Spot the Dot: Improving Arabic Reading Accuracy through Visual Attention Span Training

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Abstract

Visual Attention Span (VAS), defined as the capacity to process multiple visual elements in parallel, is a recognized contributor to reading development. While evidence supports its involvement across languages, its causal role in visually complex orthographies such as Arabic remains underexplored. Arabic's high visual density and extensive letter similarity, due to diacritics, may amplify attentional demands during early literacy acquisition. This study evaluated *Sayyadu-n-niqaat* ("The Dots Hunter"), a classroom-based visual-search training designed to strengthen VAS through fine-grained processing of Arabic letter features. Seventy-eight second-grade Moroccan Arabic-speaking children participated in a quasi-experimental pre–post design with intact classrooms (intervention vs. business-as-usual control). Reading accuracy and speed were assessed in vowelized Modern Standard Arabic, and a subsample (n = 54) completed computerized VAS and single-letter identification threshold (SLIT) measures in Arabic and Latin scripts. After controlling for baseline reading accuracy and key covariates (nonverbal reasoning, phonological awareness, and baseline SLIT), the intervention group showed significantly higher post-test reading accuracy than controls, with no reliable effect on reading speed. Mechanistic analyses identified VAS as the primary locus of change: robust gains were observed in Arabic VAS partial report, whereas improvements in single-letter identification did not differentiate groups. VAS gains were associated with reading accuracy gains. These findings provide converging evidence that strengthening multi-element visual-attentional processing through visual search can support early reading accuracy in Arabic. They further highlight the role of attentional constraints in visually complex orthographies and support VAS as a meaningful target for early reading interventions.

1. Introduction

Visual Attention Span (VAS) refers to the capacity for multi-element parallel processing, i.e., the number of distinct elements that can be simultaneously processed in a visual array (Valdois, 2022). VAS plays a critical role in reading by enabling the simultaneous processing of multi-letter chunks, such as graphemes, syllables, morphemes or whole words. It reflects the amount of visual attention capacity that is distributed across the input letter string. Readers with limited visual attention resources can only identify a limited number of letters at once, which results in less efficient word recognition and more serial processing (Steinhilber et al., 2023; Valdois et al., 2021). In contrast, individuals with high visual attention resources are more likely to process larger chunks in parallel and recognize familiar words by sight. Visual attention span (VAS) is now widely acknowledged as a key contributor to reading development (Gavril et al., 2021; Liu et al., 2023; Perry & Long, 2022). Converging evidence from behavioral and neurocognitive studies indicate that VAS contributes to reading, independently of phonological skills (Gavril et al., 2021; Liu et al., 2023; Liu et al., 2022; Valdois, 2022). Intervention studies further highlight that strengthening VAS can improve reading outcomes in both beginning readers (Valdois et al., 2025) and dyslexic children (Zhao et al., 2019; Zoubrinetzky et al., 2019).

While the role of VAS in multi-letter processing and word reading is well established, its contribution to letter knowledge acquisition warrants closer examination. Letter recognition involves the rapid identification of visually similar forms and the extraction of their distinctive features. According to LaBerge and Samuels (1974), visual attention is especially critical at the early stages of literacy acquisition, when children must progressively integrate visual features into higher-order letter units for letter recognition and their association with the corresponding phonemes.

This role of VAS may be even more critical in visually complex alphabetic systems. Arabic orthography is characterized by high graphic density, extensive letter similarity, and the presence of diacritics, which together impose a substantial perceptual load (Verhoeven & Perfetti, 2022). These characteristics likely increase demands on visuo-attentional resources, both for isolated letter recognition and for the identification of orthographic chunks and whole words. However, empirical evidence on the role of VAS in Arabic reading remains limited and heterogeneous (Awadh et al., 2016, 2022; Lallier et al., 2018), leaving open the question of its actual weight in this orthographic context.

Recent findings provide new insight into this issue. In beginning readers of Arabic, Ghandour et al. (2025) showed that letter knowledge was the strongest predictor of reading performance, at both syllabic and lexical levels. Importantly, the effect of VAS on reading was not direct but mediated by letter recognition. These results suggest that VAS supports reading acquisition primarily by facilitating the processing and integration of the visual features that constitute letters. In a dense orthographic system such as Arabic, where many letters differ only by a dot or a subtle orientation change, this mediated relationship appears particularly meaningful. It highlights the letter as a central unit, whose recognition mobilizes a substantial share of available attentional resources.

The centrality of letter knowledge has led to the development of numerous educational and speech-language intervention approaches. Traditional methods emphasize sensorimotor training (**Araujo et al., 2022**). They often rely on repeated copying (Bara & Gentaz, 2010; James & Engelhardt, 2012; Longcamp et al., 2005), which combines visual perception with motor programs to consolidate graphemic memory. Other approaches emphasize multisensory and haptic experiences, such as tracing letters on various surfaces or modeling them with clay (Bara et al., 2007; Gentaz et al., 2003; Labat et al., 2021; Torres et al., 2021), thereby engaging the sensorimotor system to support memory consolidation. Another approach involves composing letters from their elementary distinctive features (vertical strokes, curves, dots), a process that requires fine-grained visual analysis without engaging graphomotor skills. Evidence that composition is as effective as handwriting to improve letter recognition emphasizes the importance of detailed visual analysis in the acquisition of letter representations (Courrieu & De Falco, 1989; Seyll et al., 2020; Seyll & Content, 2022).

Beyond interventions focused on consolidating letter knowledge, a complementary research avenue targets visual attentional mechanisms. Initially introduced to account for specific profiles of developmental dyslexia (Bosse et al., 2007), the concept of VAS led to the development of remediation programs designed to strengthen the simultaneous processing of multiple visual elements. The COREVA© program (Valdois et al., 2014), based on paper-and-pencil tasks, trained children to process increasingly long target strings and discriminate them from visually similar distractors, yielding gains in both VAS and word recognition. To overcome the lack of strict temporal constraints in this program, the MAEVA© software (Valdois et al., 2025) introduced two critical parameters: a gradual increase in the number of elements to be processed and a progressive decrease in presentation time, promoting genuine parallel visual processing. Studies with dyslexic children confirmed the effectiveness of this protocol, showing improvements not only in VAS but also in reading fluency (Zoubrinetzky et al., 2019).

Related evidence also indicates that training programs not explicitly designed for reading can benefit attentional skills involved in VAS. Action video games, which heavily recruit visual perception and attentional control, have been shown to positively affect reading performance in both dyslexic children (Franceschini et al., 2012, 2013, 2017; Peters et al., 2019) and typical readers (Pasqualotto et al., 2022). Reported benefits include improvements in VAS and reading fluency (Antzaka et al., 2018; Argilés et al., 2023; Lallier et al., 2013).

A relation between VAS and visual search efficiency was further established, suggesting involvement of visual attention and parallel processing in both reading and visual search tasks (Khan et al., 2016; Lallier et al., 2013; Rayner, 2009). Last, the combination of the ingredients for effective VAS training with the core principles of action video games in a visual search paradigm has proven highly effective to improve reading development in beginning readers (Valdois et al., 2025).

Building on these foundations, recent work has opened a new avenue by embedding visual search paradigms into letter and feature recognition training. Vialatte et al. (2023) developed the VisioCogLetters program, based on visual search tasks in which children must detect a target symbol or letter among visually similar distractors. This paradigm strongly engages selective attention and VAS, as it requires rapid and precise recognition of relevant elements within a visually saturated field. A daily 10-minute training over four weeks led to significant improvements in reading accuracy in dyslexic children, with stronger effects observed in highly compliant participants. Subsequent work by Vialatte et al. (2025) showed that performance on a visual search task involving multi-feature symbols correlated significantly with reading speed and accuracy in large samples of primary school children. This approach also proved effective in identifying struggling readers.

These studies fit within a broader reflection on intervention philosophies in reading. Symptom-based approaches directly target observable reading skills such as decoding accuracy or fluency, often yielding rapid gains (Ehri et al., 2001; Torgesen et al., 2001). In contrast, deficit-based approaches act upstream on cognitive mechanisms, such as phonological awareness (Melby-Lervåg et al., 2012; Snowling & Hulme, 2012) or VAS (Valdois et al., 2025; Zoubrinetzky et al., 2019), with the aim to strengthen the cognitive foundations of reading. As emphasized by Frith (1986), these levels of intervention are complementary rather than mutually exclusive, and their combination might be particularly effective for reading improvement.

