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Exploring the writing-reading connection among Arabic-speaking kindergarten children: the role of fine motor skills and orthographic knowledge

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Abstract

Although most studies in the field of literacy development suggest that writing and reading are two sides of the same coin, very little is known about writing in kindergarten in comparison to the vast number of studies on reading. In this study, we explored the connections between writing and reading using correlation and regression analyses conducted on data collected from 60 normally developing Arabic-Speaking kindergartners. Kindergartners' writing (handwriting and spelling), reading (reading accuracy and reading fluency), and orthographic and fine motor skills were measured. A large correlation was found between writing and reading measures. Separate stepwise regression analyses for writing and reading revealed that the alphabet and orthographic choice tasks were salient predictors of both skills and explained 46% and 57% of the variance in writing and reading, respectively. Surprisingly, the analysis indicated that fine motor skills did not contribute directly to writing or reading. These findings, discussed in relation to previous findings in the literature, confirm the connection between writing and reading and emphasize the role of orthographic knowledge in early writing and reading abilities, among Arabic-speaking kindergarten children.

Keywords Literacy · Reading · Writing · Fine motor skills · Orthography · Kindergarteners

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Introduction

Writing enables expression of knowledge and thoughts (Parush et al. 2010) and transmission of information across time and generations. Producing legible letters and conventional spellings is essential in the writing process and can predict the amount and quality of children's written ideas (Graham et al., 2000; Jones & Christensen, 1999).

Theoretical accounts of writing and reading acquisition suggest that various cognitive, linguistic, and motor factors contribute to the development of literacy skills (e.g., Coltheart et al., 2001; Mohamed & O'Brien, 2021; Pollo et al., 2008; Vellutino et al., 2007; Wolf, 2008). While phonological processing and cognitive skills are generally considered to be critical contributors to success in both writing (see, e.g., Caravolas et al., 2001; Michel et al., 2019) and reading (see, e.g., Ehri et al., 2001; Kirby et al., 2008), the contributions of fine motor and orthographic knowledge skills are less understood. Relatively few studies have examined the contribution of fine motor skills to writing and reading in Arabic, compared to orthographic knowledge that was much more investigated. Concurrently, knowledge that could have implications for developmental models of literacy acquisition and our understanding of the reciprocal relationship between writing and reading is also underexplored. Many researchers have emphasized the need for further research examining fine motor and orthographic skills and their involvement in early literacy acquisition (see, e.g., Caravolas et al., 2005; Conrad et. al, 2012; Dixon et al., 2002; Lehtonen & Bryant, 2005; Suggate et al., 2018). Moreover, a thorough understanding of the variables that affect writing and reading abilities in a specific language must consider the characteristics of the language's writing system (Share, 2008).

In recent years, there has been a considerable amount of research on the accuracy of writing (spelling) at an early age (Conrad et al., 2013; Mohamed et al., 2011). This study investigates the lower-level skill of writing, or as it is known in the educational field of handwriting and spelling. Specifically, this study assesses the relationship between writing and reading skills in Arabic.

Early writing development

Writing ability consists of attaining lower level skills such as handwriting and spelling (i.e., transcription skills), while also being able to utilize higher-level proficiencies such as creating, organizing, and elaborating ideas (The Simple View of Writing; Juel et al., 1986). Handwriting, as a complex skill, combines motor, cognitive and linguistic abilities (Graham & Miller, 1980) that are engaged between the intention to write and the actual execution of the writing movement (Van Galen, 1991). Handwriting is considered efficient when executed correctly, automatically, and fluently with a legible output (Christensen, 2005). Hence, measures of early handwriting abilities mainly include legibility and speed (Feder & Majnement, 2007).

Fine motor skills and early writing and reading

Early fine motor skills are commonly defined/assessed in terms of a child's ability to control and coordinate their hands and fingers in the manipulation of objects or tools, such as building a tower with blocks, writing, or copying with a writing utensil. Typically requiring close hand–eye coordination, fine motor skills are also referred to as visual-motor, perceptual-motor or psychomotor skills/integration (e.g., Cameron et al., 2015).

In studies firmly rooted in kindergarten and first grade, there has been evidence of positive correlations between fine motor skills and writing and reading skills (Pitchford et al., 2016).

Studies showing the unique contribution of fine motor skills in reading achievement have been replicated and extended to kindergarten (Grissmer, et al., 2010; Pagani, et al., 2010). These findings authenticate motor skills as a key element of school readiness. However, the results are mainly correlational, reporting significant concurrent relationships between motor and academic skills. Questions about how fine motor skills relate to key components of academic achievement during kindergarten still exist.

According to Suggate et al. (2018), there are two hypothesized pathways for the association between fine motor skills and reading. First, children with better manual dexterity might demonstrate better handwriting skills and thus, might easily copy letters, leading to an advantage in early reading development. Second, reading, and fine motor skills might share common underlying cognitive processes, such as executive functions (Cameron et al., 2016; Michel et al., 2013; Suggate et al., 2018). For children who can already decode, having greater graphomotor skills enables them to consolidate their reading skills by practicing their own handwriting (Wamain et al., 2012). Indeed, children who have greater fine motor skills, as measured by symbol copying tasks, perform better on literacy tasks (Cameron et al., 2012; Suggate et al., 2018). However, according to this account, fine motor skills only relate to reading to the extent that these result in the development of grapho-motor skills, followed by handwriting skills. This is because fine motor skills in and of themselves do not directly relate to and are not directly involved in reading. The association of manual dexterity with spelling might partly stem from the important role of precise coordinated hand movements for the acquisition of handwriting. Automatized handwriting frees cognitive resources that can be devoted to the spelling process (Doyen et al., 2017).

