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REPORT

Does the Visual Attention Span Play a Role in Reading in Arabic?

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ABSTRACT

It is unclear whether the association between the visual attention (VA) span and reading differs across languages. Here we studied this relationship in Arabic, where the use of specific reading strategies depends on the amount of diacritics on words: reading vowelized and nonvowelized Arabic scripts favor sublexical and lexical strategies, respectively. We hypothesized that the size of the VA span and its association to reading would differ depending on individual "script preferences." We compared children who were more proficient in reading fully vowelized Arabic than nonvowelized Arabic (VOW) to children for whom the opposite was true (NOVOW). NOVOW children showed a crowding effect in the VA span task, whereas VOW children did not. Moreover, the crowding in the VA span task correlated with the reading performance in the NOVOW group only. These results are discussed in light of individual differences on the use of reading strategies in Arabic.

Introduction

Most cross-linguistic studies of reading have endeavored to pinpoint the contribution of orthographic depth (the complexity and predictability of grapheme-to-phoneme conversions) to literacy development (see Lallier & Carreiras, 2017, for a review). These studies show that orthographic depth modulates the use of reading strategies and the corresponding underlying cognitive skills. For example, the regular letter-sound correspondences of shallow orthographies favor the use of sublexical strategies and the development of phonemic awareness (Ziegler & Goswami, 2005), whereas reading in deep orthographies boosts lexical strategies (Frost, Katz, & Bentin, 1987) and favors a wider distribution of visual attention (VA) over letter strings (Lallier & Carreiras, 2017). The role of visual attentional processes for reading development (see Gori & Facoetti, 2015, for a review) has only recently been approached from a cross-linguistic perspective (e.g., Lallier, Molinaro, Lizarazu, Bourguignon, & Carreiras, 2017). The present study focuses on the cross-linguistic modulations that affect the VA span and its association with reading.

The VA span corresponds to the number of visual elements processed simultaneously in a multielement array (Bosse, Tainturier, & Valdois, 2007) and plays an important role in reading acquisition through the buildup of orthographic knowledge (Bosse, Chaves, Largy, & Valdois, 2015). Cross-linguistic studies suggest that both the size and the shape of VA span are affected by orthographic depth (Awadh et al., 2016; Lallier, Acha, & Carreiras, 2016). In addition, Awadh et al. (2016)'s study of adults showed that there was a significant relationship between VA span and reading skills in a deep orthography (French), but not in two shallow orthographies (Spanish and Arabic). This result in shallow orthographies is at odds with similar studies carried out on children (e.g., Lallier, Valdois, Lassus-Sangosse, Prado, & Kandel, 2014). This suggests

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that a wide distribution of attention might no longer be critical for expert reading in shallow languages. If age-related factors can explain differences between French and Spanish in Awadh et al.'s study, additional variables have to be considered in the case of Arabic.

Arabic is unique because two oral forms (standard and colloquial Arabic) and two scripts (vowelized and nonvowelized) coexist. The two scripts vary in the *size and type* of the orthographic chunks that have to be attended and differ in the amount of vowels (diacritics) provided in words. Arabic scripts therefore vary from fully vowelized (each letter marked with a diacritic) to fully nonvowelized (no diacritics). Of importance, the pronunciation and meaning of words, which are derived from three- or four-consonant root morphemes, depend on their vowel structure. In the nonvowelized script, readers rely on fast root morpheme recognition, and word pronunciation and meaning are deduced from contextual information only (e.g., Abu-Rabia, 2007). In contrast, when reading vowelized Arabic, to decode and access the meaning of words, one can rely on the additional help from vowels using letter-by-letter decoding strategies (Weiss, Katzir, & Bitan, 2016).

At the beginning of reading acquisition for children in Qatar, diacritics are used to foster decoding development. Around Grade 3, consonantal roots must be memorized, as children are mostly presented with nonvowelized texts. Last, a nonfrequent fully vowelized script, used for poetry and religious texts, must be mastered from Grade 4 onward. For expert readers of the nonvowelized script, fully vowelized Arabic is composed of nonfamiliar orthographic forms (Weiss, Katzir, & Bitan, 2015) for which letter-by-letter recoding strategies have to be applied (see Weiss et al., 2016) to prevent the automatic access to root morphemes from interfering with reading.

