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Original article

Investigation of basic cognitive predictors of reading and spelling abilities in Tunisian third-grade primary school children

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Abstract

Background: This study investigated first the main cognitive abilities; phonological processing, visual cognition, automatization and receptive vocabulary in predicting reading and spelling abilities in Arabic. Second, we compared good/poor readers and spellers to detect the characteristics of cognitive predictors which contribute to identifying reading and spelling difficulties in Arabic speaking children.

Methods: A sample of 116 Tunisian third-grade children was tested on their abilities to read and spell, phonological processing, visual cognition, automatization and receptive vocabulary.

Results: For reading, phonological processing and automatization uniquely predicted Arabic word reading and paragraph reading abilities. Automatization uniquely predicted Arabic non-word reading ability. For spelling, phonological processing was a unique predictor for Arabic word spelling ability. Furthermore, poor readers had significantly lower scores on the phonological processing test and slower reading times on the automatization test as compared with good readers. Additionally, poor spellers showed lower scores on the phonological processing test as compared with good spellers. Visual cognitive processing and receptive vocabulary were not significant cognitive predictors of Arabic reading and spelling abilities for Tunisian third grade children in this study.

Conclusions: Our results are consistent with previous studies in alphabetic orthographies and demonstrate that phonological processing and automatization are the best cognitive predictors in detecting early literacy problems. We suggest including phonological processing and automatization tasks in screening tests and in intervention programs may help Tunisian children with poor literacy skills overcome reading and spelling difficulties in Arabic.

Keywords: Arabic orthography; Phonological processing; Automatization; Visual cognition; Receptive vocabulary; Reading and spelling

Research on reading acquisition in alphabetic orthographies has revealed that reading and spelling is no easy process for young children and demands the adequate development of cognitive phonological, visual, rapid naming speed and vocabulary processes. It has been widely accepted that phonological processing represents a core deficit of developmental dyslexia in English speaking countries [1–3]. Individuals with reading difficulties showed poor performance on phonological processing tasks including non-word repetition and reverse order repetition. Moreover, phonological

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processing is known to predict the reading level of normal developing children and also children with poor reading skills [4,5]. However, other findings in cognitive studies argued that phonological processing alone was not enough to account as the sole core deficit of developmental dyslexia. Rapid naming deficit was shown to be a good predictor of reading and spelling abilities in English. There is substantial evidence that poor readers tend to perform slower on rapid naming tasks of letters, digits, colours and objects presented in random order [6–9]. It has been reported that RAN performance in children can distinguish average readers from poor readers [10]. In non-alphabetic orthographies, faster naming time in Rapid Automatized Naming trials has been found to be a good indicator of reading competence in Chinese [11] and in Japanese [12]. In transparent alphabetic orthographies such as Dutch and German, RAN was seen to better predict reading ability compared to non-transparent alphabetic orthographies such as English and French [13]. In contrast, other scholars reported that the cognitive abilities underlying reading difficulties are caused by deficits in visual cognitive processing involving deficits in visual memory and visual perception [14]. However, Wolf and Bowers [15] proposed the double deficit hypothesis in which deficits in phonological processing and naming speed represent two independent sources of reading dysfunction, resulting to three subtypes of reading disability. The phonological deficit subtype caused by deficits in phonological processing without affecting naming speed processes. The rate-deficit subtype caused by deficits in naming speed processes alongside with normal phonological processes. Finally, the double-deficit subtype caused by deficiencies in both phonological and naming speed processes [16]. Regarding vocabulary, several English studies have reported that vocabulary knowledge represented an important factor for successful reading in young children [17,18]. Biemiller [19] claimed that the amount of oral experience young children is exposed to may have an important impact on the increase of vocabulary knowledge and children's ability to understand and decode words. Ouellette [20] reported that receptive vocabulary uniquely predicted decoding performance in reading among fourth grade English speaking children. Previous studies also suggested that lexical access (i.e., matching a word to its representation stored in the brain) and comprehension are easier for concrete words than for abstract words [21–23]. Research has also shown that response times in naming [24] and recall tasks [25] are shorter for concrete words than for abstract words when they are presented in neutral sentence or passage contexts. Furthermore, participants are able to think of word and image associates more quickly for concrete words than for abstract words [26]. As memory for abstract words relies more heavily on linguistic coding ability than does memory for concrete words, poor readers showed to have much greater difficulty on recall of abstract words than did normal readers. However, poor readers' levels of recalling concrete words varied much more in comparison with normal readers [27]. In Kunisue and colleagues' study [28] on comparison between PVT (Picture vocabulary Test, a test widely used internationally as a receptive vocabulary test) and SCTAW, he reported that SCTAW has several advantages over PVT in that SCTAW can be applied in adults, it is a highly sensitive evaluation procedure that does not show ceiling effect among senior grade students' vocabulary and acquired language. In our study, as a receptive vocabulary task, we used ACTAW. With this test, we collected data on 116 third grade Tunisian participating children and calculated the average SD. Thus as ACTAW differs from original Japanese version (SCTAW), vocabulary size would be estimated by the Arabic version ACTAW. As this test is the first time to be used and continues to be in its beginning stages to be developed, more data is needed to be collected from different primary grade levels to fully confirm its validity.

Nevertheless, evidence from cross-linguistic studies suggests that phonological, visual and rapid naming processing in predicting reading and spelling abilities may differ depending on the complexity and different features of orthographic scripts [11,29–31].