Orthographic knowledge and early writing and reading

Orthographic knowledge is one of the major contributors to word identification. Therefore, it is considered a candidate to explain additional writing and reading variance (Cutting & Denckla, 2001; Holland et al., 2004). Although the exact underlying mechanisms are not fully understood, authors generally agree that orthographic knowledge is acquired through repeated exposure to print (Barker

et al., 1992; Berninger, 1994; Fletcher-Flinn & Thompson, 2004). Orthographic knowledge refers to knowledge about legal letter patterns, including structural redundancies (i.e., possible letter combinations in different words), sequential dependencies (i.e., which letters are allowed to follow other letters), and letter position frequencies (i.e., in which position letter combinations occur frequently or rarely; Perfetti, 1984). Previous literature has proposed other views regarding orthographic knowledge. In one such view, orthographic knowledge is defined as the sensitivity to written letter patterns (Deacon, 2012) or to the orthographic structure of words (Georgiou et al., 2008). It is thought of as knowledge about regularities of visual and orthographic aspects of the written language (Roman et al., 2009).

However, there is a growing consensus that orthographic knowledge is multidimensional and consists of, both, word-specific and general orthographic knowledge (Conrad et al., 2013; Rothe et al., 2015). Ziegler and Goswami (2005) propose that reading in consistent orthographies involves small linguistic units, whereas reading in inconsistent orthographies require the use of larger units. Hence, the *grain size theory* seems to present an improved and modern alternative to the orthographic depth hypothesis (e.g., Frost et al., 1987), which historically emerged from classical dual-route models. The clear advantage of grain size over dual-route theory is that it examines the size of the computed phonological units, thereby allowing the use of a continuous measure rather than a dichotomous concept such as "lexical" or "prelexical" phonology (see also Frost, 1998, for a discussion on skilled reading and grain size, according to the strong phonological theory).

Intuitively, this two-level view seems plausible. If an individual has sufficient word-specific (lexical) orthographic knowledge to recognize or produce written words, fluent reading or writing can occur (e.g., Ehri, 2014). However, when confronted with a word without a lexical representation, the individual must use their general (sub-lexical) orthographic knowledge as part of the process of encoding (i.e., spelling) or decoding (i.e., reading) the word (e.g., Apel, 2011; Ehri, 2014). This two-level view is consistent with several theories of reading and writing development (e.g., Masterson & Apel, 2007; Share, 2004). Notably, all these different definitions consider orthographic knowledge as an understanding of the conventions of a writing system (Conrad et al., 2013).

The current literature examining orthographic knowledge is largely limited to studies conducted in English or other alphabetic European orthographies (Share, 2008). Studying literacy acquisition and processes in Arabic is argued to be important for research and theory because of the unique characteristics of the Arabic language and its orthography. Several studies have suggested that specific characteristics of Arabic orthography negatively affect the acquisition of reading and writing in this Semitic language (Mahfoudhi et al., 2011; Saiegh-Haddad, 2017; Saiegh-Haddad & Joshi, 2014). Furthermore, some authors have suggested that even among skilled readers, these characteristics might explain slower reading and writing in Arabic than in other languages (Abdelhadi et al., 2011; Asaad & Eviatar, 2013; Eviatar et al., 2004; Ibrahim & Aharon-Peretz, 2005).

Arabic orthographic characteristics

The Arabic Semitic writing system written from right to left includes 29 consonant letters (defined as an '*abjad*' system), of which three also serve as long vowels. Short vowels are represented by diacritical marks placed above or below the letters and represent an optional system (see Saiegh-Haddad & Henkin-Roitfarb, 2014). When presented with short vowels, which are considered as a source of visual density and complexity, orthography is considered shallow. This is because full phonological information is presented, and there is a good grapheme-phoneme correspondence (Abu-Rabia et al., 2003; Saiegh-Haddad & Henkin-Roitfarb, 2014). When presented without short vowels, Arabic script is considered a deep orthography, because part of the phonological information is missing, and many words become homographic. In this case, the reader must rely on linguistic cues and context to pronounce these words correctly (Abu-Rabia, 2001). Recent views have suggested that the restoration of the missing phonological information of unvowellised Arabic words is possible only because of the internal morphological structure of the words (Saiegh-Haddad, 2013; Saiegh-Haddad & Schiff, 2016). At the orthographic level, two additional elements add to the complexity of the Arabic writing system. The first relates to the visual similarity between letters. This is evidenced by the fact that the system comprises several dyads or triads of letters that have the same basic form but are differentiated by the presence or absence of dots, by their number and location (1–3 dots, inside or below the letter). For example in the letters <ب> and <ت> for the letters /B/ and /T/ and <ح> <خ> <ج> for /ħ/, /x/ and /dʒ/ (Asadi et al., Asadi, Ibrahim, et al., 2017). This visual similarity, together with other phonological similarities, increases orthographic ambiguity (Taha & Khateb, 2013). Another aspect of orthographic complexity in Arabic is that 22 letters connect to preceding and following letters (i.e., from the right and left) and six letters connect only to preceding ones in the words. When connected, written letters change their basic form based on their location: at the beginning, middle, or end (Khateb et al., 2013, 2014). Thus, these and other features are thought to pose serious challenges for children during the early stages of literacy development and might be at the origin of reading and spelling/writing difficulties (Abdelhadi et al., 2011; Asaad & Eviatar, 2013; Asadi et al., Asadi, Khateb, et al., 2017, Asadi, Ibrahim, et al., 2017; Khateb et al., 2014; Taha & Khateb, 2013).