Therefore, fully vowelized and nonvowelized scripts are read with distinct strategies (Frost & Bentin, 1992), which might also be associated with distinct visual attention distribution modes. Whereas fully vowelized Arabic should require narrow visual attentional captures on each letter to access all the vowel information (Weiss et al., 2016), efficient nonvowelized script reading may require the homogenous distribution of attentional resources across the words to promote automatic access to root morphemes *as wholes* (Frost & Bentin, 1992; Frost et al., 1987; Katz & Frost, 1992). Although this arguably suggests that a large VA span should be critical for nonvowelized reading, Awadh et al. (2016) *could not* report any relationship between the VA span and nonvowelized text reading skills. We suggest that a feature specific to Arabic contributed to this result.

Given that Arabic readers master both fully vowelized and nonvowelized reading from Grade 4 onward, the VA span–reading relationship might be different between readers with distinct preferred reading strategy: One may be better at reading in one script compared to the other, and favor this "preferred" strategy when reading in either script. Thus, the VA span–reading relationship should be visible in a subgroup of readers who are more expert in a script for which lexical strategies and a wide distribution of attention over letter strings contribute to fluent reading (i.e., nonvowelized script). On the other hand, the reading performance of Arabic speakers whose preferred script requires letter-by-letter decoding (i.e., fully vowelized script) should not depend as much on the number of visual elements processed under one attentional capture.

Here, we examined the VA span and reading skills of Qatari children who are in Grade 4. If script and reading strategy preferences are associated with specific visual attention distribution modes, children who have better reading skills to deal with the nonvowelized script than the fully vowelized one should exhibit a more homogeneous distribution of attention over letter strings compared to the other group of children. In addition, we predicted that there would potentially be a stronger VA span–reading relationship for those readers who are better at reading nonvowelized Arabic than fully vowelized Arabic.

Material and methods

Participants

Fifty-nine Grade 4 native Arabic speaker children from Al-Bayan Independent School in Doha, Qatar, participated in this experiment (right-handed, female; *M* age = 127 months ± 4). We focused on this age group because children are supposed to master both nonvowelized and vowelized reading at this age. All of the participants had normal or corrected-to-normal vision, and none were reported to have reading difficulties or developmental disorders. The Qatar Foundation ethical committee approved the experiment. The written consent of each child's legal tutor was obtained.

Task battery

Nonverbal IQ

Nonverbal IQ skills were measured with the Egyptian version of the Wechsler Intelligence Scale for Children nonverbal IQ subtests (Ismael & Maleka, 1993) including the picture completion, picture arrangement, block design, object assembly, digit-coding symbol, and mazes subtests. The standard score was calculated.

Fully vowelized and nonvowelized text reading

Two Arabic texts were created. For both texts, a fully vowelized version and a nonvowelized version were created and presented to participants on a different sheet of paper. The four texts (Text 1 vowelized, Text 1 nonvowelized, Text 2 vowelized, Text 2 nonvowelized) were administered in two sessions spread over 2 weeks. In the first session, children read the nonvowelized version of Text 1 and the vowelized version of Text 2. One week later, children read the nonvowelized version of Text 2 and the vowelized version of Text 1. They were instructed to read the text out loud as well as possible, and they knew that they were being timed. Participants were given a maximum of 6 min to read each text. Both the time taken to read the text and the number of words correctly read were recorded. The number of correct words read per minute was computed in order to obtain comparable outcome measures for the four texts. For each participant, the mean *z* score obtained from the vowelized texts was subtracted from the mean *z* score obtained from the nonvowelized texts. Participants scoring above the median were assigned to the group of children with better nonvowelized than vowelized reading skills (NOVOW group), and those scoring below the median were assigned to the group of children with better vowelized reading skills than nonvowelized reading skills (VOW group; see Figure 1). Table 1 presents further information about the groups' characteristics and reading performance.