Despite advancements in research on reading and spelling in alphabetic, studies on cognitive abilities as predictors of Arabic reading and spelling skills has not been well documented and is of interest. The Arabic alphabet consists of 28 letters, all of which are consonants with the exception of three letters used as long vowels. Arabic orthography includes two kinds of scripts: vowelized Arabic (a transparent orthographic script) and non-vowelized Arabic (a non-transparent orthographic script).There exists no vowelization degree in Arabic. Vowels are presented as diacritical marks located above or below the consonantal letters and carry the phonological information needed to convey a specific meaning of a word. Arabic is read from right to left and all Arabic words are derived from a root composed of three or four consonants conveying the principal meaning of a word. There exists a regular grapheme-phoneme correspondence between Arabic letters and their sounds. The visual complexity of each letter is simple; however, the form of each letter is inconsistent as every letter can take three or more forms depending on its position in a given word (beginning, middle or ending position). In primary school education, children begin to learn to read Arabic using vowelized Arabic. However, skilled and adult readers usually read Arabic using non-vowelized Arabic which is often found in newspapers, magazines, books and in the media. As children move to upper grades in school, the use of vowelized Arabic tends to slowly and gradually fade away.

Starting from junior high school, all Arabic texts are written in non-vowelized Arabic. Arabic has many homographs; words that share the same written form but convey different meanings [32]. To avoid ambiguity in word reading, vowelized Arabic is used at the early stages of primary school education for beginners learning to read and also for poor readers, as earlier research suggested that vowels are crucial in facilitating word recognition in poor and skilled readers [33]. However as children progress to more advanced grade levels and as vowels are gradually omitted, young readers become more exposed to non-vowelized texts. In this case, Arabic orthography becomes less transparent and readers heavily rely on context to achieve word recognition, and to avoid homographic ambiguity in words [34].

The first purpose of this study was to investigate the basic cognitive abilities; phonological processing, visual cognitive processing, automatization and receptive vocabulary in predicting reading and spelling abilities in Arabic. The second purpose was to compare good/poor readers and spellers to detect the characteristics of cognitive predictors which contribute to the identification of reading and spelling difficulties among young Arabic speaking children. We selected Tunisian children attending third grade primary school, as it is expected that at the level of third grade Tunisian children would have acquired 2 years of literacy instruction in Arabic, and third grade level is also the point where it is assumed that learning with vowelized Arabic should have been achieved. Results of this study will have implications in including appropriate cognitive predictors in clinical tests which will in time help children with poor literacy skills prevail over the challenge of reading and spelling difficulties in Arabic.

1. Method

1.1. Participants

A total of 123 Tunisian third-grade primary school children participated in this study. The children were aged between 7 and 9 years old ($M = 7.93$ months, $SD = 0.43$) and were registered at six different Tunisian primary schools in the suburbs of Tunis, Tunisia. Children were administered the general intelligence test, i.e., Raven's Coloured Progressive Matrices test (RCPM). Among 123 children, 116 children whose scores showed normal performance (above -1.5 SD) took part in this study. The tests were conducted in November 2010, 3 months after the beginning of the school year. A license provided by the Tunisian Ministry of Education to access public schools was obtained, and informed consent and approval were granted by the school principals, classroom teachers and children. All participants were recruited through the schools and their cooperation in this study was conducted voluntarily. There were no known risks for participants experiencing neither physical, psychological distress nor discomfort in this study. This study was approved by the Research Ethics Committee of the Graduate School of Comprehensive Human Sciences at the University of Tsukuba (ID NO. 21-408). Participants were free to decide to stop being part of the study at any time without explanation.

1.2. Stimuli and procedures

There were two test sessions. The first test session was a group session in which the RCPM, Standardized Comprehensive Test of Abstract Words test (SCTAW), Rey-Osterrieth Complex Figure Test (ROCFT) and word spelling were administered in the participants' respective classrooms. In the individual session, the Rapid Automatized Naming test (RAN), reading tests including word reading, non-word reading and paragraph reading, non-word spelling test and phonological tests including non-word repetition were administered individually in a quiet room. As Arabic is highly homographic, only vowelized Arabic was used in reading stimuli in order to avoid any ambiguity in reading and to in order to avoid multiple reading choices for the case of single word reading tasks. Meaning with vowelized Arabic, only one reading was acceptable and children needed to focus on vowel position in each word to obtain the correct reading.

1.3. Tests and materials

1.3.1. Cognitive tests

1.3.1.1. Nonverbal intelligence test.

Raven's Coloured Progressive Matrices (RCPM) [35] is a nonverbal intelligence test that was administered to one hundred and twenty-three children. Previous studies have shown that the RCPM score highly correlated with the WISC-III scores [36]. RCPM contains 36 items in 3 sets (A, AB, B). Each set includes 12 items. In each test item, a coloured pattern with a missing part was presented to the participant who was then asked to identify the missing element out of 6 choices of elements (Fig. 1). The maximum score for this test was 36. The participant's score was calculated by adding up the total number of correct scores on the 3 sets. (Cronbach alpha reliability was .70).

1.3.1.2. Phonological processing.

The phonological processing tests consisted of the following two subtests of phonological short term/working memory. The phonological/working memory subtests were: repetition in reverse order was administered to assess the ability to store verbal information for a short period of time and manipulate that information prior to production. The repetition in reverse order task involved the child to carefully listen to a verbally