This study aimed to investigate the relationship between early writing and reading in Arabic, and to examine the contribution of orthographic knowledge and fine motor skills towards writing (handwriting and spelling) and reading (accuracy and fluency) abilities among kindergarten children, while taking into consideration the orthographic characteristics of Arabic for developing scoring measures (see below).

This study addresses the following questions:

Q1 Is there a relationship between early writing and reading among Arabic-speaking kindergartners?

Q2 To what extent do fine motor skills and orthographic knowledge predict early writing and early reading in Arabic-speaking kindergartners?

The current study, due to small sample size, represents a first step towards a future larger study. The data collection for such an enterprise would only be justified if relevant relationships involving unique variance are first established in a regression-based research design. We hypothesized that fine motor skills (grapho-motor and manual dexterity) will significantly explain variance in writing, but not in reading. Orthographic knowledge will significantly explain variance in both writing and reading.

Material and methods

Participants

This study included 60 kindergarten children (girls = 25; boys = 35; $M_{\text{age in year}} = 6.1$; $SD = 0.3$) recruited from four Arabic-speaking Israeli kindergartens in the Western Galilee region. The selected kindergartens were chosen based on demographic information supplied by the district, which indicated that these schools represented high as well as low socioeconomic groups. Based on kindergarten records, children receiving special education services and children with obvious upper extremity impairments or visual deficits were excluded from the study. The study was conducted during the third trimester of kindergarten. After receiving approval from the Ministry of Education and the Ethics Committee of [blinded for review] for the study procedure, informed consent forms were sent to parents of participating children through kindergarten teachers.

Literacy instruction in Israeli kindergartens

In the Israeli education system, students start primary (elementary) school when they turn six years old. Younger children attend kindergartens. In Israeli kindergartens, children write their own names on their artwork and recognize their names printed at fixed sites, such as clothes hooks and personal lockers. Lists of letters, magnetic letters, printed words, and texts are displayed around the room. Children are frequently read from storybooks, view TV programs based on storybooks, and voluntarily browse books. Games aimed at promoting phonological awareness prevail, such as segmenting words into syllables, counting syllables, and rhyming. In addition, worksheets are commonly used for training visual discrimination (including letter discrimination) and letter copying. Invented spelling and graph phonemic awareness are encouraged in some kindergartens. Little time is devoted to alphabet recitation or letter naming. Formal instruction in reading and writing begins with entry to school at the age of six or seven years (Share & Lavin, 1999).

Material and procedure

All children participated in two testing sessions, 15 min each, conducted individually in a quiet place within the kindergarten. The testing sessions were conducted

on two consecutive days. In the first session, four tasks were administered to evaluate writing and reading: (i) copying letters to evaluate handwriting legibility and speed, (ii) writing to dictation to evaluate spelling, (iii) a word reading task, and (iv) an Arabic letter naming task to evaluate reading fluency. Writing was measured by copying letters, for legibility, and speed of handwriting and word spelling, to evaluate accuracy. In the second session, the same students completed, in the same order, different tasks that provided independent orthographic knowledge and fine motor coordination variables.

Measures

Word reading, spelling, and delayed copying measures were developed for this research based on a pilot study conducted on 25 kindergarten children, sampled from six kindergartens in the same district. The choice of items in the tasks was based on the instructions of the program of the Israeli Ministry of Education, which details the skills expected to be acquired in the third trimester of kindergarten and the criteria for their evaluation in Arabic. Items with a 50% success rate were selected. "Appendix" details the different measures used in this study.

Writing measures

This domain included two tasks, copying letters and spelling ability.

First, an Arabic letter form copying task was used to measure children' ability to copy the 29 Arabic letters from the models on the writing page. This measure was used to evaluate legibility and speed of handwriting. For legibility, the scoring was adapted to Arabic letters from a letter form copying test, the Scale of Children's Readiness in PrinTing (SCRIPT), which was developed for kindergarten children by Weil & Amundson (1994). The letters on the SCRIPT are scored as correct or incorrect according to the following criteria:

(1) The letter is quickly and easily recognized as itself, and no gross errors in proportion are present.
(2) The letter has no missing parts or dots and no extra parts.
(3) No lines extend beyond the intersection by more than two millimeters.
(4) Dots must not touch the letter, and have no more than the three-millimeter distance used for the letters (خ/x /, ج/dʒ /, غ/ɣ /,ف/f/, ق/k/, ض/ḍˤ /, ب/B/,ي/ i:,/ ظ/ðˤ /, ذ /ð /, ع/ʕ /ت, /t/, ن/n /, ث/θ /).
(5) Letter forms must be closed correctly, with no more than a two-millimeter gap, used for the letters (و/u:/ ظ / ðˤ / ق/q/ ف/f/ هـ/h/ ض/ ḍˤ / ط/ṭˤ / م/M/ ص /sˤ/).
(6) Curved lines must be curved, and straight lines must be able to fit within a two-millimeter space.
(7) Angles must be present, used for the letters خ /x/ ح /ħ /ج/ dʒ / ك/k/ د/d/ ذ/ ð /.
(8) There is no rotation of more than 45° in any part of the letter: no reversals are present.