In this perspective, the present study builds upon visual search paradigms while explicitly integrating a letter-specific focus tailored to the Arabic script. The objective was to train visual attention span through a visual search task involving complex targets – composed of multiple visual features – embedded among distractors (Vialatte et al., 2021). Letters or letter-like symbols displaying visual features specific to the Arabic script were used as stimuli. The study evaluates the feasibility and effectiveness of "*Sayyadu-n-niqaat*" (the dots hunter), a visuo-attentional training program specifically designed for Arabic letters in children, at an early stage of literacy acquisition. We hypothesize that the training will improve reading performance, enhance VAS and result in greater gains in Arabic letter knowledge in the experimental group compared to an untrained control group.

2. Method

2.1. Participants

The initial sample included 91 second-grade pupils enrolled in a private school in the Rabat region (Morocco). At study completion, 74 children had completed all planned assessments and were retained for analyses (38 girls, 41 boys). The training group consisted of one intact classroom (n = 33), and the control group comprised two intact classrooms (n = 41). The control group was an untreated group of business-as-usual students.

All children were native speakers of Moroccan Arabic (Darija). Formal reading and writing instruction at school was delivered in fully vowelized Modern Standard Arabic (MSA), consistent with the national curriculum, and French was taught as a foreign language. Daily oral interactions at school occurred mainly in Darija. Before entering primary school, pupils had completed three years of kindergarten, including initial exposure to Arabic and Latin letters. Data were collected between February and May (mid-second grade), after approximately 15 months of explicit literacy instruction in vowelized MSA.

School records indicated normal hearing and normal or corrected-to-normal vision for all children, with no reported neurological or developmental disorders. The school served mainly families from a low-to-middle socioeconomic background.

The study used a quasi-experimental pre–post design with intact classes. Ethical approval was granted by the Ethics Committee of Mohammed VI Polytechnic University **(PASEM project, ref. ECAIRESS-002-2024)**. Written parental consent was obtained and children provided assent. Teachers and parents in both groups were informed about study goals and procedures.

2.2. Design and overview of assessments

Children were assessed at two time points: pre-test (before the intervention) and post-test (immediately after the intervention). The full assessment battery was administered at pre-test. At post-test, only measures directly targeted by the intervention were re-administered: letter knowledge, visual attention span, and reading.

Due to the limited availability of standardized tools in Arabic, several tasks were adapted from prior protocols and/or specifically developed for the present research, with adjustments to match the Moroccan linguistic context and second-grade level.

2.3. Measures

Nonverbal reasoning

Fluid reasoning was assessed using Raven's Colored Progressive Matrices **(RCPM;** Raven, 2000**)**, consisting of three sets of 12 matrices in which the child selects the missing element. In the absence of Moroccan norms, performance was indexed by accuracy adjusted for administration time (score per minute).

Expressive vocabulary

Expressive vocabulary was measured using the picture naming subtest of the ELO-L **(**Zebib et al., 2019), adapted to the Moroccan context. Children named 35 pictures presented individually. Responses in MSA were encouraged; Darija responses were also accepted when they matched the intended target. The score was the number of correct responses (maximum = 35).

Rapid automatized naming (RAN)

The stimulus set comprised five highly frequent monosyllabic items shared across Darija and MSA: elephant (/fiil/), eye (/ʕayn/), hand (/yad/), door (/baab/), and cup (/kuub/). Each picture appeared 5 times in a 5 × 5 grid, scanned right-to-left to match Arabic script direction. After a familiarization phase ensuring correct identification of each picture, children named the entire grid as quickly and accurately as possible without interruptions. The dependent measure was total naming time (in seconds).

Phonological awareness

Phonological awareness was evaluated in MSA using two oral deletion tasks designed to reduce diglossia effects by selecting frequent words with limited divergence from Darija **(**Saiegh-Haddad et al., 2020). **Syllable deletion**: children repeated a word after deleting its initial syllable (10 test items, preceded by 4 practice items), covering varied syllable structures (CV, CVV, CVC). Example: ṣaaruuχ "rocket" → /ruuχ/. **Phoneme deletion**: children repeated a word after deleting its initial phoneme (10 test items + 4 practice items). Stimuli were monosyllabic (3–4 phonemes). Example: fiil "elephant" → /iil/ after deleting /f/. Responses were scored for accuracy.

Letter knowledge

Letter knowledge was extensively assessed. We first used five complementary tasks designed to capture both explicit knowledge of letter names/labels and visual recognition of letter forms, including allographic variability, which is a core feature of Arabic orthography. For naming tasks, both the canonical letter name (e.g., */daal/* for د) and the letter sound with /a/ (e.g., */da/*) were accepted as correct to accommodate variability in instructional practices, following the rationale used in prior work with Arabic letter-name tasks **(e.g.**, Tibi et al., 2021). Each task yielded a score from 0 to 28.

In the two tasks of isolated letter naming (LetName) and Allograph naming (AllogName), 28 isolated letters and 28 allographs (one per letter) were presented one by one in a randomized order. The child was instructed to name each letter/allograph as quickly and accurately as possible.

In the two tasks of isolated letter Designation (LetDes) and Allograph Designation (AllogDes), a target letter was orally produced and the child selected the matching letter/allograph from a four-option array. Distractors were systematically constructed to include: (a) a phonological distractor (phonologically similar letter; e.g., /s/ vs. /ṣ/), (b) a visual distractor (graphically similar form; e.g., □ vs. □), and (c) an unrelated distractor (neither visually nor phonologically similar).

In the task of Allograph choice in context (AllogChoice), children were shown a short vowelized Arabic word with a missing letter position (e.g., initial/medial/final) and were asked to choose, among three allographic options, the form that correctly fits that position. Options included the correct positional variant and two plausible distractor allographs.

Two computerized tasks of Single-Letter Identification Threshold (SLIT) were further administered, one using 10 Arabic letters and one using 10 Latin letters. The protocol was the same as in Bosse & Valdois (2009**).** On each trial, a single letter was displayed briefly at variable exposure durations (from 33ms to 101ms, in 16 ms increments), immediately followed by a visual mask; children named the letter. Performance was computed using a weighted threshold score (maximum = 150) and then rescaled to a continuous 0–1 metric to facilitate comparisons across participants and scripts.

Visual attention span (VAS)

VAS was assessed using the two standard computerized tasks of global and partial letter report **(**Valdois, 2022**)**. Each task was administered twice, once with Arabic letters and once with Latin letters. In each trial, a 5-consonant string was presented for 200ms. The strings were built up from sets of 10 consonants selected to minimize visual confusability and represent distinct graphic families for Arabic, namely B, P, T, F, L, M, D, S, R, H and □ □□□ □□ □□ □□ □□ □□ □□ □□ □□, respectively. The strings were randomly generated while excluding real words, roots, or existing morphological patterns. In global report, children were asked to verbally recall as many letters as possible from each string immediately after presentation (20 trials; maximum score = 100). In partial report, a vertical cue appeared immediately after the string offset, indicating the position of the target letter to be reported (50 trials; maximum score = 50).

Reading

Reading was assessed using three standardized lists from BELEA **(Henri et al., in preparation)**: high-frequency words, low-frequency words, and pseudowords (20 items per list). All stimuli were presented in fully vowelized MSA. Children read each list aloud as quickly and accurately as possible. Two indices were computed for each list: accuracy (number correct) and speed (time to read the list).

2.4. Intervention: *Sayyadu-n-niqaat* (The dots hunter)

The training program was designed to strengthen visual processing of Arabic letters by specifically targeting diacritics (dots) through visual search activities, with minimal linguistic demands. The full training program includes two complementary modules; however, the present pilot implemented only the first module (*Sayyadu-n-niqaat* / The dots hunter) and, within this module, only the first two (of three) booklets.

Training rationale and focus. Tasks emphasized rapid detection and discrimination of fine graphic features (presence, number, and position of dots) in isolated stimuli, aiming to support letter recognition by improving visuo-attentional processing of distinctive features (e.g., discriminating □/□/□ ;□/□/□).

Structure. The full module comprises 18 sessions organized in three progressive phases (three booklets), six sessions each. In this pilot, implementation covered:

- Booklet 1 (Sessions 1–6): dot detection within non-alphabetic shapes **(**Fig. 1A**-left)** and pseudo-letters **(**Fig. 1A**-right)** built from Arabic letter fragments to reduce activation of stored orthographic/lexical knowledge.
- Booklet 2 (Sessions 7–12): dot detection within real isolated Arabic letters, maintaining the feature-focused, non-lexical format.