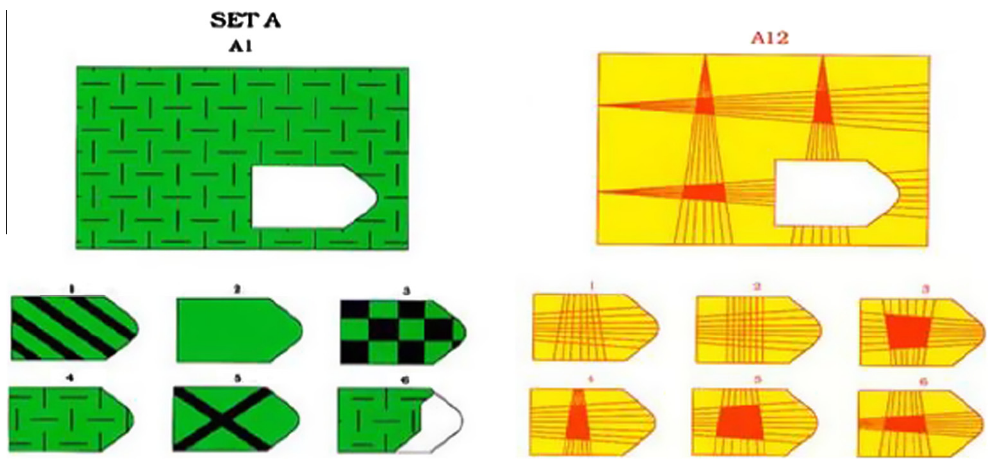

Fig. 1. General intelligence test: Raven's Coloured Progressive Matrices test (RCPM).

presented Arabic word and repeat the word in reverse order it was presented. This test measures phonological working memory. The non-word repetition task involved the repetition of non-words, a test that measures phonological short-term memory [37,38]. The task used in the present study was consistent with previous work in that it required the child to repeat sequences of simple non-words that did not exist in the language tested.

1.3.1.3. Non-word repetition test.

Ten Arabic non-words of three to six syllables were used as the test stimuli. All ten stimuli were presented orally to the participating children. All stimuli were verbally presented to the participating children. The child was asked to carefully listen and then repeat each stimulus non-word. The maximum score for this task was 10. The total score was calculated in accordance with the number of correctly repeated non-words by the participants. (Table 1) (Cronbach alpha reliability was .70).

1.3.1.4. Reverse order repetition test.

Five frequently-used Arabic words of three to six syllables were used as the test stimuli. All five stimuli were selected from the third-grade Arabic primary school reading textbook. All stimuli were verbally presented to the participating children. Each participating child was asked to carefully listen and then repeat each stimulus word in reversed order. The maximum score for this task was 5. The total score was calculated in accordance with the number of correctly reversed ordered non-words performed by the participants. (Table 1) (Cronbach alpha reliability was .69).

1.3.1.5. Visual cognitive processing.

The Rey-Osterrieth Complex Figure Test (ROCFT) [39] assesses visual perception and memory. Three conditions were used for the assessment: copy drawing, immediate recall and delayed recall. In the copy drawing condition, the participants were required to copy a complex drawing. Once the copy was complete, the stimulus figure and the participant's copy were removed from their view. During the immediate recall condition, the participants were asked to recall what they remembered from the complex drawing. In the delayed recall condition after 20–30 min, the participants were asked to recall the complex drawing one more time (Fig. 2) (Cronbach alpha reliability was .83).

1.3.1.6. Automatization.

Rapid Automatized Naming (RAN) [12] is a rapid naming task that included 20 stimuli: 4 rows of 5 stimuli. The stimuli were line drawings of objects (cat, ship, feet, hat, pencil, dog, banana, chair, scissors, and umbrella) and digits (1–9) presented on a one A4 size sheet of paper in random order. The participants were instructed to name aloud as quickly and accurately as possible the drawings and digits they saw (See Fig. 3). Participants were given one trial practice prior to the task and three trials during the task. We measured the duration of response time of the three trials by means of a stopwatch (Fig. 3) (Cronbach alpha reliability was .71).

1.3.1.7. Receptive vocabulary.

The Arabic Comprehension Test of Abstract Words (ACTAW) is an auditory comprehension test composed of sixteen abstract Arabic target words. For each abstract target word six pictures were presented. Participants were verbally given an abstract target Arabic word and were asked to carefully listen to the abstract word and choose one picture out of the six pictures that corresponded to the target word. This test was adapted into Arabic from the Japanese Standardized Comprehension Test of Abstract Words (SCTAW) [31], as the Japanese version of the test included abstract pictures strongly related to Japanese culture, and Tunisian children are

Table 1
Scores on cognitive, reading and spelling tests in 116 Tunisian third-graders

Variable (score)	Mean	SD	Minimum	Maximum
Nonverbal intelligence				
RCPM (/36)	23.64	5.60	7.00	35.00
Cognitive abilities tests				
Receptive vocabulary				
ACTAW (/16)	11.20	2.07	5.00	16.00
Visual cognitive processing				
ROCFT copy (/36)	25.63	6.24	7.50	35.00
ROCFT immediate recall (/36)	11.30	5.89	1.00	26.50
ROCFT delayed recall (/36)	10.84	6.34	0.00	26.00
Automatization				
RAN (seconds)	16.33	2.55	10.00	21.80
Phonological processing				
Non-word repetition (/10)	9.14	0.95	5.00	10.00
Reverse order repetition (/5)	5.30	2.49	0.00	5.00
Reading tests				
Word reading (/23)	14.18	5.20	4.00	23.00
Non-word reading (/25)	11.89	3.02	3.00	19.00
Paragraph reading(/100)	66.10	22.76	23.00	100.00
Spelling tests				
Word spelling (/10)	9.14	1.19	4.00	10.00
Non-word spelling (/5)	4.28	1.13	0.00	5.00

Note: The means, standard deviations (SD), and minimum and maximum scores among the 116 children are shown. *Note:* ACTAW = Arabic Comprehension Test of Abstract Words, ROCFT copy = Rey-Osterrieth Complex Figure Test copy drawing, ROCFT immediate = Rey-Osterrieth Complex Figure Test immediate recall, ROCFT delayed = Rey-Osterrieth Complex Figure Test delayed recall, RCPM = Raven's Coloured Progressive Matrices, RAN = Rapid Automatized Naming. $N = 116$ for all analyses. For the RAN test, scores were calculated according to time speed. All values represent raw, non-standardized scores.