Each letter must pass each criterion to be awarded one point. Failure on any one criterion results in a score of zero for that letter (Marr et al., 2001). The writing sample was judged by grading each letter individually and then calculating the overall score of correct letters for legibility (maximum score of 29). The speed of handwriting was determined in terms of the total time taken by the child to copy the letters.

Next, to assess the children's word spelling ability, they were asked to write a series of eight dictated words, with no time limit for dictation. The first three items were words consisting of two letters (كف/kaf/, دب/dob/). The remaining five items included more complex spelling conventions and consisted of three letters (شمس/ʃams/ فيل /fi:l/).:l/). To score the spelling of each dictated word, one point was given for each correct letter and one point for each correct ligaturing of two sequential letters. The maximum score that could be obtained for the eight words was 32. The reliability (Cronbach's α) for this task was 0.80.

The writing variable used in the analysis was derived from individual handwriting legibility and speed (i.e., copying letters) and spelling (word dictation) z-scores, computed because of the scale differences. The individual mean z-score was then computed as the writing variable, based on the factor analysis of the three measures.

Reading measures

As children in kindergarten do not have any formal reading instruction experience, we used two different tasks to capture letter and word decoding skills.

Children's *reading accuracy* was measured by reading a list of eight frequently used words consisting of two to four familiar letters. The selected words were separated (unconnected), partially connected, and fully connected. The words were presented at the center of a computer screen. The children were asked to read each word without time constraints. The accuracy score consisted of the number of accurately decoded words. The reliability of this task was Cronbach's $\alpha = 0.80$.

Regarding *letter naming,* the children were presented with 29 letters of the Arabic alphabet, each letter written on a white card using its basic unconnected form (ب، ج، ل). The cards (4×5 cm) were presented randomly by the examiner, and the child was asked to name each letter (font size 72). Testing started with a short training session that used the first three letters of the alphabet, which are considered the most familiar. A wrong answer or no answer on each of these three letters was corrected by providing the standard Arabic name. The children were asked to say the standard name of the letter that appeared on the card. We adapted the rules to allow letter-sounds as correct responses because in Arabic, children typically do not learn letter names early, but rather the sounds they represent. Accordingly, this measure can be considered as an early decoding measure. Time was measured and correct answers (each scored 1) of letter name/letter sounds were counted (maximum score = 29, Cronbach's $\alpha = 0.91$). The individual letter naming score and time to name the 29 letters served to compute the reading fluency measure as correct letters per minute. We then computed the mean z-score of the individual z-scores of *word reading* and *letter naming* tasks, based on the strong significant correlation between the two measures ($r = 0.76$, $p < 0.001$).

Orthographic knowledge measures

To measure orthographic knowledge, three tasks were used: the alphabet task, delayed copying, and orthographic choice.

For the *alphabet task,* students were instructed to write alphabet letters from memory, in their basic form and correct order, as quickly as possible, but legibly, so that others could recognize each letter. The individual final score was calculated as the number of correctly written letters (correct order and form) within 15 s.

Delayed copying measures a person's orthographic knowledge and children's visual-orthographic copying skills. For this purpose, children were asked to copy an unfamiliar word after they saw it on a computer screen briefly. This task requires rapid encoding and retrieval of visual patterns. Based on previous work (e.g., Pak, et al., 2005), there was one practice item and three experimental items in this task. Each item consisted of a ready-check screen, a fixation, a target, and a blank screen. In the ready-check screen, the experimenter asked participants if they were ready to start the trial. Once participants indicated that they were ready, the experimenter pressed a button and a fixation point appeared on the screen for one second. Immediately after fixation, a target word (font-size: 200) appeared on the screen for two seconds followed by a blank screen. The participants were asked to write the target word on a piece of paper. Scores were given according to copied letters and the letters' position. Bonus points were given if the first or last letter was correct. For example the item عصفور / ʕusfu:r/ will get 5 points for letters, 5 points for letters' position within the word and 2 points for writing the first and the last letter. The maximum possible score for each word was 12. The maximum possible score on the task was 36. The reliability of this test was Cronbach's $\alpha = 0.65$.

The *orthographic choice* test examined the children's ability to identify incorrect orthographic patterns (courtesy of I. Asadi, unpublished test). A list of 32 items was created. Each item included three patterns that were presented to the children along the line. The participants were asked to identify and mark the incorrect form *("the one that did not seem to be a real word")* among three distracters within three minutes. The incorrect forms included patterns with non-Arabic letters /ﻫﺸﺘﺎ/ and symbols that are not letters /ﻛ☺ﺭﺓ/ as well as those with illegibility in letters' combination and sequence /ﺣﺤﺪﺪﺪ/. The task was stopped after 3 min, and participants' score was based on the number of correctly marked incorrect forms, with a maximum possible score of 32. The reliability of the task was Cronbach's $\alpha = 0.73$.

Fine motor coordination tasks

Three tasks were used to assess fine motor coordination: making dots in circles, Beery-VMI and Functional Dexterity Test.