Task types. Each session included four visual search tasks presented in two layouts **(**Fig. 1B**)**:

- Linear layout (rows facilitating scanning) (left)
- Random layout (spatially scattered items increasing attentional demands) (right)

The four task types were **(**Fig. 1C**)**:

1. Simple detection: mark all items containing at least one dot.
2. Dot quantity: mark items with a specified number of dots (1, 2, or 3).
3. Dot position: mark items with dots in a specified location (above vs. below the letter body).
4. Target letter search: find a given target letter among distractors (fine processing).

Progression parameters. Task difficulty increased through a controlled combination of parameters: (a) a gradual increase in the number of items per page, (b) a progressive reduction in character size, (c) a decrease in the target-to-distractor ratio, and (d) a systematic increase in visual similarity between targets and distractors, ranging from clearly dissimilar items to highly confusable forms sharing most graphic features. This progression was implemented alongside a staged transition from non-alphabetic shapes to pseudo-letters, isolated Arabic letters, and – at later stages of the program (booklet 3) – letter sequences and real Arabic words. **(**Fig. 1D**)**

Overview of the "Sayyadu-n-niqaat" visual attention span training program and task progression

Procedure

The study was conducted during the second semester (February–May 2024) with a pre-test / post-test schedule. Assessments were administered in a dedicated room at school to minimize distractions. Testing was conducted one-to-one by trained examiners, under the remote supervision of the doctoral researcher. Responses and times were recorded in real time. All oral reading responses were audio-recorded to allow subsequent verification of scoring accuracy.

Each child completed the battery across two to three sessions of approximately 30–45 minutes each, spread over several days to reduce fatigue. Test order was counterbalanced across participants. Instructions were delivered in Darija to ensure comprehension.

Training implementation and dosage

Training was delivered only to the experimental group over 10 weeks (26 February–10 May 2024), excluding school holidays (10–17 March; 9–10 April; 28 April–5 May). Sessions took place 2–3 times per week, lasting 20–30 minutes, for a total of 12 sessions (approximately 6 hours of training). Training was implemented by the classroom teacher after preparation by the doctoral researcher using an explanatory video. Booklets were distributed to pupils and corrected collectively.

Fidelity and monitoring

To document implementation fidelity, teachers completed a session tracking grid and a brief questionnaire reporting on session delivery and their impressions. Control classes followed their usual instruction and did not receive additional activities during the same period.

3. Results

First, we report results collected on the whole sample of 78 second graders (*N* = 78; Control = 42, Intervention = 36) to study the evolution of reading performance in the intervention group compared to the control group. Second, we focus on the subsample of 54 children (*n* = 54; Control = 26, Intervention = 28) who have completed the computerized tasks of VAS and SLIT, to examine the underlying mechanisms of the intervention effect. For all baseline covariates except VAS and SLIT, missing data were minimal and were imputed using classroom-stratified medians (5 values across 5 variables; 4/78 children had 1 or 2 imputed value). No imputation was applied to the VAS/SLIT tasks.

3.1. Results for the whole sample (*N* = 78)

Baseline comparison of the control and intervention groups

Table 1 summarizes the results of the two groups of participants (*N* = 78) for all tasks at pre-test.

Table 1
Descriptive statistics for all the variables and for the two groups of participants (*N* = 78).

Variable	Control	Intervention	*t*(*df*)	*p*	*d*
Raven (score/min)	5.21 (1.41)	5.04 (1.86)	0.45(76)	0.650	-0.10
Vocabulary (prop.)	0.69 (0.12)	0.69 (0.14)	-0.01(76)	0.994	0.00
RAN (s)	22.44 (5.28)	23.64 (5.74)	-0.89(76)	0.377	0.20
Phonological Awareness (prop., composite)	0.65 (0.18)	0.75 (0.17)*	-2.40(76)	0.019	0.54
Syllable Deletion	0.69 (0.13)	0.74 (0.20)	-1.44(76)	0.153	0.33
Phoneme Deletion	0.61 (0.31)	0.75 (0.27)*	-2.07(76)	0.042	0.47
Letter Knowledge (prop., composite)	0.98 (0.03)	0.97 (0.03)	0.63(76)	0.532	-0.14
Letter Naming	0.98 (0.03)	0.97 (0.04)	1.19(76)	0.238	-0.27
Letter Designation	0.97 (0.04)	0.98 (0.04)	-0.11(76)	0.912	0.03
Allograph Knowledge (score/min, composite)	27.06 (4.84)	26.15 (4.33)	0.86(75)	0.395	-0.20
Allograph Naming	44.42 (9.35)	43.40 (8.15)	0.51(76)	0.612	-0.12
Allograph Designation	25.05 (5.49)~	22.60 (5.32)	1.99(76)	0.050	-0.45
Allograph Choice	11.70 (3.24)	12.61 (3.60)	-1.16(75)	0.251	0.26
Reading Accuracy (prop., composite)	0.83 (0.15)	0.82 (0.14)	0.42(76)	0.679	-0.09
HF Words	0.87 (0.16)	0.85 (0.19)	0.64(76)	0.525	-0.15
LF Words	0.79 (0.21)	0.76 (0.24)	0.76(76)	0.451	-0.17
Pseudowords	0.83 (0.14)	0.85 (0.16)	-0.63(76)	0.532	0.14
Reading Time (s, composite)	53.72 (23.59)	44.69 (12.64)*	2.08(76)	0.041	-0.47
HF Words	46.95 (23.70)	39.81 (15.08)	1.55(76)	0.126	-0.35

Note: HF: high frequency; LF: low frequency; * = $p < .05$; prop.: proportion; s: seconds; score/min: score per minute; The measures of RAN and Reading Times were log-transformed for the t-tests. Independent-samples student's t-tests (equal variance; two-tailed) and effect sizes (Cohen's *d*) are reported for group comparison.

Variable	Control	Intervention	*t*(*df*)	*p*	*d*
LF Words	57.10 (29.08)	46.53 (14.40)*	2.03(76)	0.046	-0.46
Pseudowords	57.12 (19.93)	47.75 (12.44)*	2.47(76)	0.016	-0.56
Note: HF: high frequency; LF: low frequency; * = $p < .05$; prop.: proportion; s: seconds; score/min: score per minute; The measures of RAN and Reading Times were log-transformed for the t-tests. Independent-samples student's t-tests (equal variance; two-tailed) and effect sizes (Cohen's *d*) are reported for group comparison.					

Baseline comparisons indicated that the Intervention and Control groups were relatively well matched. There were no group differences in Age, Raven, RAN, or Vocabulary. As expected in this age range, Letter Knowledge (Denomination and Designation) was at ceiling in both groups, and similar ceilings appeared for Allograph Naming and Designation. To gain sensitivity, we derived score-per-minute indices for the allograph tasks (Naming, Designation, Choice). Group means on these indices – and on the Allograph Knowledge composite – were comparable overall ($p = .395$). Allograph Designation showed a marginal trend favoring the Control group ($t(76) = 1.99$, $p = .050$).

Importantly, reading accuracy did not differ between groups at baseline on HF, LF, or pseudowords, nor on the composite accuracy score (all $|t| \leq 0.76$, all $ps \geq .451$). Reading times were comparable for HF-words ($t(75.70) = 1.56$, $p = .123$), but the Intervention group read LF-words ($t(75.98) = 2.05$, $p = .043$) and pseudowords ($t(75.99) = 2.51$, $p = .014$) significantly faster. Finally, the Intervention group scored higher on the composite phonological-awareness measure, with a non-significant advantage on syllable deletion and a significant one on phoneme deletion.

