Scientific Studies of Reading

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/hssr20

The Contributions of Letter Features to Arabic Letter Knowledge for Arabic-Speaking Kindergartners

Sana Tibi, Ashley A. Edwards, Young-Suk Grace Kim, Christopher Schatschneider & Sami Boudelaa

To cite this article: Sana Tibi, Ashley A. Edwards, Young-Suk Grace Kim, Christopher Schatschneider & Sami Boudelaa (2022) The Contributions of Letter Features to Arabic Letter Knowledge for Arabic-Speaking Kindergartners, Scientific Studies of Reading, 26:5, 357-372, DOI: 10.1080/10888438.2021.2016769

To link to this article: https://doi.org/10.1080/10888438.2021.2016769

Published online: 22 Jan 2022.

SCIENTIFIC STUDIES OF READING
2022, VOL. 26, NO. 5, 357–372
https://doi.org/10.1080/10888438.2021.2016769

The Contributions of Letter Features to Arabic Letter Knowledge for Arabic-Speaking Kindergartners

Sana Tibi [a], Ashley A. Edwards [b], Young-Suk Grace Kim [c], Christopher Schatschneider [b], and Sami Boudelaa [d]

[a]School of Communication Science and Disorders, Florida State University, Tallahassee, Florida, USA; [b]Department of Psychology, Florida State University, Tallahassee, Florida, USA; [c]School of Education, University of California, Irvine, California, USA; [d]Department of Cognitive Sciences, United Arab Emirates University, UAE

ABSTRACT

Studies have suggested that multiple features influence letter knowledge across different orthographies. Arabic offers a unique opportunity to investigate the relations of letter properties on letter knowledge, but research on Arabic letter knowledge is scarce. This study was designed to investigate (a) letter frequency, (b) letter sequence, (c) visual similarity, (d) developmental stage of the phonemes of the letters, and (e) diglossia as possible factors that contribute to Arabic letter knowledge. A total of 142 (Mean age = 67 months) native Arabic-speaking monolingual kindergartners were administered a letter knowledge task. Data were analyzed using Cross-Classified Generalized Random-Effects analysis, which allows partitioning of variance into that due to persons and due to letters to provide a more unbiased estimate of item-level variance. Results showed that letter frequency, late developing sounds, and diglossia were statistically significant when each was entered separately in a model whereas visual similarity and letter sequence were not. However, when all letter features were entered simultaneously, letter frequency was the only feature that contributed significantly to the prediction of Arabic letter knowledge. The present study underscores the important role of letter frequency in Arabic letter knowledge. Implications for assessment and instruction are discussed.

Letter knowledge is one's knowledge of the visual graphic forms, names, and sounds (Foulin, 2005). The role of letter knowledge in word-reading acquisition is well-recognized in theoretical models of word reading (e.g., Adams, 1990) and overall reading acquisition (e.g., Kim et al., 2020). There is longstanding evidence that letter knowledge in kindergarten is a code-related foundational skill (Adams, 1990; Blaiklock, 2004; Schatschneider et al., 2004; Storch & Whitehurst, 2002; Whitehurst & Lonigan, 1998). Consistently, letter knowledge has been shown to correlate with word reading skills (Burgess & Lonigan, 1998; Caravolas et al., 2001), and is recognized as a strong longitudinal prdictor of word reading (Hammill, 2004; Lonigan et al., & National Early Literacy Panel 2008). There is also evidence from intervention studies that shows training phonological awareness with letters is more effective than training phonological awareness alone (Byrne & Fielding-Barnsley, 1991; Tangel & Blachman, 1992). This is in line with evidence that letter knowledge predicts and facilitates phonemic sensitivity (Burgess, 2002; Caravolas & Bruck, 1993; Lonigan et al., 2000), that letter knowledge accounts for unique variance in phonemic awareness (McBride-Chang, 1999), and that phonological awareness adds to letter knowledge (Kim et al., 2010). In sum, letter knowledge is critical in the acquisition of word reading in different languages varying with their orthographic depth (Blaiklock, 2004; Georgiou et al., 2012; Hassunah et al., 2017; Kim, 2011; Levin et al., 2008; Treiman et al., 2007).

CONTACT Sana Tibi sana.tibi@cci.fsu.edu School of Communication Science and Disorders, Florida State University, 201 W. Bloxham Street, Tallahassee, FL 32306-1200, USA

Letter knowledge is influenced by several factors some of which has to do with child-level factors (e.g., phonological awareness, letter in child's forename, environment), whereas others have to do with letter features which is our primary interest in the current study. Letter features include visual similarity, phonological similarity, letter frequency in printed material, and letter sequence (Kim & Petscher, 2013; Kim et al. 2011; Treiman et al., 2007). Most recently, Kim et al. (2020) investigated three letter features (visual similarity, letter frequency and letter order) as they relate to children's letter-name knowledge across different orthographies (English, Hebrew, Korean, and Portuguese) among children (Age range = 4.90–5.80). The authors reported that letter frequency was the factor that was consistently related to letter knowledge across languages.