Making dots in circles is a subtest of dexterity in the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2, Bruininks & Bruininks, 2005). In this subtest, the child holds a pencil in their preferred hand and makes one dot in each circle presented, in any order, in 15 s. A circle is incorrectly dotted if it has no dots or more than one dot. Dash was counted as a single dot. Circles that have one dot or dash that are partially inside and partially outside are counted as correctly dotted.

Beery-VMI (Beery et al., 1997) is a standardized test that evaluates visual-motor integration skills. In this test, participants were asked to copy the first nine forms (score of 12) of geometric shapes with progressively increasing difficulty. The test was stopped when the child failed to correctly copy three consecutive shapes. The final score is the number of correctly copied shapes, including the three practice items.

Functional dexterity test (FDT: North Coast Medical, Gilroy, CA) measures manual dexterity (in hand manipulation) using a pegboard with 16 cylindrical pegs arranged in four rows of four pegs. A tripod pinch is used to turn over each peg and replace it in the pegboard in a standardized pattern. A height-adjusted table was used, and hand dominance was determined by asking the child to draw a circle with a pen placed in the center of the table. The hand that the child spontaneously used was considered the dominant hand. After the test instructions were provided, a practice trial was performed to minimize the learning effect. The second trial was performed using a stopwatch. If a peg was dropped, the time was stopped, and the peg was returned to its original position. Time was restarted once the child resumed turning pegs. The overall time of turning over all pegs was measured.

Statistical analysis

Before starting the analyses, the dataset was inspected for normality and homoscedasticity of residual distribution, including checking for outliers. Following the normality assumptions testing methods of Larson-Hall (2015), histograms and p-p plots were charted for each variable. All variables formed histograms with a normal distribution. Acceptable values of skewness fall between -1 and $+1$, and kurtosis is appropriate from a range of -1 to $+1$ (Brown, 2006) in all variables.

As already indicated, the writing variable score was calculated based on handwriting (legibility and speed) and spelling standardized score. The reading variable score was computed based on word reading and letter-naming standardized scores. Descriptive statistics (means and standard deviations) of the groups were computed for the different variables. Correlations were computed between the various variables and between the dependent variables (reading and writing) and independent variables. Two stepwise linear regression models were conducted separately to examine the contribution of orthographic knowledge and fine motor skills to writing and reading. Regression analysis is a reliable method of identifying which variables have impact on a topic of interest. The process of performing a regression allows us to confidently determine which factors matter most, which factors can be ignored, and how these factors influence each other. Stepwise regression is a method of fitting regression models in which the choice of predictive variables is carried out by an automatic procedure. In each step, a variable is considered for addition to or subtraction from the set of explanatory variables based on some pre-specified criterion. In the analysis reported hereafter, we entered all variables to the analysis to assess their contribution to writing and reading.

Table 1 Descriptive analysis

	Mean	SD	Range	Min–Max
Handwriting legibility	18.7	4.1	19	10–29
Handwriting speed	80	58.5	255	80–335
Handwriting fluency	6.2	2.6	10	2.7–12.7
Spelling	14.7	7.3	30	2–32
Word reading	2.5	2.7	8	0–8
Letter naming fluency	19.9	11.3	53.5	2.6–56
Alph. task	4.0	1.3	6	2–8
Orth. choice	25.9	3.6	16	16–32
Del. copying	17.3	5.5	27	6–33
Making Dot	19.0	4.0	18.5	11–30
Beery	9.2	1.2	5	7–12
FDT	37.6	4.7	18.4	29–47

Alph. Task, The Alphabet task. Orth. choice, Orthographic choice. Del. copying, delayed copying. Making Dot., making dots in circles, FDT, the functional dexterity task

Table 2 Factor analysis-Writing tasks

Measures	Factor I
Spelling	0.686
Handwriting speed	0.572
Handwriting legibility	0.300
Eigenvalue	1.99
% of variance	51.93

Results

Table 1 presents the descriptive statistics for all measures used in the study. To verify the extent to which the different writing variables were associated, a factor analysis was conducted using varimax rotation. As shown in Table 2, this analysis showed that all variables were loaded into one factor. This factor explained 51.9% of the variance, with an eigenvalue of 1.99.

Table 3 shows the correlations between all collected measures. The results showed significant correlations between almost all writing, reading, and orthographic measures. Interestingly, both spelling and word-reading accuracy were found to correlate significantly with the three orthographic knowledge measures. In addition, handwriting correlated with manual dexterity and the functional dexterity test, but not with the Beery test. The Beery test correlated neither with handwriting nor with other motor coordination measures. For the purpose of producing the combined writing and reading dependent variables, this analysis showed a relatively large correlation between handwriting and spelling ($r = 0.48$, $p < 0.001$) and a strong correlation between word reading and letter naming ($r = 0.80$, $p < 0.001$).