Effects of the intervention for the whole population (N = 78)

Change in reading accuracy from pre- to post-test in the intervention and control groups (N = 78), for the three reading measures and their composite score. Note. Error bars represent standard errors

The evolution of reading accuracy from pre- to post-test is illustrated in Fig. 2 for the intervention and control groups. Because the primary outcome is a proportion bounded between 0 and 1 and showed pronounced ceiling at post-test (43.6% at 100% correct; 70.5% ≥ 95% correct) together with over-dispersion (binomial deviance/*df* = 6.28), we analysed post-test reading accuracy with an ANCOVA implemented as a quasi-binomial GLM (logit link). The model predicted post-test accuracy from Group (Intervention vs. Control) while adjusting for baseline accuracy, phonological awareness (composite), and Raven (performance/min). Adjusting for baseline targets the causal contrast of interest – expected post-test performance if groups were equal at baseline – and improves precision while mitigating regression-to-the-mean, even when randomization yields comparable groups (Vickers & Altman, 2001). Given heavy ceiling, we report percentage-point differences rather than odds ratios, which can be inflated near ceiling. Inference used HC3 (heteroskedasticity-consistent, type 3) robust standard errors. As a robustness check, a Gaussian ANCOVA on logit-transformed accuracy reproduced the same qualitative conclusion (reported in the Supplementary S2). We also examined the Group × baseline interaction to assess the parallel-slopes assumption; no evidence of violation was observed (see Supplementary S1).

The Intervention group significantly outperformed the Control group on post-test reading accuracy after adjusting for baseline performance and covariates ($\beta = 1.28$, $SE = 0.42$, $z = 3.05$, $p = .002$). Adjusted mean accuracy was .976 (95% CI [.956, .988]) for the Intervention group compared to .920 (95% CI [.877, .949]) for Controls, a difference of 5.7 percentage points. Among covariates, only nonverbal reasoning was significantly associated with post-test accuracy ($\beta = 0.28$, $SE = 0.14$, $z = 2.01$, $p = .044$), whereas baseline accuracy ($\beta = 1.91$, $SE = 1.30$, $z = 1.47$, $p = .142$) and phonological awareness ($\beta = 0.44$, $SE = 1.05$, $z = 0.42$, $p = .676$) were not. This effect remained significant after additionally controlling for baseline Allograph Knowledge (see S6).

Because baseline phonological awareness differed between groups and is theoretically linked to reading growth, we examined whether the intervention effect on reading accuracy varied across its distribution. We re-estimated the quasi-binomial ANCOVA within quartiles of baseline phonological awareness (Q1–Q4; n = 21/20/19/18), adjusting for baseline accuracy and Raven. Adjusted post-test accuracy favored the Intervention group in all quartiles; however, this advantage was statistically reliable only for children with higher baseline phonological awareness (Q3: Intervention .997 vs Control .970, + 2.7 points, $p = .008$; Q4: Intervention .985 vs Control .912, + 7.3 points, $p = .008$). For children with lower baseline phonological awareness, differences were smaller and not statistically significant (Q1: +6.3 points, $p = .259$; Q2: +1.3 points, $p = .767$). This pattern suggests that the intervention may be more effective for children who have already developed foundational phonological skills.

The evolution of reading times from pre- to post-test is illustrated in Fig. 3 for the two groups of participants. As shown in Fig. 3, reading times exhibited minimal change from pre- to post-test overall. Post-test reading times were analysed with a Gaussian ANCOVA on log-RT, predicting post-test log-RT from Group (Intervention vs. Control) while adjusting for baseline log-RT, phonological awareness (composite), and Raven (score/min). The intervention effect on reading times was not significant ($\beta = 0.085$, $SE = 0.071$, $t(73) = 1.20$, $p = .234$). Back-transformed adjusted means were 44.8 s (95% CI [40.7, 49.3]) for the Control group and 48.7 s (95% CI [43.8, 54.2]) for the Intervention group. Baseline log-RT strongly predicted post-test log-RT ($\beta = 0.463$, $SE = 0.113$, $t(73) = 4.08$, $p < .001$), and higher Raven scores were marginally associated with faster times ($\beta = -0.039$, $SE = 0.021$, $t(73) = -1.86$, $p = .068$). Phonological awareness was not significantly related to reading times ($\beta = 0.358$, $SE = 0.215$, $t(73) = 1.66$, $p = .101$).

Analyses by list type (HF, LF, pseudowords) showed no reliable Group differences for HF ($p = .624$) or LF ($p = .267$) items; for pseudowords there was a small, non-significant tendency toward longer times in the Intervention group ($\beta = -0.068$ on the log scale; $p = .053$), consistent with the composite result. To probe change directly, we modelled "Δ log-RT = post – pre test" with the same covariates. Change was negatively related to baseline log-RT ($\beta = -0.429$, $SE = 0.105$, $p < .001$), a pattern consistent with regression-to-the-mean and practice effects at the individual level; the intervention effect on change remained non-significant (β = −0.043, *SE* = 0.033, *p* = .185). Raven again predicted slightly larger improvements (β = −0.043, *SE* = 0.019, *p* = .029), whereas phonological awareness did not (*p* = .266).

3.2. Underlying mechanisms of the intervention effect (reduced sample of 54 children)

In this section, our goal was to determine whether the intervention had positive effects on visual attention span (VAS), Arabic letter knowledge (SLIT), or both. To this end, we focused on the subgroup of 54 children who completed the computerized tasks of VAS and SLIT, to examine whether the intervention produced measurable effects on these variables and, if so, whether the observed improvements were associated with gains in reading accuracy over time.

Preliminary analyses.

Before addressing these issues, we conducted preliminary analyses to verify that the intervention and control groups were comparable at baseline within the reduced sample (*N* = 54), as was the case in the full sample, and that they showed similar intervention effects on reading performance. The results of the analyses conducted on the reduced groups are presented as Supplementary Materials S4. At baseline, the two reduced groups performed similarly on most variables (see Table S3). Importantly, they were matched on VAS tasks, with either Latin or Arabic letters. However, consistent with the pattern observed in the full sample, the Intervention group showed a tendency for stronger phonological awareness (*M* = .76, *SD* = .16 vs *M* = .67, *SD* = .16; $t(51.08) = -1.97$, *p* = .054). The two groups also differed at baseline on SLIT performance, with the Intervention group showing faster isolated-letter identification speed in both Arabic (*M* = .89, *SD* = .08 vs *M* = .70, *SD* = .20; $t(31.76) = -4.55$, $p < .001$) and Latin (*M* = .85, *SD* = .13 vs *M* = .74, *SD* = .20; $t(41.51) = -2.49$, *p* = .017) scripts. These baseline differences were considered when interpreting subsequent SLIT analyses.

The analysis of reading accuracy in the reduced sample (*N* = 54) also revealed significant intervention effects. Since the intervention group showed baseline advantages on phonological awareness and SLIT–Arabic, we re-estimated the quasi-binomial ANCOVA adding baseline SLIT-Arabic as a covariate. The intervention effect remained significant ($z = -2.41$, *p* = .016), corresponding to a + 7.25 percentage-point advantage on adjusted post-test accuracy (Control = .908, 95% CI [.832, .952]; Intervention = .981, 95% CI [.951, .993]). Baseline SLIT-Arabic did not predict post-test accuracy ($z = -0.59$, *p* = .557); baseline accuracy showed a non-significant trend (*z* = 1.64, *p* = .100), and phonological awareness and Raven were not significant ($|z| \leq 1.32$, *p*s ≥ .19). Crucially, the intervention advantage in post-test reading accuracy persisted after adjusting for both phonological awareness and SLIT–Arabic.

Intervention effects on isolated-letter identification (SLIT).

ANCOVAs on post-test SLIT scores, adjusting for baseline performance, phonological awareness, and nonverbal reasoning, revealed significant group differences for both scripts. For SLIT Latin, the group difference was significant ($p < .001$); adjusted means – Control = 0.837 [0.799, 0.875], Intervention =

0.937 [0.900, 0.973]. For SLIT Arabic, the group difference was likewise significant ($p < .001$); adjusted means – Control = 0.779 [0.729, 0.828], Intervention = 0.934 [0.887, 0.982]. However, because groups differed substantially at baseline on SLIT measures, we also examined Time × Group interactions to test whether the intervention produced differential change. Interactions were not significant (Arabic: $F(1,52) = 0.06$, $p = .814$; Latin: $F(1,52) = 0.15$, $p = .703$), indicating that both groups improved at similar rates and that post-test differences reflect pre-existing baseline differences rather than intervention effects.

Intervention effects on visual attention span (VAS).