VA span

A visual one-back paradigm was used. Stimuli were created using 13 Arabic consonants in their isolated form (ب/ج/ف/ع/ذ/ك/ط/م/ن/ل/ي/ر/ص). The consonant strings did not include clusters corresponding to root morphemes, and consonants could be included only once in the same string. The task included 104 five-consonant strings presented on a white screen in black uppercase Arial font. Children were seated 70 cm away from the screen so that the stimulus width was between 5.3° and 5.55° of visual angle and the center-to-center distance between each adjacent letter was 1.2°. At the start of each trial, a central fixation point was displayed for 1,000 ms followed by the centered consonant string during 200 ms. Then, a white screen lasting 100 ms was presented, followed by a consonant (target) appearing below the median horizontal line. Target consonants were presented in red with a bold italic font. Children were instructed to respond as fast as possible by pressing the M key when the target was present in the previous consonant string and the Z key when it was absent. The target disappeared after the child's response, and a screen with a question mark was presented until the experimenter decided to initiate the next trial. The 104 trials included 65 trials in which the target was present in the consonant string (each consonant presented five times as target, once at each position) and 39 trials in which the target was absent (each consonant presented three times as target). The task was preceded by five practice trials. Trial order was randomized. For each position, target detection accuracy (%) and sensitivity (*d*') were computed.

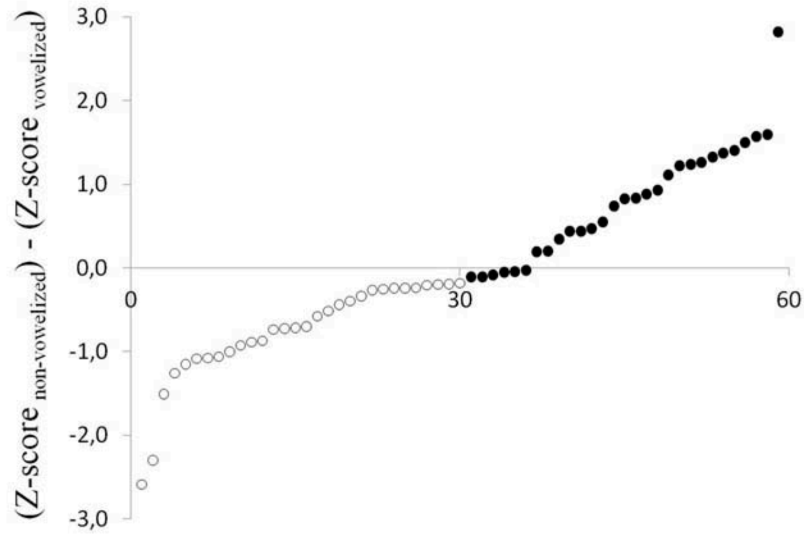

Figure 1. Caterpillar plot depicting the distribution of the difference scores obtained from the reading performance on the nonvowelized and the vowelized texts. *Note*. White dots represent children in the VOW group (children with better vowelized reading skills than nonvowelized reading skills; n = 30), and black dots represent children in the NOVOW group (children with better nonvowelized than vowelized reading skills; n = 29).

Data analyses

All analyses included nonverbal IQ and age as covariates. To quantify group differences on reading skills, an analysis of covariance (ANCOVA) on text reading *z* scores was conducted with group (NOVOW, VOW) as the between-subject factor and script (vowelized, nonvowelized) as the within-subject factor. Then, ANCOVAs on the mean d prime (*d'*) and percentage scores from the VA span task were conducted with group (NOVOW, VOW) as the between-subject factor and target position (1, 2, 3, 4, 5) as the within-subject factor. Post hoc tests were performed using Bonferroni corrections. Last, partial correlations within each group were performed between VA span and reading *z* scores for the vowelized and the nonvowelized texts separately.

Results

Vowelized and nonvowelized text reading

Reading scores are presented in Table 1. There was a Group × Script interaction, $F(1, 55) = 81$, $p < .001$, $\eta^2 = 0.60$. Post hoc exploration showed that the VOW group was better at reading the vowelized than the nonvowelized texts, and the NOWOV group was better when reading the nonvowelized than the vowelized texts ($ps < .001$). The two groups had similar reading performance on the fully vowelized texts ($p > .05$), whereas the NOVOW groups was better at reading the nonvowelized texts than was the VOW group ($p = .01$).