Table 3 Correlations between the different independent variables and writing and reading measures

	1	2	3	4	5	6	7	8	9	10
1. Handwriting	1									
2. Spelling	0.48**	1								
3. Word Reading	0.31*	0.70*	1							
4. Letter naming	0.51**	0.79**	0.80**	1						
5. Alph. task	0.56**	0.64**	0.48**	0.60**	1					
6. Ortho. choice	0.20	0.53**	0.41**	0.47**	0.21**	1				
7. Del. copying	0.50**	0.43**	0.37**	0.43**	0.48**	0.10	1			
8. Making Dot	0.34**	0.40**	0.34**	0.44**	0.40**	0.22	0.32*	1		
9. Beery	0.16	0.13	0.08	0.05	0.00	0.01	−0.02	0.04	1	
10. FDT	−0.30*	−0.19	−0.19	−0.20	−0.26*	−0.28*	−0.28**	−0.13	0.07	1

HW leg., handwriting legibility. HW sp., handwriting speed. WR Acc., word reading accuracy. LN flue., letter naming fluency. Making Dot., making dots in circles. FDT, the functional dexterity task. Alph. Task, The Alphabet task. Orth. Choice, Orthographic choice. Del. Copying, delayed copying. Handwriting legibility refers to copying letters legibility. That Speed refers to the number of legible letters per minute; that the score for Spelling refers to accuracy. *p < 0.05; **p < 0.01

Table 4 presents Pearson correlation coefficients computed to assess relationships between the dependent (writing and reading) and independent variables (orthographic knowledge and fine motor coordination). The results indicated a strong significant correlation between writing and reading. Writing and reading both showed moderate to large correlations with the three orthographic knowledge measures. Both variables indicated the highest correlation with the alphabetic task. Moderate correlations were mainly found with the manual dexterity task, with no correlation with the Beery task in both cases.

To examine the joint and unique predictive power of each of orthographic knowledge and fine motor skills measures for writing and reading, two separate stepwise

Table 4 Correlations between the different independent and dependents variables

	Writing	Reading
Writing	1	0.71**
Reading	0.71**	1
Alph. task	0.71**	0.57**
Orth. choice	0.43**	0.47**
Del. copying	0.54**	0.42**
Making Dot	0.43**	0.41**
Beery	–	–
FDT	−0.28*	–

Alph. Task, The Alphabet task. Orth. Choice, Orthographic choice. Del. Copying, delayed copying. Making Dot., making dots in circles. FDT, the functional dexterity task. That writing refers to the mean of the standardized score of handwriting and spelling. The reading refers to the sum of word reading speed and letter naming fluency. The dashes indicate no significant correlation. *p < 0.05; **p < 0.01

Table 5 Stepwise analysis for writing (combined measures of handwriting and spelling)

Predictors	Model 1			Model 2			Model 3		
	B	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SEB*	*β*
Alph. task	0.46	0.06	0.70***	0.42	0.06	0.63***	0.34	0.06	0.50***
Orth. choice				0.07	0.02	0.30***	0.71	0.20	0.29***
Del. Copying							0.04	0.01	0.27**
R^2		0.49			0.57			0.63	
F		56.23***			38.62***			32***	
Change in R^2		0.49***			0.08***			0.05***	

Alph. Task, The Alphabet task. Orth. Choice, Orthographic choice. Del. Copying, delayed copying *p < .05; ** p < .01; *** p < .001

Table 6 Stepwise analysis for reading (combined measures of word reading and letter naming)

Predictors	Model 1			Model 2		
	B	*SE B*	*β*	*B*	*SE B*	*β*
Alph. task	0.42	0.07	0.57***	0.36	0.07	0.50***
Orth. choice				0.09	0.02	0.36***
R^2		0.33			0.46	
F		29.10***			24.26***	
Change in R^2		0.33***			0.12***	

Alph. Task, The note: Alphabet task. Orth. Choice, Orthographic choice.*p < .05; ** p < .01; *** p < .001

regression analyses were conducted. The stepwise procedure determines the serial order in which the independent variables are included based on their orthogonal (independent) contributions to the variance in the dependent variable. As indicated in Table 4, the analysis yielded three significant models to explain writing, with the alphabet task being a robust predictor in all three models. The first model revealed that the alphabet task explained 49% of the variance. Model 2 added the orthographic choice and together explained 57% of the variance, thus increasing by 8%. Model 3 added delayed copying and explained 6% more variance to a total of 63% of the explained variance (Table 5).

Table 6 presents the stepwise regression analysis for reading. This analysis yielded two significant models. Model 1 indicated that the alphabet task explained 33% of the variance in reading. Model 2 added orthographic choice to the relation with reading and increased the explained variance from 33 to 46%, with a net increase of 13%. In both reading and writing, the alphabet task appeared to be the strongest predictor in early reading.

Discussion

The aim of this study was to assess the relationship between writing and reading among kindergarteners and to examine the extent to which orthographic knowledge and fine motor skills contribute to early writing and reading in Arabic. For this purpose, data was collected from 60 typically developing kindergarten children who completed writing (handwriting and spelling) and reading (word and letter naming) measures.

The results showed a strong correlation between the combined measures of writing and reading, but also between reading and spelling. This observation is consistent with findings from other studies conducted in various languages and orthographies, including English (Richgels, 1995), Chinese (Wang et al., 2015), and Arabic (Aram et al., 2013). This study, along with previous literature, indicates that children's ability to write letters and words accurately, and their knowledge of words' spelling, are interwoven with their ability to read because both build and rely on shared mental representation (Snow et al., 2005). Consistent with our findings, other studies also showed that correlations between word reading and writing, as in English for example, are rather high, ranging from 0.77 to 0.86 (Ehri, 2000). Such high correlations suggest that similar processes are measured in these tasks, even if different materials for writing and reading are used.