The intervention effects on VAS are illustrated in Fig. 4 for the partial report tasks. For VAS Arabic – Partial Report, the intervention effect was significant ($\beta = 0.179$, $SE = 0.047$, $t = 3.84$, $p < .001$); adjusted means were .627 [.561, .692] for the Control group and .805 [.742, .869] for the Intervention group. For VAS Arabic – Global Report, the intervention effect was also significant ($\beta = 0.051$, $SE = 0.022$, $t = 2.34$, $p = .024$); adjusted means were .551 [.520, .582] for the Control group and .602 [.572, .632] for the Intervention group. For VAS Latin – Partial Report, the intervention effect was borderline ($\beta = 0.067$, $SE = 0.035$, $t = 1.91$, $p = .062$); adjusted means were .743 [.693, .792] for the Control group and .810 [.763, .858] for the Intervention group. For VAS Latin – Global Report, there was no reliable Group difference ($\beta = -0.002$, $SE = 0.022$, $t = -0.08$, $p = .940$). Overall, the intervention effect was stronger on partial than global report and on Arabic than Latin letters.

Associations between VAS gains and reading gains.

Across participants, gains in VAS Arabic – Partial Report correlated with gains in reading accuracy ($r = .38$, $p = .005$); this association remained after controlling for Raven (partial $r = .40$, $p = .003$). VAS Arabic – Global showed a smaller association ($r = .31$, $p = .022$; Raven-controlled partial $r = .26$, $p = .061$). VAS Latin gains were not significantly related to reading gains (Partial: $r = .15$, $p = .266$; Global: $r = -.23$, $p = .101$). By group, the Arabic-Partial association showed similar direction in Control ($r = .37$, $p = .065$) and Intervention ($r = .27$, $p = .169$).

Variations in the proportion of children with simultaneous high performance (≥ 80%) in reading and VAS-partial tasks between pre-test and post-test. Note. Error bars represent standard errors

As a converging check, we compared the proportion of children who simultaneously exceeded 80% at post-test on reading accuracy and VAS Partial. Figure 5 illustrates variations in this proportion of children for the intervention and control groups and for the two Arabic and Latin VAS – partial report tasks, at pre and post-test.

For Arabic Partial × Reading, 78.6% of Intervention children (22/28) versus 15.4% of Controls (4/26) met this joint criterion (difference = 0.632, 95% CI [0.426, 0.838], $\chi^2(1) = 21.56$, $p < .001$; Fisher's exact $p < .001$). For Latin Partial × Reading, the corresponding proportions were 71.4% (20/28) and 30.8% (8/26), respectively (difference = 0.407, 95% CI [0.163, 0.650], $\chi^2(1) = 8.93$, $p = .006$; Fisher's exact $p = .006$).

These results were robust to alternative analytic approaches (see Supplementary Materials S8). These proportions reinforce that markedly higher joint performance was achieved in the Intervention group.

4. Discussion

The present study evaluated the feasibility and impact of *Sayyadu-n-niqaat* ("The Dots Hunter"), a classroom-based visual-search training designed to strengthen visual attention span (VAS) and support early reading acquisition in vowelized Arabic. Three findings stand out. First, the intervention yielded a reliable advantage in reading accuracy at post-test relative to an untreated business-as-usual control group, and this effect remained robust after adjusting for baseline reading accuracy and key baseline covariates (nonverbal reasoning, phonological awareness, and, within the reduced subsample, baseline isolated-letter identification speed). Second, the intervention did not produce measurable benefits on reading speed over the same period, consistent with an accuracy-before-fluency trajectory at this stage of learning. Third, analyses targeting underlying cognitive processes in the subsample completing computerized measures converged on VAS, particularly Arabic partial report, as the most plausible cognitive pathway underlying reading gains, whereas improvements in single-letter identification (SLIT) did not differentiate trained and untrained children.

A visual-search training improved reading accuracy in beginning readers of Arabic

The primary outcome is clear: children who received the intervention achieved higher post-test reading accuracy than controls after adjustment for baseline accuracy and covariates. This result supports the idea that training visual attention through visual search tasks that require fine-grained processing of multi-feature targets among distractors can facilitate early reading development. Importantly, the effect persisted under conservative modeling choices tailored to the data structure (bounded proportions, heavy ceiling at post-test, and robust standard errors), and remained evident when additional baseline covariates were included in the reduced-sample analyses.

The selective effect on accuracy rather than speed is also theoretically coherent. At mid-second grade in vowelized Arabic, children are still consolidating orthographic representations and grapheme-level discrimination in a visually dense script. Gains may therefore first manifest as fewer identification/decoding errors, while changes in automatization and fluency may require (i) more time, (ii) greater training intensity, and/or (iii) training components that more directly engage time pressure or repeated fast-paced decoding. This pattern aligns with prior visual-search–based interventions reporting stronger effects on reading accuracy than on speed (e.g., Vialatte et al., 2023), and with the notion that early reading progress often follows an accuracy-to-fluency developmental sequence. It is also consistent with evidence linking visual search efficiency to reading (e.g., Rayner, 2009; Lallier et al., 2013; Franceschini et al., 2013) and with studies showing that interventions targeting letter recognition can support reading, particularly when training relies on perceptual analysis rather than motor components (e.g., Seyll et al., 2020; Seyll & Content, 2022).

Notably, the present effects emerged despite a relatively short dosage (approximately 6 hours, across 10 weeks). This is consistent with intervention evidence showing that training programs targeting visual and visuo-attentional mechanisms can yield reading-related benefits with modest total exposure (10 hours or less), both in typical development (Pasqualotto et al., 2022; Valdois et al., 2025) and in dyslexia (e.g., Franceschini et al., 2012; Vialatte et al., 2023; Zoubrinetzky et al., 2019). From an applied perspective, this dosage is compatible with real-world school constraints and strengthens the feasibility of the approach as a low-cost classroom supplement. This may contrast with the relatively longer durations typically reported for phonological-awareness trainings (e.g., Ehri et al., 2001).

What changed: evidence for a VAS pathway rather than faster single-letter identification

A central goal was to clarify whether reading improvements primarily reflected (a) enhanced parallel attentional processing (VAS), (b) faster single-letter perceptual identification, or (c) a combination of both. Two features of the design were intended to disentangle these possibilities: (i) VAS was measured with global and partial report, and (ii) potential single-letter bottlenecks were assessed via SLIT, in Arabic and Latin versions.

The results converge on VAS as the most sensitive locus of change. In the reduced subsample, the intervention produced its clearest gains on VAS Arabic – Partial Report, with a smaller but significant effect on VAS Arabic – Global Report, and only borderline or null effects for Latin tasks. This pattern is informative in three ways. First, it indicates that the training affects the cognitive processes captured by VAS tasks rather than reflecting only general test–retest improvements. Second, the stronger effects on partial than global report indicate that partial report is more sensitive than global report to training effects. Third, the fact that effects were most robust with Arabic stimuli is consistent with the script-specific hypothesis that training attention to diacritics and fine-feature contrasts is particularly relevant in Arabic, where many letters are distinguished by subtle dot configurations. Overall, effects were directionally similar for Arabic and Latin, but more marked for Arabic. This leaves open the possibility that the training has a combined effect on VAS and on processing of Arabic letter forms, and that improvements in visual processing of letters may be a key determinant of the observed benefits.

By contrast, the SLIT findings help bound a key alternative explanation. Although both groups improved from pre- to post-test on SLIT (Arabic and Latin), Time × Group interactions were not significant, indicating that trained children did not improve more than controls in isolated-letter identification speed. Moreover, in the reduced-sample reading model, the intervention advantage in post-test accuracy persisted after controlling for baseline SLIT–Arabic. Together, these results argue against faster single-letter identification as the primary driver of reading gains in this dataset, and instead favor multi-element attentional processes indexed by VAS.

This would be considered as an important contribution. While prior work established that visual search among distractors engages visual attention (e.g., Rayner, 2009) and relates to VAS (Lallier et al., 2013), and that visual-search ability is linked to reading development (e.g., Franceschini et al., 2013), the present results provide direct evidence that a visual-search training improves VAS, and that such improvement is associated with reading gains. In Vialatte et al. (2023), a visual-search intervention improved reading accuracy, but VAS and letter processing were not assessed. Here, our results are consistent with their hypothesis that this type of training strengthens VAS, and plausibly involves increased recruitment of the attentional networks supporting VAS (e.g., superior parietal regions). Future work combining behavioral measures and neuroimaging within such training paradigms would be needed to test this hypothesis directly.