While there is a plethora of research investigating letter knowledge in multiple languages, research on letter knowledge in Arabic, a Semitic language that is different from the Latin-based languages, is limited to a few studies (Abu Ahmad & Share, 2021; Al-Hmouz, 2013; Aram et al., 2013; Hassunah et al., 2017; Levin et al., 2008). Arabic language has unique aspects. For example, Arabic is known for its diglossic nature (Saiegh-Haddad, 2003) which also extends to its letter names (standard and colloquial letter names, Levin et al. (2008); see below for details). Moreover, the phonological system of Arabic language includes the late developing phonemes (Amayreh, 2003) that are not fully mastered until middle childhood (e.g., 8 years old by some children), and this has an implication for acquiring the letters these late phonemes represent. Furthermore, more than two-thirds of Arabic letters can be grouped into pairs of highly visually similar letters (Levin et al., 2008). Therefore, Arabic offers an opportunity to examine whether these linguistic features play a role in children's letter knowledge, and adds to our understanding of language-general and language-specific features that contribute to letter knowledge. Although informative, previous studies on acquisition of letter knowledge in Arabic have not investigated whether and how letter features influence the accuracy of Arabic letter knowledge. In a recent study, Tibi et al. (2021) investigated the dimensionality (i.e., latent factors) of Arabic letter knowledge among native-Arabic speaking children using an item response theory framework. The authors reported that children's letter knowledge was multidimensional with some letters loading on one factor, while others loading on another factor. The authors speculated that these two groups of letters differed in difficulty; that is, one factor represented the more easily learned letters and the other the more difficult letters. However, they did not examine the characteristics of individual letters and so could not specify which letter features predicted the accuracy of children's Arabic letter knowledge.

Therefore, in this paper, we investigate the relations of multiple letter features to children's letter knowledge of Arabic. We investigate the letter features that have been examined in previous literature (e.g., letter frequency, letter sequence, and visual similarities), *and* additional features such as the developmental stage of speech sounds and diglossia. Note that letter knowledge is influenced by child factors (e.g., phonological awareness) and letter features (e.g., frequency in print materials), but in this study, we focus on the latter only.

Arabic language and orthography

Arabic is a Semitic language that is considered by the United Nations as one of the world's six official languages. Millions of people around the world speak Arabic (Gordon, 2005), and its orthography is also used in Indo-Iranian languages such as Persian and Urdu (Mirdehghan, 2010) and some traditional African languages (e.g., Hausa and Swahili). Detailed review of characteristics of Arabic language (Tibi & Kirby, 2018; Tibi et al., 2021) is beyond the scope of the present paper. Instead, we focus on the features that are specific to letter-name knowledge in Arabic. First, Arabic is characterized by its abjad orthography (consonantal alphabet) with three letters having dual functions acting as both consonants and long vowels (Saiegh-Haddad & Henkin-Roitfarb, 2014), and few short vowels that are not represented by letters, but by diacritics placed above or underneath the letters. Although morphology is beyond the scope of this study, we should note that the root, as a basic morphological unit,

from which almost all Arabic words are derived is represented exclusively by consonants, which adds an important value to Arabic letters (Boudelaa & Marslen-Wilson, 2001; Tibi, Tock, & Kirby, 2019). Also, three Arabic letters (w, b and l) carry a semantic meaning depending on the context. For example, the letter "w" functions as the conjunction "and," and the other two letters act as prepositions in certain contexts. Furthermore, Arabic letters can be grouped based on similarity in their basic shape (Abdelhadi et al., 2011; Asaad & Eviatar, 2013; Tibi et al., 2021). In fact, some visually similar letters can be distinguished by the presence or absence of dots, and the number and location of dots ranging from one to three dots, which are usually placed either above or underneath certain letters. These dots are not optional and they differentiate the name and sound of the letters (e.g., /s/ "س," and /ʃ/ "ش," or /z/ "ز," and /r/ "ر"). Levin et al. (2008) reported that the visually similar letters increased letter confusability among Arabic-speaking kindergartners from low socioeconomic status. Asaad and Eviatar (2013) also found that retrieval rates of letter names or sounds were slower for visually similar letters among first, second, and third grade Palestinian-Israeli children. Similarly, Dai et al., (2013) found that the dots slowed down reading, but did not affect the accuracy, and reported that children showed more spelling errors on items that included more dots. They concluded that letters distinguished by multi-dot diacritics posed a challenge for their third-grade participants. With an older group (grade 5) and from a different population where Arabic is the majority Perea et al. (2016, 2018) provided contrasting evidence where participants were able to quickly process the dots of Arabic letters and distinguish between words that varied only in one letter and concluded that dots are a core feature of the Arabic letters.