Recently, Molfese and colleagues (2006) expanded on Sulzby's earlier work by examining preschool children's skills in alphabetic knowledge, such as naming and writing. Using three different writing tasks, the authors studied name writing, letter writing from dictation, number writing from dictation, copied letters, and copied numbers. They found that letter naming was significantly related to letter handwriting. Significant correlations were also found between letters that were handwritten from dictation or copied. However, correlations between letter naming and handwriting the letter were stronger in the dictation condition, similar to the findings of the current study. Since dictation requires the writer to visualize the appropriate letter to write, the writer would have to know the name and its visual representation as opposed to being presented with a model to copy the letter. Consistent with the current study, Clark (2010) also demonstrated significant correlations between writing (e.g., letter writing) and reading scores. The alphabet writing test (accuracy score) correlated positively and significantly with letter-naming fluency ($r = 0.676$, $p < 0.01$). The ability to accurately write letters of the alphabet was significantly correlated to all four mid-year kindergarten reading measures. Highly significant positive correlations suggest that if students score poorly on the reading measures, they tend to score poorly on the writing measures.

As predicted, our results showed that orthographic knowledge measures contributed significantly towards writing (Asadi et al., Asadi, Khateb, et al., 2017, Asadi, Ibrahim, et al., 2017; Khoury-Metanis, et al., 2018) and reading. This supports previous observations on the Arabic language (Asadi et al., Asadi, Ibrahim, et al., 2017; Saiegh- Haddad & Taha, 2017; Taha, & Saiegh-Haddad, 2017). This observation confirms the importance of orthographic knowledge for acquisition

of writing and reading among Arabic-speaking children, as in many other languages, including English (Ehri, 2015), Persian (Rahbari et al., 2007), Chinese (Wang et. al., 2015), and Hebrew (Ravid & Schiff, 2006).

Our results indicated that the three orthographic knowledge tasks best contributed towards writing, with no contribution from fine motor skills. This finding is partially consistent with Abbot & Berninger (1993), who found no direct contribution of their fine motor factor to handwriting. However, it did contribute significantly as an indirect link through orthography and did improve the overall fit of the model. In the current study, only the direct impact of fine motor skills on reading and writing were measured, without considering the indirect effects of the cognitive skills. Which could be a limitation of this study. Other findings also support the present data, showing a relationship between orthographic knowledge and writing, indicating that letters and graphemes modulate the processes involved in the production of handwriting (Abbott & Berninger, 1993; Berninger & Rutberg, 1992; Khoury-Metanis et al., 2018).

The present study confirmed that individual differences in writing are uniquely related to proficiency in letter writing for beginners. These results suggest that automaticity in letter writing skills may offer young children more opportunities to focus on higher-order, meaning-making processes. Without automatic retrieval of letter forms, writing becomes slow and effortful, and the strategic thought processes required for writing are impeded. This finding clearly supports extant research on students at an early age (Kim et al., 2011; Puranik and AlOtaiba, 2012).

The second measure that contributes to writing is the orthographic choice measure. Orthographic knowledge includes the understanding of combinations and sequences of letters (Ehri, 2000), the regularity of these sequences (Treiman & Cassar, 1997) and the common orthographic rules and conventions in a specific language. Therefore, its contribution to writing is not surprising.

The third measure found to contribute to writing is the delayed copying task and visual orthography copying. This means that to write a character correctly, young children not only need to possess proper visual motor skills to integrate strokes into radicals and then into whole characters, but also need to know which radicals to use and how to place them legibly. All these skills were simultaneously tapped in the single task of visual-orthographic copying in our study. These results support the idea that copying practice might facilitate better spontaneous writing skills and provide a memory aid for the reproduction of correct forms of Arabic words. To some extent, visual-orthographic copying might best capture the visual-orthographic and motor skills involved in Arabic writing activity.

Contrary to our hypothesis, none of the fine motor skills directly contributed to writing. This finding does not mean that motor skills are not involved in writing. It rather calls attention to the fact that writing is more than just a motor act or merely penmanship. It is seen as *"Language by Hand,"* and an opportunity to develop an orthographic understanding of the writing system (Abbott & Berninger, 1993; Berninger et al., 1998; Graham & Weintraub, 1996). Nevertheless, there is increasing evidence indicating that fine motor skills are important for writing skills, particularly legibility (Daly et al., 2003; Feder & Majnemer, 2007). However, our study did not show any direct contribution of fine motor skills towards writing. We used an

analytic scale to evaluate the copied letters (through their general look) and the quality of the letter formation as correct or incorrect according to specific criteria. This evaluation was apparently unable to go beyond the analysis of the written product to provide substantive information about the writing process. The inability to evaluate the writing process per se constitutes a significant limitation of this analysis. Some authors believe that a comprehensive description of the real-time dynamics of a child's writing can provide insight into the motor control mechanisms of normal handwriting and of handwriting difficulties, especially for beginner writers, that the digitizer-based technology can provide (Graham & Weintraub, 1996; Longstaff & Heath, 1997; Rosenblum et al., 2001).

Another reason could also be attributed to the age of the participants and the difficulty of spelling words. At a young age, it is reasonable that the children may not have developed proper encoding skills needed for the spelling task. Additional skills that were not included in the model may also come into play, such as phonological awareness and cognitive skills. This relation, however, was found to be stronger in other scripts, such as in early Chinese writing (Wang et al., 2014) and English (Cameron et al., 2012).