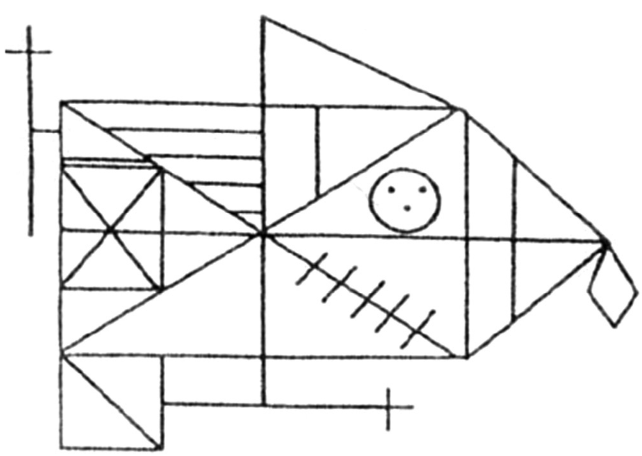

Fig. 2. The Rey-Osterrieth Complex Figure Test (ROCFT) [39].

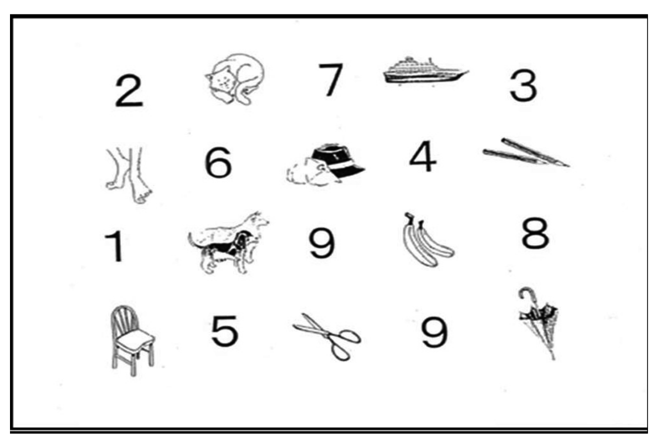

Fig. 3. Rapid Automatized Naming (RAN) [12].

not familiar with Japanese customs. These abstract pictures were replaced by neutral pictures representing everyday life situations in the Arabic version of ACTAW, in order not to confuse Tunisian children. Fig. 4 represents two examples of abstract pictures taken from SCTAW the original Japanese version (A1 and B1) and the adapted version for Arabic ACTAW (A2 and B2). In A1 and A2, the target abstract Japanese word was "無事" meaning "safety" in Japanese. This target abstract word was translated into Arabic "أمان". The

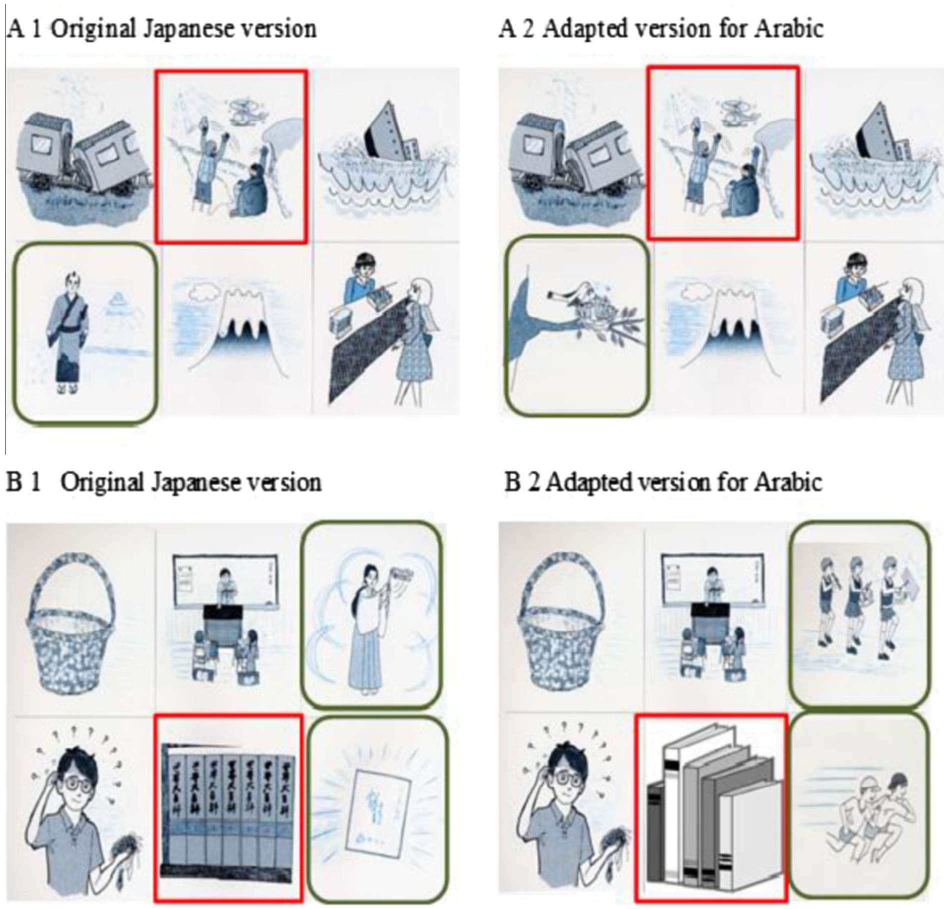

Fig. 4. The Standardized Comprehension Test of Abstract Words (SCTAW) [31] original version (A1 and B1), and adapted Arabic version, Arabic Comprehension Test of Abstract Words (ACTAW) (A1 and B2).

