 15, 227-245.

Fusco, N., Germano. G.D., & Capellini, S.A. (2015). Efficacy of a perceptual and visual-motor skill intervention program for students with dyslexia. *Codas*, 27, 128-134.

Georgiou, G., Parrila, R. & Kirby, J.R. (2009). RAN components and reading development from Grade 3 to Grade 5: What underlies their relationship? *Scientific Studies of Reading*, 13, 508–534.

Germano, G. D., Reilhac, C., Capellini, S. A., & Valdois ,S. (2014). The phonological and visual basis of developmental dyslexia in Brazilian Portuguese reading children. *Frontiers in Psychology,* 5, 1169.

Giovagnoli, G., Vicari, S., Tomassetti, S., & Menghini, D. (2016). The role of visual-spatial abilities in dyslexia: age differences in children's reading? *Frontiers in Psychology*, 7. 1997. https://doi.org/10.3389/fpsyg.2016.01997

Goswami, U. (2003). Why theories about developmental dyslexia require developmental designs. *Trends in cognitive sciences*, *7*(12), 534–540.

Hautus, M., Setchell, G., Waldie, K., & Kirk, I. (2003). Age-related improvements in auditory temporal resolution in reading-impaired children. *Dyslexia*, 9. 37-45.

Hawelka S., Huber C., & Wimmer H. (2006). Impaired visual processing of letter and digit strings in adult dyslexic readers. *Vision Research,* 46, 718–723

Hulme, C., Bowyer-Crane, C., Carroll, J. M., Duff, F. J., & Snowling, M. J. (2012). The causal role of phoneme awareness and letter-sound knowledge in learning to read: combining intervention studies with mediation analyses. *Psychological Science*, *23*(6), 572–577.

Hulme, C., & Snowling, M.J. (2009). *Developmental disorders of language learning and cognition*. New Jersey, USA: John Wiley & Sons.

Ibrahim A. A., Ibrahim, R., & Khateb, A. (2017). What contributes to spelling in Arabic? A cross-sectional study from first to sixth grade, *Writing Systems Research*, 9 (1), 60-81.

Jones, M. W., Branigan, H. P., & Kelly, M. L. (2008). Visual deficits in developmental dyslexia: relationships between non-linguistic visual tasks and their contribution to components of reading. *Dyslexia*, 14, 95–115.

Kavale, K. A., & Forness, S. R. (2000). Auditory and visual perception processes and reading ability: a quantitative reanalysis and historical reinterpretation. *Learning Disability Quarterly,* 23, 253–270.

Khateb, A., Michel, C. M., Pegna, A. J., O'Dochartaigh, S. D., Landis, T., & Annoni, J. M. (2003). Processing of semantic categorical and associative relations: an ERP mapping study. *International journal of psychophysiology*, *49*(1), 41–55.

Kibby, M.Y., Dyer, S.M., Vadnais, S.A., Jagger, A.C., Casher, G.A., & Stacy, M. (2015). Visual processing in reading disorders and attention-deficit/hyperactivity disorder and its contribution to basic reading ability. *Frontiers in Psychology.* 6, 1635. 10.3389/fpsyg.2015.01635

Lachmann, T., & Geyer, T. (2003). Letter reversals in dyslexia: Is the case really closed? A critical review and conclusions. *Psychologische Beitrage, 45*, 50–70.

Layes, S., Cohen, M., and van Viersen, S. (2022). The triple-deficit hypothesis in Arabic: Evidence from children with and without dyslexia. Applied Psycholinguistics. https://doi.org/10.1017/ S0142716422000327

Layes, S., Khenfour, H., Lalonde, R., & Rebai, M. (2019). Orthographic and morphological masked priming effects in Arabic: evidence from lexical decision task in children with and without dyslexia. *Reading Psychology,* 40, 243-268.

Mann, V., & Wimmer, H. (2002). Phoneme awareness and pathways into literacy: A comparison of German and American children. *Reading and Writing*, 15, 653-682.

McBride-Chang, C., Lam, F., Lam, C., Chan, B., Fong, C.Y., Wong, T.T., & Wong, S.W. (2011). Early predictors of dyslexia in Chinese children: familial history of dyslexia, language delay, and cognitive profiles. *Journal of Child Psychology & Psychiatry*, 52 (2), 204-11.

Melby-Lervåg, M., Lyster, S-A., & Hulme, C. (2012). Phonological skills and their role in learning to read: A meta-analytic review. *Psychological Bulletin,* 138, 322-352.

Menghini, D., Finzi, A., Benassi, M., Bolzani, R., Facoetti, A., Giovagnoli, S., Ruffino, M., & Vicari, S. (2010), Different underlying neurocognitive deficits in developmental dyslexia: A comparative study. *Neuropsychologia*, 48, 863-872.

Mesman, G.R., & Kibby, M.Y. (2011). An examination of multiple predictors of orthographic functioning. *Journal of Learning Disabilities*, 44, 50–62.

Nelson, J. M., Lindstrom J. H., Lindstrom W., & Denis D. (2012). The structure of phonological processing and its relationship to basic reading. *Exceptionality* 20 179–196.