Finally, the link between VAS improvement and reading improvement was supported by converging correlational evidence: gains in VAS Arabic – Partial Report were associated with gains in reading accuracy, including after controlling for nonverbal reasoning. The joint “high-performance” criterion further reinforced this association: at post-test, a much larger proportion of trained children simultaneously exceeded 80% on reading accuracy and VAS partial report (for both Arabic and Latin). While these associations do not establish causality on their own, they are consistent with intervention studies that report reading benefits when VAS is strengthened (Valdois et al., 2014, 2025; Zoubrinetzky et al., 2019; Zhao et al., 2019) and provide a coherent mechanistic account of the present training effects. These results are also consistent with evidence from computer-based visual-attention trainings (Franceschini et al., 2012; Pasqualotto et al., 2022) and more specifically VAS-targeted programs (Valdois et al., 2025). From an applied standpoint, it may be useful to further articulate the respective strengths of paper-and-pencil versus digital formats, particularly for younger children.

Positioning relative to prior visual-search and VAS intervention work

The present findings extend recent work embedding visual-search paradigms in literacy-related training. Vialatte et al. (2023) showed that daily brief visual-search practice targeting letter-like processing can improve reading accuracy in dyslexia, but VAS and letter processing were not directly assessed. Here, we provide complementary evidence in beginning readers, showing that a paper-and-pencil visual-search program can yield reading-accuracy benefits and is accompanied by measurable changes in VAS, especially for Arabic stimuli. This supports the proposal that visual-search training can operate, at least in part, by strengthening parallel attentional processing capacity (VAS) and/or its deployment, a mechanism previously suggested by links between visual search, attention, and reading (Franceschini et al., 2013; Lallier et al., 2013; Rayner, 2009). Overall, the pattern of findings suggests that training based on visual search for relatively complex targets (symbols or letters composed of multiple features) improves VAS, which in turn supports reading acquisition. This is in line with prior intervention work (Valdois et al., 2014, 2025; Zhao et al., 2019; Zoubrinetzky et al., 2019) and is consistent with a causal role of VAS in reading development.

Cross-linguistic implications: orthographic complexity and attentional constraints

The Arabic context also contributes to the broader cross-linguistic discussion on how orthographic features modulate the balance of cognitive constraints in reading development. Arabic is characterized by high visual density, extensive letter similarity, and the systematic use of diacritics, all of which increase perceptual and attentional demands during early literacy acquisition (Verhoeven & Perfetti, 2022). In such script, stabilizing letter representations and parsing letter strings may place greater demands on visual-attentional resources than in less visually confusable alphabetic systems.

In this respect, the present findings align with prior correlational evidence in Arabic showing that the effect of VAS on reading is indirect and mediated by letter recognition (Ghandour et al., 2025). Together, these results suggest that improving attentional allocation across multi-element arrays may support early reading in Arabic partly by facilitating the identification and integration of distinctive letter features – particularly diacritics – within a highly confusable orthographic environment.

More broadly, these findings are consistent with cross-linguistic frameworks emphasizing that while core cognitive components of reading are shared across writing systems, their relative functional weight may vary as a function of orthographic structure (Wydell, 2023). In visually complex scripts such as Arabic, attentional constraints may play a more prominent role in early reading acquisition, particularly at the level of letter processing, than in orthographies with lower visual similarity among symbols. From this perspective, Arabic provides a valuable testing ground for examining how visual-attentional mechanisms interact with orthographic properties to shape reading development.

Individual differences: phonological awareness as a potential gating factor

Exploratory stratification suggested heterogeneity as a function of baseline phonological awareness: the intervention advantage in reading accuracy was most reliable for children in the upper half of the phonological awareness distribution. This pattern is consistent with a "gating" interpretation in which improved visual attention can support reading growth more readily when phonological decoding constraints are not themselves dominant. VAS and phonological skills are often described as independent contributors to reading (e.g., Liu et al., 2023; Perry & Long, 2022), and when one component is weak, strengthening the other may be insufficient to produce short-term observable gains. This hypothesis is consistent with the idea that symptom-based and deficit-based interventions can be complementary (Frith, 1986): for children with low phonological awareness, coupling visuo-attentional training with explicit phonological/decoding support may be necessary to translate attentional gains into reading gains.

Given the exploratory nature of this analysis and the modest quartile sample sizes, this moderation pattern should be tested in larger samples with designs that allow formal interaction tests and sufficient power.

Limitations and future directions

Several limitations motivate cautious interpretation and point to clear next steps.

Design and baseline differences. The study relied on a quasi-experimental intact-classroom design. Although analyses adjusted for baseline performance and key covariates (and baseline adjustment improves precision and mitigates regression-to-the-mean; Vickers & Altman, 2001), groups differed at baseline on phonological awareness and (in the reduced subsample) on SLIT. Future work should use larger samples enabling tighter matching or randomization at the individual level, and should explicitly model clustering and class/teacher effects. In addition, the information provided to teachers and the absence of blinding may have introduced expectancy or engagement effects; future trials should specify procedures to minimize such bias and/or include designs that better balance teacher involvement across conditions.

Ceiling effects and sensitivity. Reading accuracy showed pronounced ceiling at post-test, and several letter-knowledge measures were at ceiling at baseline. While analytic choices were tailored to these constraints, future studies would benefit from more sensitive outcomes at this grade level, including more challenging reading material, broader difficulty ranges, and potentially item-response approaches.

Active control and expectancy effects. The control group followed business-as-usual instruction. An active control condition (e.g., an equally engaging training targeting a non-reading-related domain) would better control for non-specific effects of additional structured activity and teacher engagement.

Breadth of post-test measures and follow-up. Only targeted outcomes were re-administered at post-test. Reassessing phonological awareness would help confirm the specificity of effects on visual attention, as shown in other work (e.g., Valdois et al., 2025). In addition, the absence of a delayed follow-up limits conclusions about durability and about whether accuracy gains later translate into fluency gains; longer follow-up windows are needed.

Mechanistic scope. Although SLIT helps rule out a single-letter pathway as the dominant explanation, more fine-grained measures of feature-level processing (e.g., dot-specific discrimination tasks) and, ideally, combined behavioral and neurocognitive measures would help test the hypothesis that visual-search training increases recruitment of attentional networks (as suggested in VAS-related accounts) and clarifies how script-specific visual constraints shape learning trajectories.

Finally, applying the program to younger children in a prevention framework is an important perspective to explore, given the potential value of strengthening visuo-attentional mechanisms before reading difficulties consolidate. Moreover, the program appears well suited for children with developmental dyslexia who present a visual attention span deficit profile, for whom strengthening parallel visual processing may address a core constraint underlying reading difficulties and complement phonological interventions.

5. Conclusion

Overall, this pilot study provides converging evidence that a brief, classroom-implementable visual-search training focusing on Arabic diacritics can improve reading accuracy in early readers and is accompanied by measurable gains in visual attention span, particularly in Arabic partial report. The pattern of results – VAS gains without differential improvement in single-letter identification – supports the view that strengthening multi-element parallel attentional processing is a plausible pathway for improving reading in visually complex orthographies. These findings encourage larger controlled trials, including active controls and longer follow-up, to establish generalizability, durability, and optimal integration with phonological instruction in early Arabic literacy programs.

Declarations

Author Contribution

A.G.: Conceptualization, Methodology, Data curation, Formal analysis, Investigation, Writing – original draft. E.T.: Methodology, Data curation, Formal analysis, Investigation, Visualization, Writing – original draft.D.G.: Funding acquisition, Supervision, Project administration, Writing – review and editing.S.V.: Conceptualization, Methodology, Resources, Supervision, Validation, Writing – review and editing.

Data Availability

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

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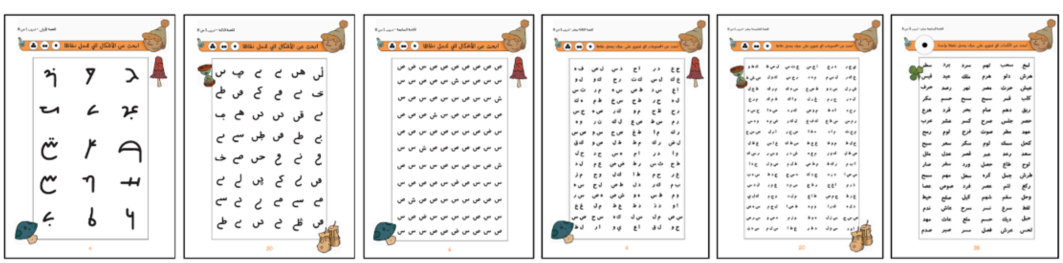
Figures

(A) Stimulus types across early training stages.
Left: Non-alphabetic shapes containing dot-like features used to train basic visual detection without activating orthographic knowledge.
Right: Pseudo-letters constructed from Arabic letter fragments, preserving visual characteristics of the script while minimizing lexical and phonological activation.