Another characteristic of Arabic language is diglossia (Ferguson, 1959) which refers to the difference between two forms of the same language (formal and informal). That is, the literary (or standard) form is the language of written materials and is learned formally at schools. In contrast, the informal form (colloquial) is used at home in daily conversations and in informal settings. There are many different variations of dialects even within the same Arabic country (for a detailed review on diglossia, see Maamouri, 2009, and Saiegh-Haddad & Henkin-Roitfarb, 2014). Diglossia manifests itself at multiple linguistic levels including letter names (Levin et al. 2008; see below the Letter Feature section). The diglossic nature of Arabic has been shown to influence reading accuracy, reading fluency, and phonological awareness (Saiegh-Haddad, 2003; Saiegh-Haddad & Haj, 2018; Saiegh-Haddad et al., 2020).

Letter features

The following is a review of the literature that addressed different letter features as predictors of letter knowledge. In addition, we added two more features in this study: one that relates to the developmental stage of the phonemes of the letters, and the other is diglossia.

Letter frequency

Exposure to letters in literacy materials has been one of the features that have been frequently investigated in the literature on letter knowledge, and is usually noted as letter frequency. However, the evidence on the contribution of letter frequency to letter knowledge is mixed. Some researchers found that letter frequency facilitated young children's letter knowledge (lower case letter naming: Huang & Invernizzi, 2012; letter names in Hebrew and English: Treiman et al., 2007; Letter sound knowledge in Hebrew: Treiman et al., 2012; Upper and lowercase letter naming: Turnbull et al., 2010), whereas as others did not find a role for letter frequency (English letter name and letter sound knowledge: Evans et al., 2006; Korean letter name and letter sound knowledge; Kim & Petscher, 2013). In fact, Phillips et al. (2012) noted that a mixed evidence exists on whether more frequent letters are more easily acquired than less frequent letters. Most recently, Kim et al. (2020) investigated letter name knowledge across four different orthographies (English, Hebrew, Korean, and Portuguese), and reported that letter frequency was consistently and uniquely related to letter accuracy, which lead the researchers to suggest that letter frequency is a language-general mechanism in letter learning regardless of languages, scripts, and environments.

Research on the role of letter frequency in Arabic-speaking children's letter knowledge is nonexistent. In fact, Arabic letter frequencies have just been availed by Boudelaa et al., (2020) based on a 40-million word corpus (Boudelaa & Marslen-Wilson, 2010), but it is not clear how these letter frequencies relate to children's letter knowledge. According to Boudelaa et al. (2020), four letters have the highest frequencies and these letters are: /l/ "ل," /w/ "و," /j/ "ي" and /t/ "ت") which overlaps with the frequencies that were based on a much smaller corpus of 147,527 words from children's textbooks (Belkhouche et al., 2010). It is of note that the letters with the lowest frequencies correspond to the late developing sounds (Amayreh, 2003; Amayreh & Hamdan, 2007) which will be discussed below. Interestingly, some of these late developing sounds represented by the lowest frequency letters have dialectal forms; i.e., sounds in dialects are different from formal Arabic (diglossic).

Letter sequence

Another feature of letters that has been considered in letter knowledge is the order of the letter in the alphabets; that is, whether the letter occurs at the beginning or later in the alphabets. The existing literature used the terms "sequence" or "order" to refer to where the letter occurs in the order of the alphabet. It has been noted that the letters that occur in the beginning of the alphabets (A, B, C) are usually the letters that children get introduced to first whether formally or informally (e.g., alphabet song and games) and therefore, are more accurately recognized than the letters that occur toward the end (e.g., Y) (English uppercase letter naming: Justice et al., 2006; English uppercase letter name and letter sound knowledge; McBride-Chang, 1999). However, some studies did not find a significant main effect for letter sequence after accounting for other factors such as phonological awareness (Kim & Petscher, 2013; Kim et al., 2020). Kim et al. (2020) explained that the possible reason for the lack of an independent contribution of letter sequence to letter knowledge in their study, unlike the others, could be attributed to the fact that other letter features were accounted for. Previous studies also investigated the role of letter sequence on letter knowledge from the perspective of adjacency which refers to the preceding, or following, of a specific letter (e.g., F and G). For example, Treiman and colleagues (Treiman et al., 2006; Treiman et al., 2007) found that adjacency of letters were a source of confusability in multiple orthographies (English, Hebrew, and Brazillian-Portuguese). With regard to Arabic, the effect of letter sequence was not examined per se. However, Levin et al. (2008) found a slight effect of letter adjacency, and the effect was greater when the adjacent letters were visually similar especially among the intervention group who was taught the letters according to their order in the alphabet. That is, if the adjacent letters were visually similar, this affected letter naming accuracy more so than if they were adjacent but not visually similar. While Tibi et al. (2021) did not test the specific letter features as noted previously, the authors reported that there was a variability among the teachers in terms of the sequence they followed when teaching Arabic letters. For example, some teachers followed the abjad sequence, whereas others preferred to teach the letters in groups based on their respective visual similarities.