correct picture for this abstract target word is represented by the red square. In A1, the distractor picture represented by the green square shows a picture of a Japanese man in a male Kimono. This picture was replaced in A2 by a scene with birds on a branch in a tree. In B1 and B2, the target word was "知識" meaning in Japanese "knowledge". This abstract target word was translated into Arabic "المعرفة". The correct picture for this abstract target word is represented by the red square. In B1, the target picture shows an image of book with Kanji writing. The target picture was replaced by a more neutral picture of a book with no Kanji writing in B2. The distractor pictures in B1 represented by the green squares show a Japanese woman in kimono and an envelope with Japanese writing. These distractor pictures were replaced in B2 by a school band and two boys racing. The maximum score for this task was 16. The total score was calculated in accordance with the number of correct target pictures chosen by the participants (Fig. 4) (Cronbach alpha reliability was .73).

1.3.2. Reading tests

The reading tests consisted of the following three subtests.

1.3.2.1. Word reading.

Twenty-three frequently-used Arabic words consisting of three to six syllables were used. Stimulus words were selected from the Tunisian primary school reading textbooks used in the private and government schools. Participants were required to read aloud all 23 stimuli that were presented by the tester (Cronbach alpha reliability was .69).

1.3.2.2. Non-word reading.

Twenty-five Arabic non-words of three to six syllables were used as stimuli of reading decoding skill. Starting with real Arabic words, one syllable located in the initial, middle or ending position of a word was substituted with another syllable. Participants were asked to read aloud all 25 stimuli presented by the tester (Cronbach alpha reliability was .67).

1.3.2.3. Paragraph reading.

The text was an original text and consisted of 100 Arabic words derived from the Tunisian primary school reading textbooks used in the private and government schools. The participating children were asked to read aloud the entire paragraph in one minute.

Reading accuracy was estimated as the number of correctly read words (correct words/total number of words read within one minute) (Cronbach alpha reliability was .66).

1.3.3. Spelling tests

The spelling tests consisted of two subtests.

1.3.3.1. Word spelling to dictation.

Ten frequently-used Arabic words of three to six syllables were used as the stimuli. Stimulus words were selected from the Tunisian primary school reading textbooks used in the private and government schools. The participating children were asked to write down each word dictated to them by the tester. The number of correctly spelled written words was noted (Cronbach alpha reliability was .70).

1.3.3.2. Non-word spelling to dictation.

Five Arabic non-words of three to six syllables were used as stimuli to test children's knowledge of sound letter rules. These Arabic non-words were derived from real Arabic words by substituting one syllable located in the initial, middle or ending position of a word with another syllable. The participating children were asked to write down each word dictated to them by the tester. The number of correctly spelled non-words was noted (Cronbach alpha reliability was .68).

Statistical analyses were performed using the SPSS Statistics 17.0 program.

2. Results

Regarding descriptive analysis, scores on the Rey-Osterrieth Complex Figure Test (ROCFT) immediate recall, Rey-Osterrieth Complex Figure Test delayed recall, word reading, non-word reading, reversed order repetition and non-word spelling tests of the 116 participants covered the full range of scores on all tests with means falling near the middle of these ranges. Paragraph reading, word spelling and non-word repetition displayed ceiling effects, with the mean score being very close to the maximum score of each test. The time duration of Rapid Automatized Naming test (RAN) time displayed a reasonable range that was slightly deviated away from faster times (Table 1).

Significant correlations were found among almost all measures of cognitive abilities, i.e., among ROCFT, Raven's Coloured Progressive Matrices (RCPM), RAN, reversed order repetition and non-word repetition (from $r = 0.19$ to $r = 0.82$), and also among all three measures of reading (from $r = 0.27$ to $r = 0.48$). The highest correlation was found between word reading and paragraph reading measures ($r = 0.81$). The word spelling measure was significantly correlated with reading measures (from $r = 0.22$ to $r = 0.46$). In addition, RCPM and RAN were significantly correlated with the three reading measures: word reading, non-word reading and paragraph reading (from $r = 0.28$ to $r = 0.48$). On the other hand, reversed order repetition was correlated with word spelling measure as well as with all reading measures (from $r = 0.30$ to $r = 0.43$). However, low correlations were found between ROCFT copy and spelling measures ($r = 0.14$ and $r = 0.15$), and between RAN and word spelling measure ($r = 0.21$). Similar patterns of data were found between RCPM and word spelling ($r = 0.19$), between non-word repetition and non-word reading measure ($r = 0.12$), and among Standardized Comprehensive Test of Abstract Words (SCTAW), word reading and paragraph reading ($r = 0.15$ and $r = 0.14$) (Table 2).

To investigate the basic cognitive abilities; phonological processing, visual cognition, automatization and receptive vocabulary in predicting reading and spelling abilities in Arabic, a series of multiple linear regression analyses was performed (Table 3). Prior to carrying out the multiple regression analyses, the independent cognitive variables were chosen according to the correlations found between all cognitive variables. We included word reading, non-word reading and paragraph reading tests as the dependent variables for reading. Word spelling and non-word spelling tests were included as the dependent variables for spelling. Receptive vocabulary, visual cognitive processing, automatization and phonological processing tests were included as independent variables in the multiple regression analyses. ROCFT immediate was excluded from this analysis as it showed a very high correlation with ROCFT delayed variable ($r = 0.82$). Results of the multiple regression analysis revealed that automatization ($\beta = -0.352$, $p < .001$) and phonological processing as measured by reverse order repetition ($\beta = 0.285$, $p < .01$) uniquely predicted Arabic word reading ability ($F\ (1,114) = 32.742$). Automatization ($\beta = -0.487$, $p < .001$) uniquely predicted Arabic non-word reading ability ($F\ (1,114) = 35.366$). Moreover, automatization ($\beta = -0.308$, $p < .01$) and phonological processing as measured by reverse order repetition ($\beta = 0.253$, $p < .01$) uniquely predicted Arabic paragraph reading ability ($F\,(1,114) = 23.503$). For spelling, results of multiple regression analyses revealed that phonological processing as measured by reverse order repetition ($\beta = 0.300$, $p < .01$) uniquely predicted Arabic word spelling ability ($F\ (1,114) = 11.289$). However, no cognitive abilities were found to predict Arabic non-word spelling ability. In addition, receptive vocabulary and visual cognitive processing were not significant cognitive predictors of Arabic reading and spelling abilities for Tunisian third grade children in this study.