(B) Task layouts.
Left: Linear layout, in which stimuli are organized in rows to facilitate sequential scanning strategies.
Right: Random layout, in which stimuli are spatially scattered to increase visuo-attentional demands and reduce predictability of search.

(C) Task types targeting dot-based feature processing.
Examples illustrate the four types of visual search tasks included in each session (from left to right):
(1) Simple detection: identifying all stimuli containing at least one dot;
(2) Dot quantity: identifying stimuli based on a specified number of dots (e.g., one, two, or three);
(3) Dot position: identifying stimuli according to the spatial position of dots (e.g., above vs. below the letter body);
(4) Target letter search: identifying a specific target letter among visually similar distractors requiring fine-grained discrimination of graphic features.



(D) Progression of task difficulty and stimulus complexity.
Illustration of the gradual increase in difficulty across sessions and booklets, combining multiple parameters: increasing number of items per page, decreasing stimulus size, reduced target-to-distractor ratio, and increasing visual similarity between stimuli. This progression is accompanied by a staged transition from non-alphabetic shapes to pseudo-letters, isolated Arabic letters, and, in later stages of the full program, letter sequences and real Arabic words.

Figure 1

Overview of the “Sayyadu-n-niqaat” visual attention span training program and task progression

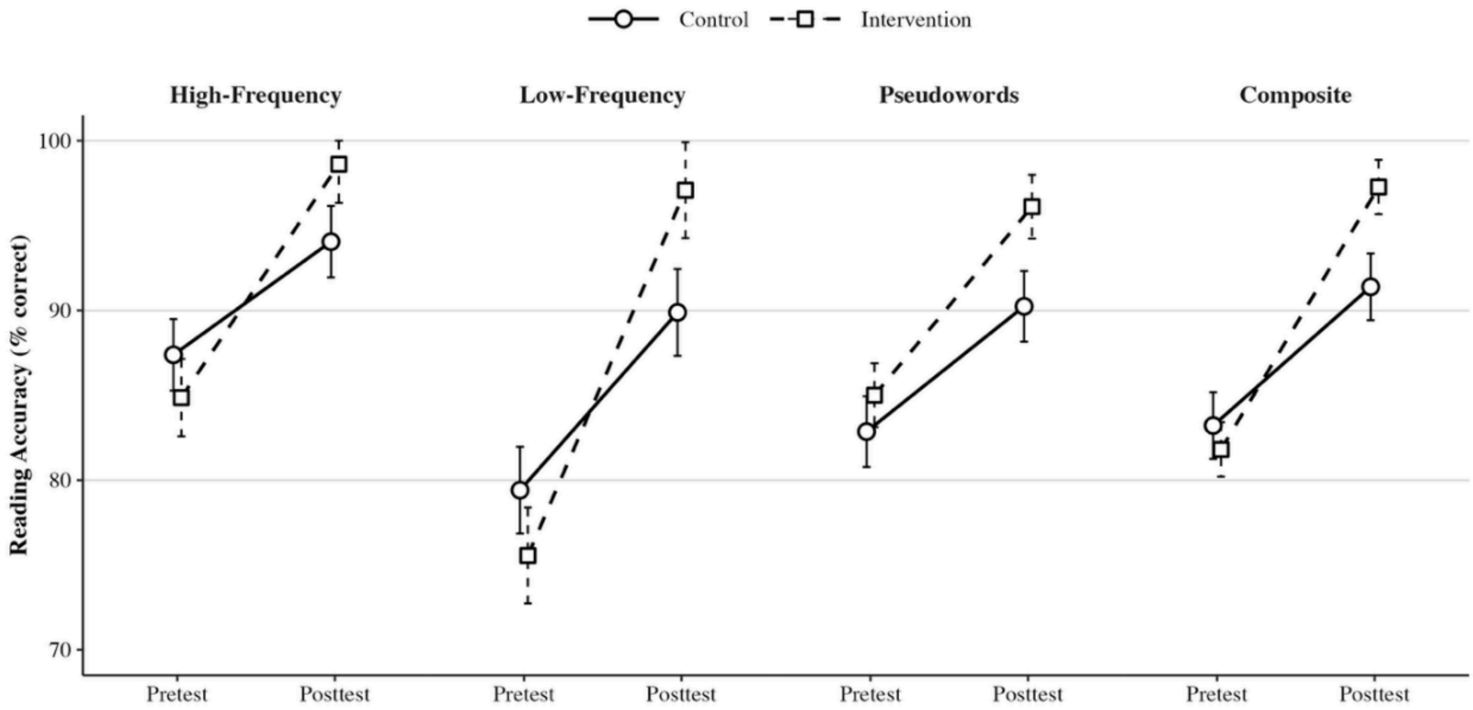


Figure 2

Change in reading accuracy from pre- to post-test in the intervention and control groups (N = 78), for the three reading measures and their composite score. Note. Error bars represent standard errors

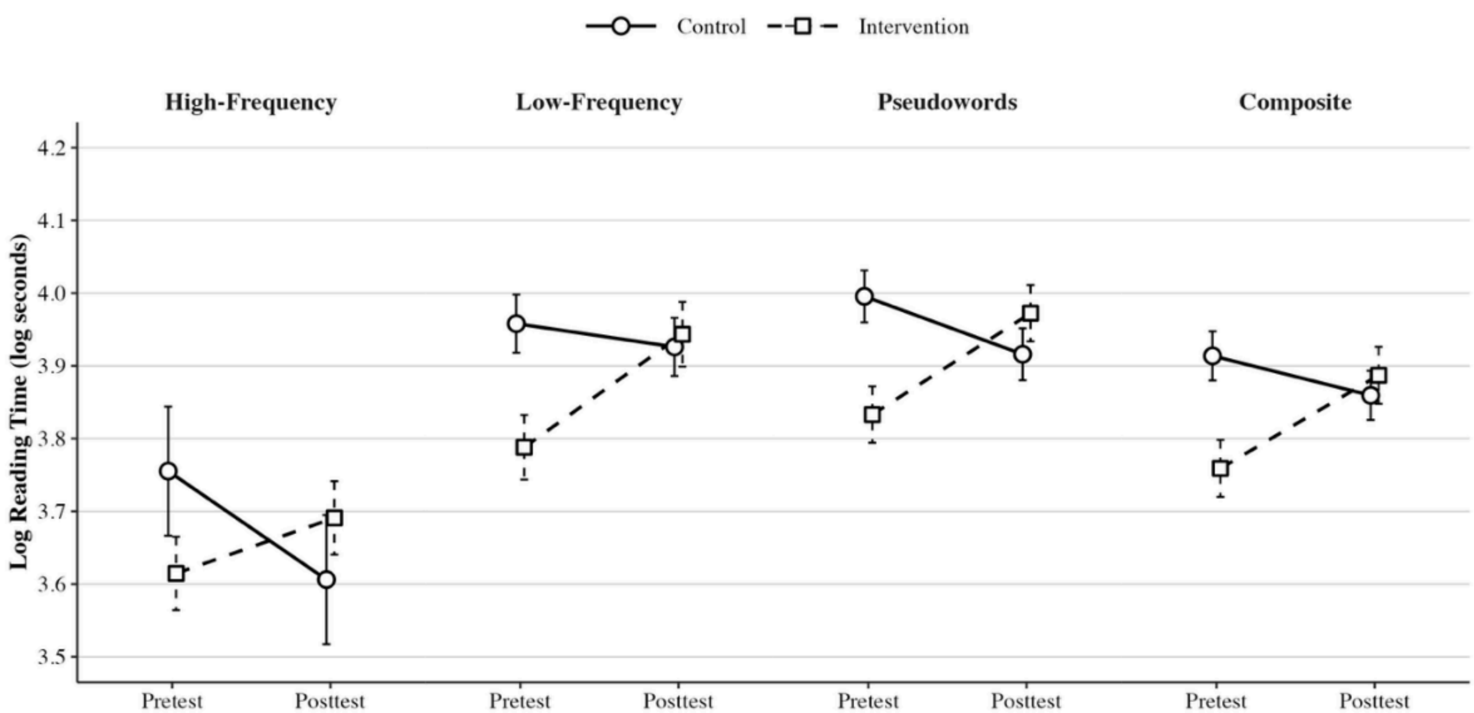


Figure 3

Pre-test-post-test evolution of reading times for the two groups, the three types of words and their composite measure. Note. Error bars represent standard errors