The results of this study provide evidence that orthographic knowledge plays a significant role in early writing and reading. This finding is consistent with those of previous studies. In this regard, writing studies have reported that children who were defined as slow writers showed difficulties in rapidly accessing orthographic information rather than in writing execution speed (Sumner et al., 2013; 2014). This latter observation suggests that poor orthographic knowledge is a larger constraint than fine motor skills among children with writing difficulties. In the current study, the alphabet task demonstrated the highest contribution towards writing and explained 49% of the variance. This means that when a child knows what to write, they first have to retrieve the correct letters from memory and convert phonemes into graphemes before the corresponding motor program is initiated and executed (Berninger & Swanson, 1994; Graham & Weintraub, 1996; Van Galen, 1991). This knowledge, which enables children to represent letter forms correctly in memory and develop routines for their automatic retrieval from memory, has been shown to be important for both, handwriting and spelling (Abbott & Berninger, 1993).

Regression analysis also examined whether fine motor skills and orthographic knowledge explained variance in early reading. We found no evidence that fine motor skills are linked directly to word reading. Consistent with our findings, a previous correlational study conducted on 5–6-year-old kindergarteners found no evidence of a link between fine motor skills and word reading and letter naming (Suggate et al., 2018; Taylor, 1999). However, links were found to be significant in older (7 and 8-year old) children. Notably, only a small number of studies were conducted with children during the preschool period and examined early reading (i.e., Cameron et al., 2012, but to later reading also Grissmer et al., 2010; Pagani et al., 2010). Furthermore, because fine motor skills and reading were measured in different ways in each of the studies, it remains difficult to draw precise conclusions about these skills that might relate to each other.

As expected, orthographic knowledge contributed significantly to reading in Arabic. Previous evidence has emphasized the importance of orthographic knowledge

for reading in Arabic (Abu-Rabia et al., 2003; Badian, 2005; Ibrahim et al., 2002; Saiegh-Haddad, 2005) and in other languages (Bekebrede, et al., 2009; Cornad et al., 2013; Holland et al., 2004; Katzir et al., 2006; Ravid & Schiff, 2006; Share, 2008 Shatil & Share, 2003). As suggested by Conrad et al. (2013), orthographic knowledge may contribute to reading in two ways. First, storing orthographic representations in long-term memory through the linking of a word's spelling with its pronunciation and meaning (Ehri, 2005), which is thought to assist in identifying written words more automatically and accurately. These connections are also influenced and formed through the growing knowledge of combinations and sequences of letters, recurring orthographic patterns, regularities, consistencies in different words (Ehri, 2000; Treiman & Cassar, 1997) and the growing knowledge of the common orthographic rules and conventions in a specific language (Apel, 2011). By learning these recurring orthographic patterns, readers can use larger units to form connections to memorize specific words. Hence, orthographic knowledge may play an important role in the connection forming processes necessary to establish word-specific representations in memory (Conrad et al., 2013), thus, supporting basic reading (i.e., word level).

Conclusions, limitations and future directions

To summarize, the current study emphasizes the importance of orthographic knowledge in early writing and reading in pre-school Arabic-speaking children. The results showed that young Arabic children at the initial stage of literacy acquisition appear to make use of similar skills in learning to write and read. It is important to note that despite the lack of direct contribution of fine motor skills towards writing and reading in our study, the findings should not be misinterpreted. At this stage of their development, it is imperative that children practice and improve their fine motor skills to facilitate writing and reading development.

Although this was the first study, to our knowledge, that investigated the role of fine motor skills in early Arabic writing and reading, we cannot discount fine motor skills as an important readiness indicator for later school achievement. Findings from this study do not extend to later achievements because the sample was confined to kindergarten children, who are not systematically taught to write and read in Arabic.

Accordingly, it might prove fruitful to test whether fine motor skills predict readiness—children with greater fine motor skills at school entry develop reading and writing skills more rapidly in school. Previous studies have shown that graphomotor skills, as copying novel script and handwriting, are the most important precursors to early reading development. Hence, future studies should reconsider the definition of grapho-motor skills (as used in this study) that rely on pencil operation skills without cognitive knowledge of letters. Moreover, discrimination between fine motor skills and graphomotor skills is needed. Graphomotor skills might be related to early reading development. Children with greater grapho-motor skills might operate a pencil more easily and thereby experiment with letters and words. Thus, children who write more letters and words may develop stronger mental representations.

This might explain the strong contributions of the Alphabet task towards writing and reading in the current study, compared to fine motor skills.

The current study represents a first step towards a future larger study investigating writing and reading in Arabic, should be conducted with a larger sample size in order to perform analysis allowing assessing indict effects (such as executive functions, vocabulary knowledge, phonological awareness, etc.) that are known to contribute to writing and reading in early. Furthermore, future studies are needed to compare children with normal development and those with learning disabilities. A focus on the early years of formal education will help establish, for each skill, the critical point for early prevention and intervention. Moreover, it will also highlight skills important at a given stage.

Appendix

Study measures

	Measure	Variable
Writing	Copying letters	Legibility
		Speed
	Spelling	Accuracy
Reading	Word reading	Accuracy
	Letter naming	Fluency
Orthographic knowledge	The Alphabet task	Letter patterns retrieval
	Delayed copying	Visual orthographic copying
	Orthographic choice	Identifying incorrect orthographic patterns
Fine motor skills	The Beery	Graphomotor
	Dots in circles	Manual dexterity
	The functional dexterity test	In hand manipulation

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