Visual similarity

Visual similarity is another letter feature that has been investigated in several studies representing different languages and orthographies. This feature refers to the similarity between letters in terms of their graphic shapes, and has been shown as a source of difficulty as seen in the type of errors students make with visually similar letters. Although several studies reported on the effect of visual similarity on letter errors (Bowles et al., 2014; Evans et al., 2006; Treiman & Kessler, 2003; Treiman et al., 2006; Treiman et al., 2007, 2012), there is evidence from other research that did not find the same effect, particularly after controlling for other factors at the child factors and the letter features (e.g., Kim & Petscher, 2013). Arabic letters are characterized by a high degree of visual similarity between some letters. Specifically, 22 out of the 28 letters can be grouped in dyads or triads of visually similar letters that follow one another in a successive manner (e.g., د ذ or ب ت ث). Studies showed that naming visually similar Arabic letters was more confusing than visually dissimilar letters among their kindergarten

participants (mean age 5.5) who were children with low socioeconomic status (Levin et al., 2008). Visual similarity among Arabic letters was also tested in school age children (grades 1, 3, 5) and university students and results showed that visual similarity affected the speed of retrieving the names or the sounds these letters represented, and that this speed of retrieval decreased inversely with age (Asaad & Eviatar, 2013). As noted previously, some Arabic letters share the exact main shape, but differ only in the presence/absence and/or number of diacritic dots (e.g., ب ت ث or س ش), and this influences word reading and spelling for developing readers (Dai et al., 2013).

Developmental stage of the phonemes of the letters

To the best of our knowledge, this feature as it relates to letter knowledge was empirically investigated only in one study (Justice et al., 2006) who referred to it as the "consonant-order hypothesis." Justice et al. categorized English letters into six categories based on the age of the phoneme acquisition, and reported that letters corresponding to consonantal phonemes that are mastered earlier (e.g., /b/ and /m/) have an advantage over the ones mastered later; that is, children were 1.09 times more likely to know the letter associated with the early phoneme in the early category compared to the following category. Justice et al. explained that children's phonological skills influence their alphabet learning. We chose to include this feature in our investigation because letters represent phonemes, and letter names are basically comprised of phonological sequences (Foulin, 2005). Undoubtedly, letter name knowledge and phonological sensitivity are interrelated and both are crucial for later literacy skills (Ball & Blachman, 1991; Burgess, 2002; Muter & Diethelm, 2001; Wagner et al., 1997). Accordingly, it is relevant to address the issue of the normal development of speech sounds which, later on, children learn to use to represent the letters they are learning. After all, letters are visual representations or "graphic vehicles of phonemes" (Foulin, 2005, p. 144). In the context of Arabic language, it is particularly relevant to discuss speech sounds because all Arabic letter names, whether colloquial or standard, include the relevant sound of the letter (Levin et al., 2008). It is acknowledged that letters whose names provide cues to their initial sounds (e.g., B) are learned more rapidly than those whose sound cue is at the end of the letter name (e.g., F) or letters with names and sounds are not associated (e.g., W) (Piasta & Wagner, 2010a, 2010b; Treiman et al., 1997; Treiman et al., 1998). Furthermore, according to the developmental progression of speech sounds, Arabic phonemes are categorized according to three developmental stages: early sounds (<2;0–3;10 years), intermediate sounds (4;0–6;4 years) (Amayreh & Dyson, 1998), and late sounds – late sounds are difficult to produce in terms of articulation and begin to develop as late as 6.6 years old and are not mastered until 8;4 years (Amayreh, 2003; Amayreh & Hamdan, 2007). The late-developing sounds is pertinent to letter knowledge because children begin learning about letters formally at least two or 3 years prior to having fully developed the late sounds.

Diglossia

Of specific interest here is the quality of phonemic representations as it pertains to letter knowledge, because it is well established that reading in alphabetic languages begins with letter knowledge and mapping the letters onto their phonemes (Bowey, 2005; Snowling & Hulme, 2011). Thus, it is important to have robust phonemic representations when matching letters onto their corresponding phonemes. The standard names of Arabic letters, including the dual letters when they act as consonants, begin with the sound the letter represents, hence, are termed acrophonic. For example, the letters /fa:ʔ/, /ka:f/, and /mi:m/ begin with the phonemes /f/, /k/, and /m/, respectively. On the other hand, the colloquial names of Arabic letters start with a glottal stop followed by a vowel /ʔɛ/ and end with the sound of the letter (hence are termed iconic) as such: /ʔɛf/, /ʔɛk/, and /ʔɛm/, respectively. Levin et al. (2008) reported that their low socioeconomic kindergarten participants used the colloquial form to name some letters, but were able to shift to the standard form after the seven-month intervention. Recently, however, Abu Ahmad and Share (2021) stated that these colloquial names are in fact what they called "demi-phonemes" or "quasiphonemes" because they consistently begin with the same prefix syllable /ʔɛ/ and end with the consonant sound of the letter, yielding the