The second aim of this study was to detect the characteristics of cognitive predictors that contribute to the

Table 2
Pearson Correlation analysis of all variables

Variable	Correlations												
	1	2	3	4	5	6	7	8	9	10	11	12	13
(1) ACTAW	–	.035	−.046	−.008	.219*	−.079	.039	.061	.041	−.072	.151	.052	.147
(2) ROCFT copy		–	.557**	.494**	.325**	−.107	.256**	.274**	.146	.159	.073	.157	.061
(3) ROCFT immediate			–	.820**	.198*	.005	.070	.165	.011	.148	.004	.082	.011
(4) ROCFT delayed				–	.126	.000	.009	.150	−.013	.089	−.037	.032	−.052
(5) RCPM					–	.272**	.139	.327**	.198*	.025	.369**	.280**	.277**
(6) RAN						–	−.118	.419**	.271*	−.001	.472**	.487**	.413**
(7) Non-word repetition							–	.111	−.019	.109	.048	.124	.044
(8) Reverse order repetition								–	.300**	−.018	.433**	.340**	.381**
(9) Word spelling									–	.030	.359**	.226*	.460**
(10) Non-word spelling										–	−.168	−.133	−.146
(11) Word reading											–	.642**	.818**
(12) Non-word reading												–	.581**
(13) Paragraph reading													–

Note: Pearson Correlation analysis of all variables was performed to ascertain the relationships between the scores on cognitive tests, reading tests and spelling tests. ACTAW = Arabic Comprehensive Test of Abstract Words, ROCFT copy = Rey-Osterrieth Complex Figure Test copy drawing, ROCFT immediate = Rey-Osterrieth Complex Figure Test immediate recall, ROCFT delayed = Rey-Osterrieth Complex Figure Test delayed recall, RCPM = Raven's Coloured Progressive Matrices, RAN = Rapid Automatized Naming. $N = 116$ for all analyses.

* $p < 0.05$.

** $p < 0.01$.

identification of reading and spelling difficulties among Arabic speaking children. In order to investigate this, the 116 children were divided into two groups; good/poor readers and good/poor spellers restrictively according to the results of scores on reading and spelling tests. According to the scores on reading tests, 100 good readers had reading scores over −1.5 SD of the mean score and 16 poor readers had reading scores below −1.5 SD of mean score. Based on the scores on the spelling tests, 105 good spellers had spelling scores over −1.5 SD of mean score and 11 poor spellers had spelling scores below −1.5 SD of mean score. We then compared scores on the cognitive tests between good and poor readers/spellers by applying the Mann–Whitney U-test and/or the independent sample T-test. Poor readers had significantly lower scores than good readers on the phonological processing test as measured by reverse order repetition test ($U = 350.5$, $p = 0.00$) and automatization test ($t = 3.95$, $p = 0.00$). On the automatization test, good readers had significantly faster reading times than poor readers. These results indicate that phonological processing and automatization significantly predicted reading difficulties among Tunisian third-grade primary school children (Table 4A). As to spelling (Table 4B), the Mann–Whitney U-analysis of scores between good and poor spellers in relation to the cognitive abilities revealed a significant difference in the phonological processing test as measured by reverse order repetition test. Indeed, poor spellers had significantly lower scores on the reverse order repetition test compared with good spellers. These results indicate that phonological processing is a unique predictor of spelling difficulties in Tunisian third grade children.

3. Discussion

Overall, the results of our study revealed that word reading ability and paragraph reading ability were predicted by automatization and phonological processing. However, automatization was the unique cognitive predictor of non-word reading ability. We interpret these results by the presence of individual differences in word reading skills. These findings are consistent with previous studies on individual differences in reading skills in English language. In a study on individual differences in reading skills, Foorman and colleagues [40] reported that individual differences between word reading and non-word reading are significant predictors of later reading performance in first grade English speaking children [40]. Additionally, readers with difficulty in rapid naming tasks may have sufficient phonological processing skills necessary for decoding words, but they will not be fluent readers if their rapid naming recall ability is affected [15]. Consequently, these results may imply that reading deficits in non-word reading may be the result of a naming speed impairment. In sum, according to the double-deficit hypothesis, individuals with a reading deficit can have selective deficits in phonological processing, rapid naming, or both, and it is those readers with both impairments who tend to be the most severely affected in their reading ability [15]. These results suggest that phonological processing and automatization may

Table 3
Multiple regression analysis for cognitive predictors of reading and spelling abilities.