VA span

The ANCOVA on *d'* values did not reveal any main or interaction effect. However, a significant interaction between target position and group was found on percentage scores, $F(4, 220) = 3.07$, $p = .017$, $\eta^2 = 0.05$ (Figure 2). Post hoc tests did not show any group difference at any position (all $ps > .50$). In addition, the VOW group had similar performance across positions ($ps > .50$), whereas the NOVOW group exhibited better performance at Position 5 than Positions 2 and 4 ($p < .001$ and $p = .04$, respectively), reflecting a

Table 1. Characteristics of the Two Groups.

	NOVOW[a]			VOW[b]		
	M (SD)	Range	z Score	M (SD)	Range	z Score
Age (months)	126.6 (3.5)	121–131	—	127.9 (3.3)	122–133	—
IQ (standard score)	103.1 (11.3)	80–118	—	103.5 (9.1)	80–120	—
Arabic script reading (cwpm)						
Nonvowelized	76.2 (19.0)	47–126	0.42	59.8 (19.8)	30–101	−0.3
Fully vowelized	48.8 (12.5)	27–78	−0.03	51.8 (16.0)	27–83	0.13
Difference score	27.4 (9.9)	14–48	0.4	8.0 (6.7)	−4–23	−0.4

Note. NOVOW = children with better nonvowelized than vowelized reading skills; VOW = children with better vowelized reading skills than nonvowelized reading skills; cwpm = correct words per minute; difference score = (nonvowelized) — (fully vowelized).
[a]*n* = 29. [b]*n* = 30.

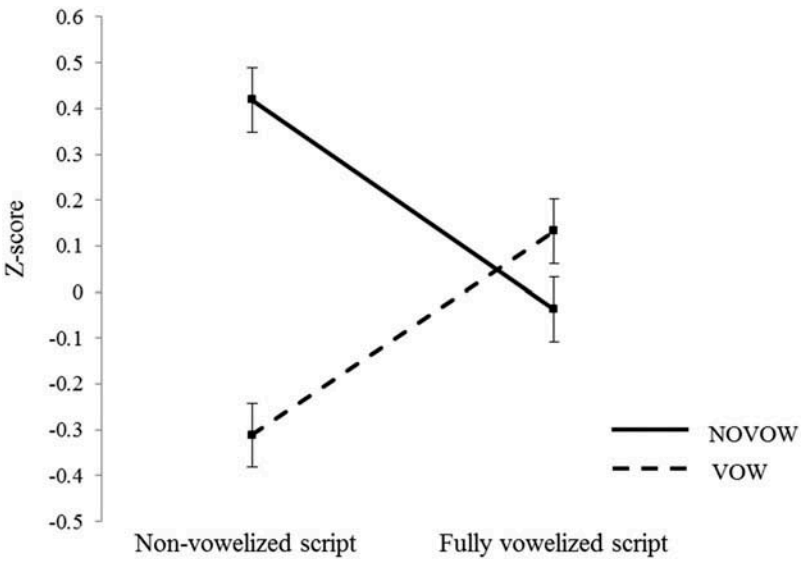

Figure 2. Reading performance on the two scripts in the two groups of participants. *Note*. Vertical bars denote 95% confidence intervals corrected with Cousineau's (2005) method. NOVOW = group of children with better nonvowelized than vowelized reading skills; VOW = children with better vowelized reading skills than nonvowelized reading skills.

significant serial position function (Grainger, Dufau, & Ziegler, 2016), henceforth referred to as "crowding" effect,[1] although we are aware that it also reflects acuity effects. An ANCOVA controlling for overall sensitivity (mean *d*' across positions) resulted in similar results.