phonological structure /ʔɛC/. These colloquial names (demi-phonemes) are used to teach the sounds instead of the single phonemes, because of the difficulty in articulating the abstract consonantal sounds in isolation; hence adding the prefix /ʔɛ/ to aid with sound articulation (Abu Ahmad & Share, 2021). Abu Ahmad and Share (2021) reported that their preschool participants (mean age 5.06 years) retrieved the demi-phoneme /ʔɛC/ rather than the isolated phoneme. This was also reported by Al-Hmouz (2013) who noted that in Jordan, the Arabic letter sounds are taught by adding /ʔɛ/ before the consonant when the letter has no short vowel placed on top or underneath (e.g., the letter "b" sounds as /ʔɛb)/. Al-Hmouz also added that the letter sounds are taught as a CV structure by adding each of the three short vowels to the C (e.g., /ba/, /bu/, and /bi/). This CV phonological unit was also previously documented by Levin et al. (2006) and reported as the preferred way to produce letter sounds in Hebrew especially among their young participants (Mage =5.10) rather than the C phoneme alone (Treiman et al., 2012). Moreover, other studies of Arabic have reported that their participants had superior performance on letter names than letter sounds, attributing this to the teaching of standard letter names prior to their sounds (Abu Ahmad & Share, 2021; Al-Hmouz, 2013) and Hebrew (Levin et al., 2006).

Diglossia also manifests itself at the phonological level in that some sounds in formal Arabic have dialectal phonemic variants (Amayreh, 2003; Amayreh & Dyson, 1998). The four phonemes /ð/ ذ, /θ/ ث, /ðˤ/ ظ, and /q/ ق are almost always replaced by other phonemes in the Palestinian dialect. In addition, the three phonemes /sˤ/ ص,/dˤ/ ض, and /k/ ك are produced in formal and informal Arabic for some words, but may have phonemic variants in Arabic dialects in other words. A number of studies showed that diglossia interferes with the quality of phonological representations of the words that are different in their Arabic dialect from standard Arabic (Saiegh-Haddad & Haj, 2018; Saiegh-Haddad et al., 2020). Hamdan and Amayreh (2007) also noted that the consonant sounds that have dialectical forms in Jordanian Arabic are usually less accurate in spontaneous production. It is worth noting that all the diglossic phonemes are late developing sounds except for the phoneme /k/. Asaad and Eviatar (2013) found that children were slower at naming the letters that map onto sounds that are not represented in their dialect. Altogether, it is reasonable to consider diglossia as a feature that would play a role in Arabic letter naming.

The current study

The primary purpose of this study was to explore the letter features that contribute to performance on Arabic letter knowledge. Specifically, the study asked the following question: which of the following letter features (a) letter frequency, (b) letter sequence, (c) visual similarity, (d) developmental stage of the phonemes of the letters, and (e) diglossia, is related to Arabic-speaking children's letter name knowledge? To the best of our knowledge, no previous research on Arabic letter knowledge has investigated all these five features combined in a native group of Arabic-speaking children where Arabic is the dominant language. Moreover, no previous study has investigated Arabic letter knowledge using the Arabic letter frequencies developed recently by Boudelaa et al. (2020), and employed Cross-Classified Generalized Random effects as a method of analysis, because it allows for the simultaneous estimation of multiple letter features in addition to estimating the person variance. In other words, this analytic approach has the benefit of allowing person and item level variance to be estimated to provide a more unbiased estimate of item-level variance. We hypothesized, based on the research reviewed earlier, that each of the five letter features will predict performance on letter identification accuracy. We also hypothesized that diglossia and the developmental stage of the phoneme would have strong effects on letter knowledge due to a) the difference between the standard and colloquial forms, and b) children learn to read the standard letter names before they master the acquisition of the late-developing sounds that represent some of the letters, and c) all the diglossic sounds, except one /k/, are mastered two-three years after formal instruction of letter names begins.

Method

Participants

Data for the present study were taken from Tibi et al., 2021. Participants were recruited from six kindergartens in the city of Nablus. Kindergartens[1] were randomly selected from a list of Kindergartens provided by the Ministry of Education in Ramallah to represent different geographical locations, and various socioeconomic status (SES) levels. All children in the selected Kindergartens were invited to participate. Only the children with parental consent and child assent were tested; the consent rate was 87%. The participants were 142 Arabic-speaking kindergarten children (66 girls; Mean age = 67 months, SD =4.0 months). None of the participants showed signs of hearing, visual, language or cognitive impairment as confirmed by the first author and the principals. Testing took place in the spring term (March–May)-toward the end of the academic year. All participants were native Arabic-speaking children who spoke the Palestinian dialect, and formal Arabic is the mode of instruction at their kindergartens. Arabic is also the only language spoken in the children's homes and the majority language of the community.