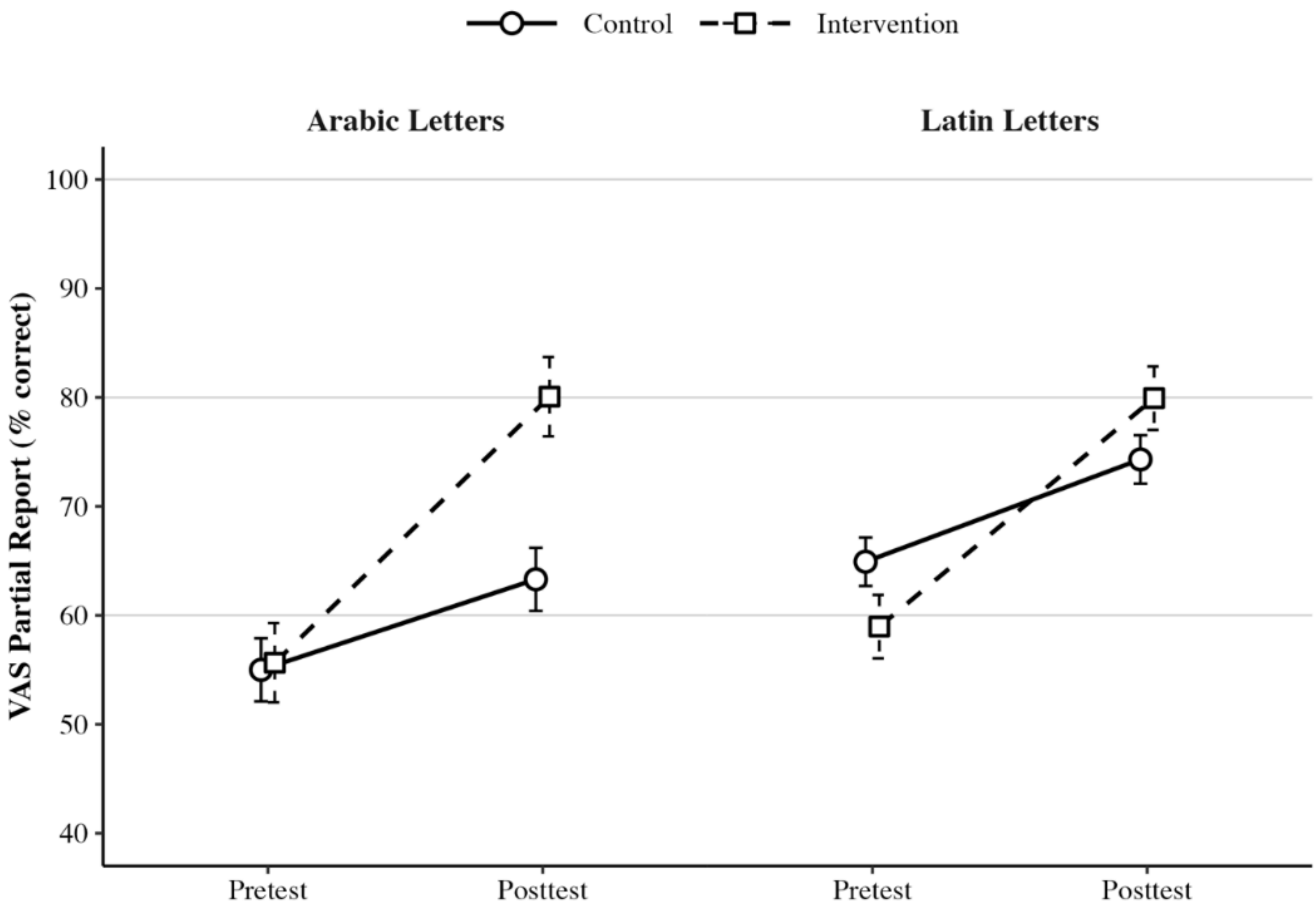


Figure 4

VAS (Partial report for Arabic and Latin letters) improvement from pre-test to post-test in the intervention and control groups. Note. Error bars represent standard errors

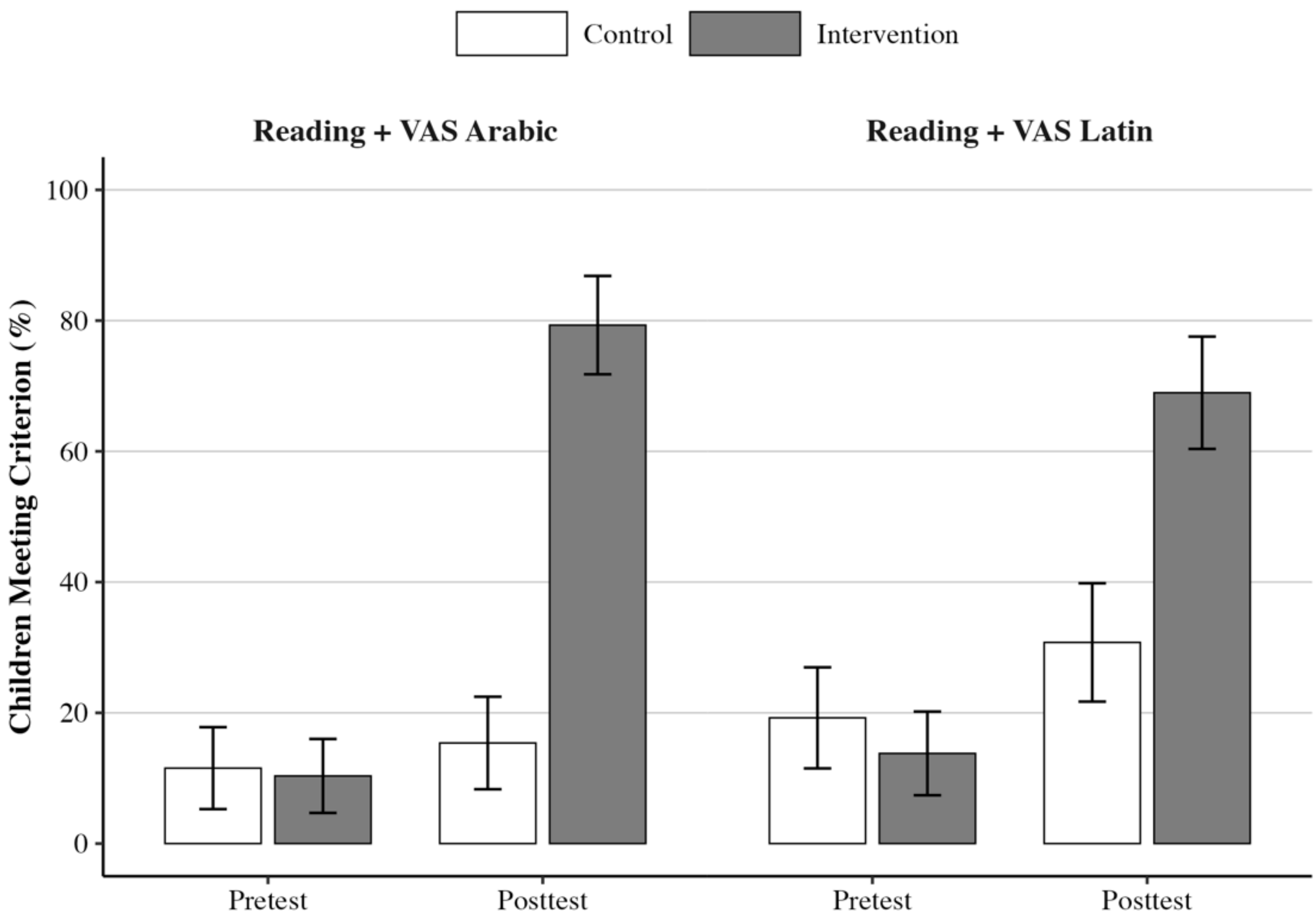


Figure 5

Variations in the proportion of children with simultaneous high performance (≥ 80%) in reading and VAS-partial tasks between pre-test and post-test. Note. Error bars represent standard errors

Supplementary Files

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