Correlations between VA span and reading in Arabic

There was no significant link between overall sensitivity (*d*') on the VA span task and text reading scores within the whole group and the VOW group (*ps* > .30). In the NOVOW group, the lower target detection sensitivity, the better the reading of both nonvowelized, $r(29) = -0.43$, $p = .025$, and fully vowelized texts, $r(29) = -0.41$, $p = .03$.

[1]Crowding effects in reading refer to perceptual difficulties at identifying letters within words that stem from the interference produced by lateral masking between adjacent letters. In a five-letter word, letters in Positions 2 and 4, which are surrounded by letters in both sides, will be the most affected by crowding.

Follow-up analyses were also conducted to explore the "crowding" effect that differentiated group performance on the VA span task. Individual crowding scores were computed by subtracting the mean *d*' over Positions 2 and 4 from the mean *d*' over Positions 1, 3, and 5 (see the serial position function in VA span tasks; Ziegler, Pech-Georgel, Dufau, & Grainger, 2010), so that positive scores corresponded to large crowding effects. Small crowding effects were associated with low target detection sensitivity within the whole group, $r(59) = 0.91$, $p < .001$; the VOW group, $r(30) = 0.95$, $p < .001$; and the NOVOW group, $r(29) = 0.87$, $p < .001$. Last, smaller crowding effects were also linked to better reading skills in the NOVOW group only—nonvowelized text–NOVOW, $r(29) = -0.37$, $p = .05$; VOW: $r(30) = 0.04$, $p > .50$; whole group: $r(59) = -0.06$, $p > .50$; fully vowelized text–NOVOW: $r(29) = -0.35$, $p = .07$; VOW: $r(30) = -0.07$, $p > .50$; whole group: $r(59) = -0.10$, $p > .50$ (see Figure 3). The correlation coefficients tended to differ between the groups for the vowelized text ($p = .06$; nonvowelized text: $p = .14$) (see Figure 4).

Discussion

The present study aimed to explore the relationship between the VA span and Arabic reading skills, focusing on a novel factor: individual script preferences. To do so, the performance of children who were better at reading the nonvowelized texts than the fully vowelized texts (NOVOW group) was compared to the performance of children for whom the opposite was true (VOW group).

Whereas both groups performed similarly on the reading task in the fully vowelized script, the NOVOW group was better at reading the nonvowelized text (see Figure 1). Because the quality of root morpheme representations may contribute to the ease at which nonvowelized script is read (Bar-On & Ravid, 2011; Saiegh-Haddad & Geva, 2008; Saiegh-Haddad & Henkin-Roitfarb, 2014), the poorer nonvowelized reading skills of the VOW group might stem from weaker internalization of these morphemes. In contrast, the two groups performed similarly on the fully vowelized text,

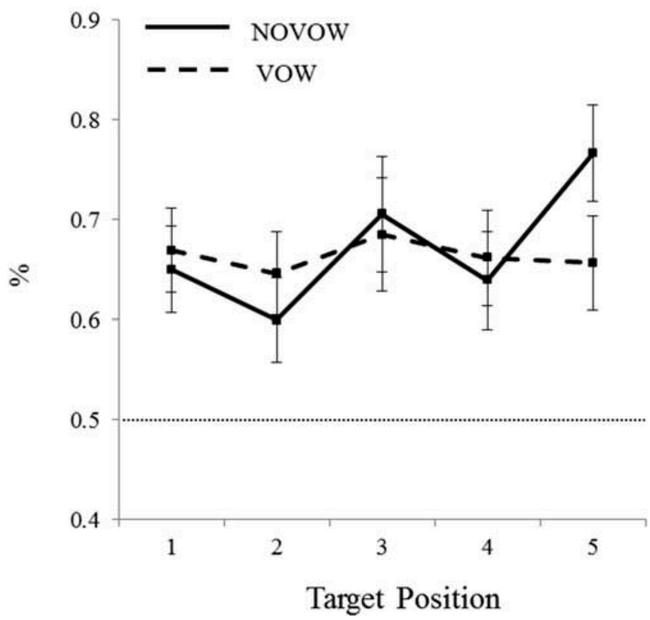

Figure 3. Mean percentage scores obtained on the visual attention span task for each group of participants. *Note*. The horizontal dashed line indicates the 0.50 chance level. Vertical bars denote 95% confidence intervals corrected with Cousineau's (2005) method. NOVOW = group of children with better nonvowelized than vowelized reading skills; VOW = children with better vowelized reading skills than nonvowelized reading skills.