Measures

Letter knowledge

The letter knowledge test was created as part of a battery of tests administered to the participants (see Tibi et al., 2021). Participants were assessed by showing a matrix of 50 letters in random order. All letters were presented on a matrix that included 5 rows with 10 letters in each row. Each letter was inside a cell in a Times New Roman font size 36. Twenty two letters, out of the total of 28 Arabic letters, were presented twice yielding a total of 44 letters. The remaining six letters were shown once each. However, only the first occurrence of a letter was included in this analysis. All letters appeared without vowels and in their isolated shape (not allographs or ligatured). Children were asked to identify all the letters as accurately as possible. There were three practice items to ensure children's understanding of the task. Children were encouraged to attempt all items with no termination rule. The participant's score was the number of items correct. Credit was given for each standard letter name produced correctly (e.g., /ba:ʔ/). It should be noted that the few children who produced the sounds /ba/, or the demi-phoneme /ʔɛb /, correctly were prompted to say the full standard name, and they did so successfully. Scores ranged from 2 to 28 with a mean of 21.46 (*SD* = 5.87).

All teachers and school principals of the participants noted that standard letter names are taught first followed by their sounds. The Ministry of Education requires the explicit teaching of all the standard letter names first followed by their sounds. Because of the difficulty in producing the consonant sounds in isolation, teachers are trained to teach sounds by placing the /ʔɛ/ syllable before the consonant yielding /ʔɛC/ (similar to that noted by Al-Hmouz, 2013,; Abu Ahmad & Share, 2021). In addition, teachers teach sounding out letters by adding short vowels (e.g., /a/, /u/, or /i/) to the consonant yielding the /CV/ syllabic structure (Al-Hmouz, 2013). The addition of the /a/ vowel was also reported by Share (2008) as the default vowel, and by other researchers (Levin et al., 2006; Taouk & Coltheart, 2004; Treiman et al., 2012).

The letters varied with regard to frequency, sequence, visual similarity, the developmental stage of the phonemes of the letters, and diglossia. We provide each of the letters and their features in Table 1.

Letter frequency

Letter frequency information was based on Boudelaa et al. (2020) recent work on Arabic letter frequencies. These frequency figures were calculated as percentages based on their 40-million word corpus of written texts as detailed in Boudelaa and Marslen-Wilson (2010). The letter frequencies ranged from .23 to 8.4 (*M* = 2.8, *SD* = 2.5).

Table 1. Letter features included in the analyses.

Letter	Proportion correct	Letter Frequency	Letter sequence	Visual similarity	Sound development	Diglossic
1 /j/ ي	0.94	7.12	28	Unique	I	No
2 /w/ و	0.98	8.36	27	Similar	E	No
3 /ʁ/ غ	0.77	0.57	19	Similar	I	No
4 /r/ ر	0.91	4.61	10	Similar	I	No
5 /h/ ه	0.44	0.74	26	Unique	I	No
6 /k/ ك	0.76	1.99	22	Unique	E	Yes
7 /s/ س	0.94	2.74	12	Similar	I	No
8 /ʤ/ ج	0.71	1.51	5	Similar	I	No
9 /q/ ق	0.68	2.14	21	Unique	L	Yes
10 /t/ ت	0.87	6.87	3	Similar	E	No
11/ðˤ/ ظ	0.29	0.23	17	Similar	L	Yes
12 /dˤ/ ض	0.48	0.7	15	Similar	L	Yes
13 /tˤ/ ط	0.46	1.1	16	Similar	L	No
14 /ʕ/ ع	0.80	2.5	18	Similar	L	No
15 /ʃ/ ش	0.87	1.11	13	Similar	I	No
16 /z/ ز	0.93	0.85	11	Similar	L	No
17 /l/ ل	0.91	8.4	23	Unique	E	No
18 /ħ/ ح	0.84	1.84	6	Similar	E	No
19 /ð/ ذ	0.48	0.37	9	Similar	L	Yes
21 /n/ ن	0.87	5.44	25	Unique	E	No
22 /f/ ف	0.87	2.82	20	Unique	E	No
23 /θ/ ث	0.52	0.43	4	Similar	L	Yes
24 /m/ م	0.93	5.77	24	Unique	E	No
25 /x/ خ	0.79	0.88	7	Similar	I	No
34 /ʔ/ أ	0.92	1.43	1	Unique	I	No
35 /b/ ب	0.95	4.17	2	Similar	E	No
36 /d/ د	0.85	2.57	8	Similar	E	No
37 /sˤ/ ص	0.57	1.06	14	Similar	L	Yes

Note. Numbers in the first column refer to the sequential position of the item on the measure with 50 items. Only these 28 first occurrences were included in the analysis. Sound development: E = early, I = intermediate, L = late

Letter sequence

Letter sequence was used to represent the position in which each letter occurs in the alphabet (see Table 1). Given that there are 28 letters in Arabic, the first letter "alif" "أ" which represents the sound /ʔ/ was represented by a 1 and the last letter "ي" which makes the sound /j/ was represented by a 28.