Variables	β coefficient	*t*	*p*	Adjusted R^2
Word reading				0.278
Receptive vocabulary	0.106	1.343	.182	
Visual cognitive processing				
ROCFT copy	−0.047	−0.568	.572	
ROCFT delayed	−0.082	−1.019	.310	
Automatization	−0.352	−4.043	.000	
Phonological processing				
Non-word repetition	−0.026	−0.327	.744	
Reverse order repetition	0.285	3.274	.001	
Non-word reading				0.230
Receptive vocabulary	0.014	0.170	.865	
Visual cognitive processing				
ROCFT copy	0.106	1.287	.201	
ROCFT delayed	0.032	0.392	.696	
Automatization	−0.487	−5.946	.000	
Phonological processing				
Non-word repetition	0.067	0.811	.419	
Reverse order repetition	0.166	1.859	.066	
Paragraph reading				0.210
Receptive vocabulary	0.108	1.307	.194	
Visual cognitive processing				
ROCFT copy	−0.044	−0.510	.611	
ROCFT delayed	−0.092	−1.095	.276	
Automatization	−0.308	−3.371	.001	
Phonological processing				
Non-word repetition	−0.021	0.249	.804	
Reverse order repetition	0.253	2.767	.007	
Word spelling				0.282
Receptive vocabulary	0.023	0.257	.798	
Visual cognitive processing				
ROCFT copy	0.069	0.737	.462	
ROCFT delayed	−0.060	−0.657	.512	
Automatization	−0.111	−1.131	.260	
Phonological processing				
Non-word repetition	−0.053	−0.590	.557	
Reverse order repetition	0.300	3.359	.001	
Non word spelling				0.036
Receptive vocabulary	−0.066	−0.702	.484	
Visual cognitive processing				
ROCFT copy	0.149	1.290	.200	
ROCFT delayed	−0.066	−0.606	.546	
Automatization	−0.044	−0.420	.675	
Phonological processing				
Non-word repetition	0.095	0.964	.336	
Reverse order repetition	−0.053	−0.503	.615	

Note: $N = 116$ for all analyses; ROCFT copy = Rey-Osterrieth Complex Figure Test copy drawing; ROCFT delayed = Rey-Osterrieth Complex Figure Test delayed recall.
** $p < .01$.
*** $p < .001$.

play fundamental roles in predicting reading deficits in Arabic at the early stages of Arabic literacy. Additionally, poor readers performed worse on automatization and phonological processing tests, confirming the importance of both cognitive abilities as significant predictors in detecting reading deficits among Tunisian third grade children. It is evident to say that by this stage, basic decoding abilities become more automatic as children become more proficient in reading vowelized Arabic. Our findings stand in support of the double deficit hypothesis in which phonological processing and automatization are both important cognitive predictors of reading ability [13]. Researchers suggested that the double deficit hypothesis was the cause of the manifestation of dyslexia in non-transparent orthographies, and evidence on the double deficit hypothesis to affect reading in transparent orthographies has also been reported [41]. As Arabic is also a transparent orthography when vowelized, we suggest that the phonological processing and automatization may be the basic cause of reading difficulty in Arabic, and therefore, the double deficit hypothesis may play a fundamental role in deepening our understanding on reading deficits in Arabic literacy.

With regard to spelling abilities, phonological processing was the unique cognitive predictors of word spelling ability and also contributed in identifying spelling deficits in Arabic speaking children. Our findings are consistent with previous work on spelling in cross-linguistic studies. Frith [42] and Snowling [43] reported that phonological processing is essential for the development of effective spelling skills. As it has been confirmed, spelling develops first through phonology [44], and then progresses at more advanced levels. Thus, there is a more direct focus on direct lexical access to spelling without phonology. As the spelling process is a complicated process that demands more advanced linguistic

Table 4
Comparison of scores on cognitive tests between good and poor readers, and between good and poor spellers

	Good readers		Poor readers		*U*-value/*t*-value	*p*-Value
	Mean	SD	Mean	SD		
(A) Good readers (N = 100) and poor readers (N = 16)						
Nonverbal intelligence test						
RCPM	23.78	5.40	22.00	5.20	$t = -1.43$	.156
Receptive vocabulary test						
ACTAW	11.20	2.08	11.31	1.62	$U = 783.5$	.945
Visual cognitive processing test						
ROCFT copy	25.77	6.08	23.66	8.76	$U = 690.5$	.412
ROCFT delayed	10.92	6.30	9.81	5.46	$t = -.757$	.502
Automatization test						
RAN	16.32	2.56	18.53	1.98	$t = 3.95$	.000
Phonological processing tests						
Reverse order repetition	5.35	2.45	3.31	1.92	$U = 350.5$	.000
Non-word repetition	9.13	0.95	8.81	1.33	$U = 679$	.329
	Good spellers		Poor spellers		*U*-value/*t*-value	*p*-Value
	Mean	SD	Mean	SD		
(B) Good spellers (N= 105) and poor spellers (N = 11)						
Nonverbal intelligence test						
RCPM	23.78	5.40	21.64	4.41	$U = 419.5$	.146
Receptive vocabulary test						
ACTAW	11.20	2.08	10.27	1.74	$U = 390.5$	.080
Visual cognitive processing test						
ROCFT copy	25.77	6.08	22.68	7.36	$U = 402.5$	.107
ROCFT delayed	10.92	6.30	9.82	5.90	$t = -.609$	.727
Automatization test						
RAN	16.32	2.56	17.46	1.93	$t = 1.574$	.159
Phonological processing tests						
Reverse order repetition	5.35	2.45	3.82	2.68	$U = 354.5$	.037
Non-word repetition	9.13	0.95	9.55	0.52	$U = 429$	.146

Note: Means and standard deviations (SDs) are shown. ACTAW = Arabic Comprehension Test of Abstract Words, RCPM = Raven's Coloured Progressive Matrices, ROCFT copy = Rey-Osterrieth Complex Figure Test copy drawing, ROCFT immediate = Rey-Osterrieth Complex Figure Test immediate recall, ROCFT delayed = Rey-Osterrieth Complex Figure Test delayed recall, RAN = Rapid Automatized Naming. The Mann–Whitney *U* analysis or independent sample *t*-test for cognitive variables was performed after applying the test of normality Shapiro-wilk.