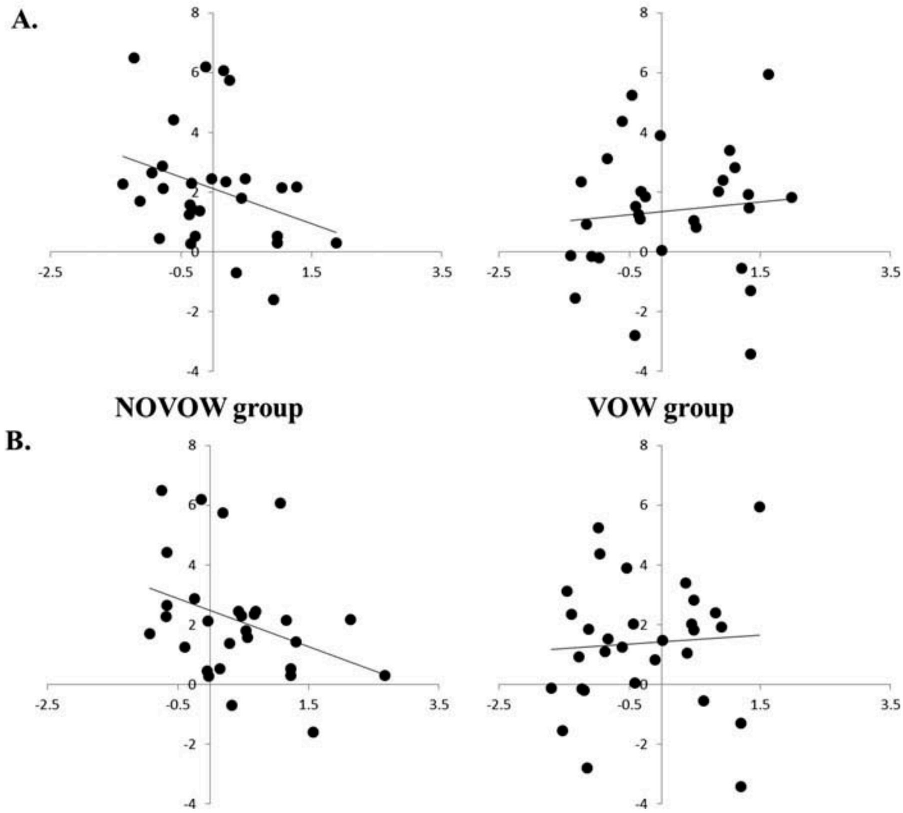

Figure 4. Scatter plots of the correlations between crowding effects on the visual attention span task and reading performance obtained on the fully vowelized (A) and nonvowelized (B) scripts, within each group. *Note*. Reading *z* scores are plotted on the *x* axis and crowding effects on the *y* axis. NOVOW = group of children with better nonvowelized than vowelized reading skills; VOW = children with better vowelized reading skills than nonvowelized reading skills.

suggesting that reading with diacritics may require skills other than morphological abilities alone, such as bottom-up grapheme-to-phoneme mappings (Weiss et al., 2015, 2016).

Reading preferences and VA span distribution mode

Because different strategies are associated with nonvowelized and fully vowelized Arabic scripts (lexical and sublexical, respectively), we first predicted that higher reading expertise in one script compared to the other would be associated with different VA span behaviors.[2] No group difference was found on the overall target detection sensitivity (*d*') on the VA span task at any of the five positions within the consonant string. This is in line with data showing no quantitative VA span differences between children across languages (see Lallier et al., 2016). However, qualitative group differences linked to the distribution mode of VA span skills (spatial bias affecting target detection) emerged: Whereas the NOVOW group showed a significant response bias to uncrowded consonant targets (first, third, and fifth positions), the position did not affect the target detection in the VOW group.[3] Contrary to our predictions, children who preferred reading in a script requiring letter-by-

[2]Performance on our VA span task may engage not only visual attention but also visual working memory or fine-grain visual perception skills. Therefore, our results may be interpreted in the context of visual theories of reading other than the VA span hypothesis alone.