Visual similarity

Visual similarity was based on Boudelaa et al. (2020) who initially ran a similarity judgment experiment in which they asked participants to rate Arabic letter pairs on 1 to 7-point scale (with 1 being very dissimilar, and 7 very similar). Subsequently they converted their similarity ratings into a distance measure by linearly rescaling the similarity on the 1–7 scale into a distance ranging from 0 to 1 using the formula: D = (7-S)/6, where D is the Distance and S is the similarity score. For the purposes of the present study, we considered as unique any letter that was at least .95 away from one or more other letters in the overall distance space. This cut off procedure yielded 9 unique letters and 19 non-unique letters; that is, letters that had no distant neighbor at a distance of .95 or more. The proportion of letters correctly identified for visually similar letters was 0.74 whereas visually unique letters was 0.84.

Developmental stage of the phonemes of the letters

Each letter corresponded to a phoneme in one of three categories according to the categorization proposed by Amayreh (2003) and Amayreh and Dyson (1998): early (acquired before 4;0 years), intermediate (acquired between 4;0 and 6;0), or late-developing sounds (6;6–>8;4). This categorization yielded ten early sounds, nine intermediate, and another set of nine sounds as late sounds. Of note, Amayreh (2003) assessed these phoneme categories in standard Arabic. In the current study, letters

with early developing sounds were correctly identified 88% of the time whereas letters with intermediate developing sounds were correctly identified 81% of the time and letters with late-developing sounds only 59% of the time.

Diglossia

There was a total of seven letters categorized as diglossic in this analysis. Despite the fact that the majority of Arabic phonemes are shared between dialect and standard Arabic (Saiegh-Haddad & Haj, 2018), some letters have different phonemic representations in the dialect of the participants in the current sample. For example, the sound for the letter ق "q" could be produced as any of these four phonemes /q/, /k/, /g/, or /ʔ/. Another example is the letter (ك) "k" which could be said either as /k/ or /ʧ/ depending on the dialect of the speaker. Other letters that have different phonemic representations are /θ/ "ث," /ð/ "ذ," /ðˤ/ "ظ," /dˤ/ "ض," and /sˤ/ "ص" with the last two produced similarly in dialect and standard Arabic for some words but not others. For example, the phoneme /sˤ/ is produced as such in both dialect and standard for some words, but could be substituted by /z/ as in the word like /zʁi:r/ "small." Diglossic letters were correctly identified 56% of the time whereas non-diglossic letters were correctly identified 84% of the time.

Procedure

Testing was administered by the first author and three native Arabic-speaking psychology graduate students as part of a battery of tests. The experimenters spoke the same dialect as the children. The graduate students were trained and supervised by the first author. Each child was individually assessed. Testing took place in a quiet room suggested by the school principals. Administration of the letter knowledge task varied in time; on average this test took less than 2 min.

Results

In order to address the research question on the relation of the five letter features (letter frequency, letter sequence, and visual similarity, developmental stage of the phonemes of the letters, and diglossia) to children's knowledge of letters, we fit a series of cross-classified generalized random effects models. These models allow for the estimation of variance due to person as well as variance due to items (letters). A binary distribution with a logit link function was used to predict the probability of getting an item correct based on the item characteristics. First, an unconditional model was fit which estimates the variance due to children (SD = 1.97), the variance due to letters (SD = 1.70), and a grand mean (intercept) that provides the probability of getting a letter correct (in logits) [intercept = 2.29, z = 6.18, $p < .0001$].

Next, five models were run with each predictor entered separately (see Table 2). Continuous predictors (letter frequency and letter sequence) were grand mean centered to aid in interpretation. When entered as the only predictor, letter frequency was statistically significantly related to the probability of a correct response such that for a one unit increase in frequency, the odds of a correct response is 1.6 times more likely. Neither letter sequence nor visual similarity contributed significantly to the prediction of the probability of a correct response. When the developmental stage of the phonemes of the letters, which was dummy coded to represent early, intermediate, and late-developing sounds, was entered in the model, a statistically significant difference was found in the probability of a correct response between early and late-developing sounds such that the odds of a correct response on late developing sounds was 0.07 times as likely as early developing sounds. Said another way, the odds of a correct response on early developing sounds were over 13 times as likely than late-developing sounds. However, there was no significant difference between early and intermediate developing sounds. Furthermore, when letters were coded as diglossic (7 letters) versus non-diglossic (21 letters), and entered in the model, there was a statistically significant difference in the

Table 2. Results from the models where each of the letter features predicting letter knowledge.

Parameter	Logit	z value	p-value	Odds ratio
Intercept	2.29	7.78	<0.001*	9.87
Letter frequency	0.49	4.95	<0.001*	1.63
Intercept	2.29	6.18	<0.001*	9.87
Letter sequence	0.00	0.10	0.924	1.00
Intercept	2.67	4.49	<0.001*	14.44
Visually similar vs. not	−0.57	−0.83	0.409	0.56
Intercept	3.36	7.33	<0.001*	28.79
Intermediate vs. early developing sounds	−0.72	−1.18	0.237	0.49
Late vs. early developing sounds	−2.62	−4.31	<0.001*	0.07
Intercept	2.91	8.54	<0.001*	18.36
Diglossic vs. non-diglossic	−2.53	−4.37	<0.001*	0.08

* $p < .05$

probability of a correct response between diglossic and non-diglossic letters such that the odds of a correct response on diglossic letters were 0.08 times as likely than for non-diglossic letters. Said another way, non-diglossic letters were more than 12 times as likely to be identified correctly than diglossic letters.