* $p < .05$.

*** $p < .001$.

levels than reading, an awareness of orthographic units is more fundamental in spelling than in reading [45]. In addition, the Arabic diglossic phonology effect; that spoken Arabic or colloquial Arabic spoken by children could also explain the reason for the phonological deficit in Arabic as young spellers struggle to master all phonetic combinations. Frith [46] reported that good speller's knowledge should exceed beyond sound-letter correspondence rules. As expected, 'the mastery' of spelling demands 'a higher degree of linguistic competence' than mastery of reading. In this sense, the Arabic language is also a highly phonetic language. Combining consonantal Arabic words and vowels creates Arabic words that are similar or different in meaning [47]. Frith [42] claimed that dyslexic children have low phonological processing in spelling, a case also observed in our study in Arabic. Moreover, Arabic has a transparent orthography when vowelized. Studies on spelling in transparent alphabetic orthographies have shown that phonological processing was highly related to spelling as the correspondence between sounds and letters are less consistent compared with reading [48,49]. These studies support our finding on spelling confirming that phonological processing clearly represents the best cognitive predictor of Arabic spelling in Tunisian third-grade school children.

Receptive vocabulary ability did not appear to have any significant contribution to reading ability. One explanation could be as vowelized Arabic is highly consistent, third grade children still make use of phonological knowledge they have gathered in reading vowelized Arabic words to access word reading. As consequence, the struggle with decoding is less challenging for most young readers. Additionally, as young children's reading skills develop and become more fluent automatization also holds an important role in Arabic reading. Our findings are consistent with studies on the role of vocabulary in alphabetic transparent languages with high consistency such as Italian and Finnish [50,51]. In these studies, researchers found that vocabulary was not a significant predictor of reading ability. However, they reported that word structure knowledge played a more important role in facilitating word reading than vocabulary. Specifically, when it comes to reading and understanding unfamiliar words or new words, for i.e. words that are derivatives of known words, young readers are able to apply their knowledge of structural components of words to access their lexical meaning. Our results are also consistent with findings in a recent cross-linguistic study by Katzir et al. [52] on reading processes among fourth-grade English- and Hebrew-speaking children. In their study, vocabulary highly contributed to word reading in English and accounted for more variance in comparison with Hebrew in which vocabulary showed no contribution to vowelized Hebrew reading. We suggest that vocabulary may be a unique cognitive predictor of word reading ability in inconsistent non transparent orthographies. However, as the sample size in our study was small and limited only to grade three, further research on the role of vocabulary in Arabic is necessary to confirm our assumption. It would also be interesting to see the individual differences between the effects of vocabulary on vowelized and non-vowelized Arabic reading ability.

Visual cognitive processing did not predict reading and spelling abilities in this study. Although previous studies have shown that visual processing predicted Arabic reading [53], our findings revealed a different opposing outcome. One explanation behind the opposing outcomes in our study may be the difference in the choice of visual cognitive tests administered. In Abu-Rabia's studies, visual cognitive processing tests consisted of different visual cognitive tests and methods: the Stanford-Binet Bead memory test which only measures short-term visual memory [54], and the Witkin embedded figures test which measures the individual's visual segmentation ability [55], however, these tests do not detect visual long-term memory. In our study, we used the Rey-Osterrieth Complex Figure Test (ROCFT) as a means of detecting visual perception, visual short-term and long-term memory, and visual reproductive/recall abilities of complex figures. Thus, differences in visual cognitive measures may affect the results. Another possible interpretation for the non-significance of visual cognitive processing may be explained by the nature of the Arabic language. It is important to point to out that all stimuli used in this study were fully vowelized which convey symbol/sound relationships and make the Arabic script highly transparent. Vowels carry the phonological information that helps young children read Arabic text more easily [47]. Evidence shows that vowels play a very important role in reading and spelling among different ages. At the level of grade three, all children have acquired the knowledge of reading and spelling all the different forms of all Arabic letters. There is no longer a focus on the visual aspect of Arabic letters but rather on the phonological components of Arabic which constitute the diacritical marks located above or below the letters in order to gain the lexical access of Arabic. We argue that visual cognitive processing may be an important process in acquiring Arabic literacy at the very early stages of learning but not after children reach third grade. Our findings demonstrate that Tunisian third grade children's reading strategy is accessed through the phonological route and clearly not through the visual route. However, further research on the role of visual cognitive processing in predicting reading and spelling ability, especially further data from early grades and advanced grades is needed to better explain our findings.

Overall, the results of the current study suggest that phonological processing and automatization are good predictors of Arabic reading ability, whereas phonological processing alone is a unique predictor of Arabic spelling ability in Tunisian third grade children. Both cognitive abilities are suggested to be the basic cause of reading deficits and with phonological processing being the unique cognitive predict in identifying spelling deficits in Arabic literacy. Deficiencies in phonological processing and automatization suggest that further studies should be performed to investigate to what extent the double deficit hypothesis affects reading and spelling abilities in Arabic. We suggest that including phonological processing and automatization tests in screening tasks and in assessment tools may help support Tunisian children with poor reading and spelling skills to overcome reading and spelling difficulties in Arabic.

This study contains certain limitations regarding the vocabulary test ACTAW. First, we carried out this test as a first trial experiment in this study as an auditory comprehension test in Arabic. A more thorough investigation should be conducted on this test in order to stabilize its validity and reliability for future research. Our aims in the present study were mainly exploratory. Future investigations on reading ability and spelling in Arabic should take into consideration these limitations.

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