Ortiz, R., Estévez, A., Muñetón, M., & Domínguez, C. (2014). Visual and auditory perception in preschool children at risk for dyslexia. *Research in Developmental Disabilities,* 35, 2673–2680.

Pennington, B.F. (2006). From single to multiple deficit models of developmental disorders. *Cognition*, 101, 385.

Peterson, R. L., & Pennington, B. F. (2012). Developmental dyslexia. *Lancet*, 379, 1997-2007.

Peterson, R. L., & Pennington, B. F. (2015). Developmental Dyslexia. *Annual Review of Clinical Psychology*, 37, 283–307.

Plaza, M. (2003). The role of naming speed, phonological processing and morphological/syntactic skill in the reading and spelling performance of second-grade children. *Current psychology letters*, 10, 1.//journals.openedition.org/cpl/88

Powell, D., Stainthorp, R., Stuart, M., Garwood, H., & Quinlan, P. (2007). An experimental comparison between rival theories of rapid automatized naming performance and its relationship to reading. *Journal of Experimental Child Psychology*, *98*(1), 46–68.

Provazza, S., Adams, A-M., Giofrè, D & Roberts, D.J. (2019). Double trouble: visual and phonological impairments in English dyslexic readers. *Frontiers in Psychology*, *10*, 2725. https://doi.org/10.3389/fpsyg.2019.02725

Ramus, F., & Ahissar, M. (2012). Developmental dyslexia: the difficulties of interpreting poor performance, and the importance of normal performance. *Cognitive Neuropsychology*, 29(1-2), 104–122.

Retief, S.A., & Heimburge, J.A. (2006). *How to reach and teach all children in the inclusive classroom*, 2nd ed. San Francisco: Jossey-Bass.

Saiegh-Haddad, E., & Joshi R.M. (Eds.). (2014). *Handbook of Arabic Literacy: Insights and Perspectives*. Dordrecht: Springer.

Seidenberg, M. (2017). *Language at the speed of sight. how we read, why so many can't, and what can be done about it*. New York: Basic Books.

Schneck, C.M. (2005). Visual perception. In: Case-Smith, J. (ed) *Occupational therapy in Children*, 5th ed. Missouri: Elservier Mosby, 412-446.

Schneck, C.M. (2009). Occupational Therapy Intervention: Performance Areas. Retrieved from: www.chirocredit.com/downloads/pediatrics/pediatrics226.pdf

Seymour, P. H., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British journal of psychology (London, England : 1953)*, *94*(Pt 2), 143–174.

Snowling, M.J. (2000). *Dyslexia*, second edition. Oxford Blackwell.

Sortor, J.M. & Kulp, M. T. (2003). Are the results of the beery-buktenica developmental test of visual-motor integration and its sub-tests related to achievement test scores? *Optometry and Vision Science*, 80(11), 758-763.

Stefanics, G., Kimura, M., & Czigler, I. (2011). Visual mismatch negativity reveals automatic detection of sequential regularity violation. *Frontiers in Human Neuroscience*, 5, 46.

Stein, J., & Walsh, V. (1997). To see but not to read; the magnocellular theory of dyslexia. *Trends in neurosciences*, *20*(4), 147–152.

Taha, H. (2013). Reading and spelling in Arabic: linguistic and orthographic complexity. *Theory and Practice in Language Studies*, 3, 721-727.

Taha, H., & Khateb, A. (2013). Resolving the orthographic ambiguity during visual word recognition in Arabic: an event-related potential investigation. *Frontiers in human neuroscience*, *7*, 821. https://doi.org/10.3389/fnhum.2013.00821.

Tibi, S. (2010). Developmental hierarchy of Arabic phonological awareness skills. *International Journal of Special Education*, *25*(1), 27-33.

Vidyasagar, T.R., & Pammer, K. (2010). Dyslexia: a deficit in visuo-spatial attention, not in phonological processing. *Trends in Cognitive Sciences*, 14, 57–63.

Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin,* 101, 192-212.

Wagner, R.K., Zirps, F.A., Edwards, A.A., Wood, S.G., & Beal, B. (2020). The Prevalence of Dyslexia: A New Approach to Its Estimation. Journal of Learning Disabilities, 53, 354–365.

Yang, L.; Li, C.; Li, X.; Zhai, M.; An, Q.; Zhang, Y.; Zhao, J.; Weng, X. (2022). Prevalence of Developmental Dyslexia in Primary School Children: A Systematic Review and Meta-Analysis. Brain Sci., 12, 240.

Zhao, J., Qian, Y., Bi, H. Y., & Coltheart, M. (2014). The visual magnocellular-dorsal dysfunction in Chinese children with developmental dyslexia impedes Chinese character recognition. *Scientific Reports*, 4, 7068.

Zhou, Y., Mcbride-Chang, C., & Wong, N. (2014). What is the role of visual skills in learning to read? *Frontiers in psychology*. 5. 10.3389/fpsyg.2014.00776.

Ziegler, J. C., Bertrand, D., To´th, D., Cse´pe, V., Reis, A., Faı´sca, L., & Blomert, L. (2010). Orthographic depth and its impact on universal predictors of reading: A cross-language investigation. *Psychological Science*, 21, 551–559.