[3]A visual inspection of Figure 2 shows that a similar but much reduced serial position function effect can be observed in the VOW group.

letter strategies (VOW group) distributed their visual attention more homogeneously across stimuli than children who preferred reading in a script where multiletter units have to be extracted (NOVOW group).

A closer look at the crowding (and serial position function) literature gives some hints to interpret this unpredicted finding. We know that the identification of crowded elements is facilitated by top-down orthographic knowledge (Grainger, Tydgat, & Isselé, 2010; Montani, Facoetti, & Zorzi, 2015). We know from another line of work that top-down contextual mechanisms help us to resolve perceptual noise and ambiguity through predictive mechanisms (Ahissar & Hochstein, 2004; Guediche, Blumstein, Fiez, & Holt, 2014; Mattys, Davis, Bradlow, & Scott, 2012; Panichello, Cheung, & Bar, 2013). In our task, participants could barely rely on lexical or contextual feedback to reduce perceptual masking between the five consonants that were presented simultaneously. Of interest, nonvowelized Arabic reading demands constant feedback between root morpheme identification and top-down processes in order to access the meaning of words (Abu-Rabia, 1997, 2001). Therefore, the children in the NOVOW group, who rely on contextual information when reading, might have experienced the greatest difficulties at inhibiting perceptual noise in our task because of the absence of contextual help. Accordingly, the NOVOW group showed significant crowding effects, whereas the VOW group did not. It is noteworthy that two interpretations of these group differences are possible, implying opposite causal directions: (a) Reading preferences resulted in a specific VA span behavior: strongly relying on contextual top-down information while reading increased the impact of crowding on orthographic processing. (b) Vulnerability to crowding resulted in specific reading preferences: visual noise exclusion deficits encouraged the alternative use of context for lexical and semantic access. Future studies are needed to differentiate between the two alternatives.

VA span–reading relationship in Arabic

We hypothesized that the contribution of VA span skills to reading would be different between groups of readers with distinct reading preferences. Although it will be important to replicate these results in larger samples, they suggest that smaller crowding effects were associated with better reading in NOVOW readers only. The absence of a significant VA span–reading relationship in the VOW group may be an indicator of weaker nonvowelized reading skills (see Figure 1) and weaker reliance on top-down processes while reading. Contrary to the NOVOW group, children in the VOW group might have resorted primarily to vocalization to mediate the access to morphemes and word meaning (Schiff, 2012), thus tending to weaken the association between crowding and reading in Arabic. Of interest, the participants tested in Awadh et al. (2016) were highly educated Ph.D. students. Arabic-speaking individuals with this educational level are likely to be frequently exposed to religious and poetry texts and be fluent in fully vowelized reading. We cannot rule out that the absence of VA span–reading relationship in Arabic in Awadh et al. might partly result from their participants' expertise in reading fully vowelized Arabic. Altogether, these findings suggest that interindividual variability regarding how much top-down knowledge is used during reading might affect the strength of the contribution of VA span skills to reading within and across languages (Awadh et al., 2016). Taking into account individual reading profiles as well as crowding effects in addition to overall sensitivity in VA span tasks should shed light on these "cross-linguistic" questions.

Conclusion

By studying the unique properties of Arabic, we showed that the dominant reading strategy of individuals (lexical/top-down over sublexical/bottom-up, and vice versa) is associated with different distribution modes of VA span skills and different VA span–reading relationship strengths. One interpretation of these results is that the relatively stronger reliance on top-down contextual information compared to letter-by-letter bottom-up strategies, whereas reading increases the vulnerability to crowding and the strength of its association with reading. Future studies should thrive on developing experimental designs testing such causal assumption. Last, our findings suggest that some strengths and weaknesses of Arabic readers could be identified on the basis of their script preferences, which, in the long run, should contribute to designing tailored reading interventions for struggling readers.

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