Finally, all of the predictors were entered into a cross-classified generalized random-effects model simultaneously to predict the probability of a correct response so that each predictor's estimate is adjusted for the effects of the other predictors in the model. Results showed that only letter frequency was statistically significantly related to the prediction of the probability of a correct response, after accounting for the other letter features, visual similarity, letter sequence, developmental stage of the letters, and diglossic letters (see Table 3). After controlling for all other predictors, for a one unit increase in letter frequency the odds of correctly identifying a letter were 1.45 times as likely.

Discussion

The primary goal of the present study was to investigate the factors that contribute to Arabic-speaking children's letter knowledge. To achieve this, we examined the following five letter features: letter frequency, letter sequence, visual similarity, the developmental stage of speech sounds, and diglossia as possible factors that contribute to the probability of a correct response among native Arabic-speaking kindergartners. Results showed that when all factors were entered simultaneously, letter frequency was the only significant predictor of the probability of a correct response. This is in accordance with findings from different studies representing different languages (Kim & Petscher, 2013; Kim et al., 2020; Treiman et al., 2007, 2012). This study extends the cross-linguistic research on letter knowledge to Arabic with a different language and certain orthographic features from the already studied languages. The present findings confirm that letter frequency is an underlying principle in letter knowledge across languages and scripts.

Table 3. Results from the simultaneous prediction model of letter knowledge.

Parameter	Logit	z value	p-value	Odds ratio
Intercept	2.82	5.31	<0.001*	16.78
Letter frequency	0.39	3.45	<0.001*	1.48
Letter sequence	−0.05	−1.46	0.146	0.95
Visually similar vs unique	−0.13	−0.23	0.819	0.88
Intermediate vs early developing sounds	0.04	0.08	0.940	1.04
Late vs early developing sounds	−0.54	−0.78	0.434	0.58
Diglossic vs non-diglossic	−1.17	−1.89	0.058	0.31

* $p < .05$

We found that letter sequence and visual similarity were not related to performance on letter knowledge even when they were entered alone without the other letter features. Our results seem to contradict findings from other research (Asaad & Eviatar, 2013, 2014; Eviatar et al., 2004; Justice et al., 2006; Levin et al., 2008; McBride-Chang, 1999). This may be attributed to the fact that we assessed only letters in isolation which children at this age are familiar with and recognize with more accuracy compared to the visually similar allograph stimuli as was done in the studies by Asaad and Eviatar (2013, 2014). Also, our task was not timed nor was limited to five letters only in each speeded letter naming test as the case in other studies (Asaad & Eviatar, 2013, 2014; Eviatar et al., 2004). Furthermore, letter knowledge was measured differently in previous studies (e.g., confusion between pairs of letters in Treiman et al., 2006, pressing a key when pairs were identical among bilingual adults in Eviatar et al., 2004). Altogether, methodological differences make it difficult to draw conclusions across studies that employed different methodologies and designs.

A unique aspect of the present study was an investigation of developmental stage of the phoneme acquisition. When the stages of phoneme acquisition (early, intermediate, and late) were entered as the only predictors, there was a significant difference in the probability of a correct response between early and late-developing sounds with the early sounds being easier. However, there was no difference between early and intermediate sounds. This aligns with earlier findings on the acquisition and mastery of Arabic speech sounds as noted previously by Amayreh and colleagues (Amayreh, 2003; Amayreh & Dyson, 1998; Hamdan & Amayreh, 2007). In fact, Amayreh (2003) noted that all late sounds are commonly replaced by the more frequent sounds or dialectal variants of these late developing and lower frequency sounds. Our findings are also in accordance with Justice et al. (2006) "consonant-order hypothesis" who found that the letters that correspond to early developing phonemes are acquired earlier than those that correspond with late-developing phonemes. It is also worth noting that the letters representing the late-developing sounds also happen to have very low frequencies (Boudelaa et al., 2020), which may explain why this difference is no longer significant when accounting for letter frequency.

As noted above, an important feature of Arabic is diglossia, and the present study revealed its role in letter name acquisition. When diglossia was entered independently, it had a negative effect on children's letter knowledge. This is in line with previous literature on the impact of diglossia on phoneme isolation, letter knowledge, and word reading (Levin et al., 2008; Saiegh-Haddad, 2003). However, when diglossia was entered with the other letter features, it did not add a unique contribution to letter knowledge that seems to contradict the existing literature. Recall that all diglossic phonemes, except /k/, are also late-developing sounds and have low frequencies that indicates that it is not diglossia alone that affects letter accuracy. Another possible explanation for diglossia not contributing uniquely over and above other predictors is the participants' level of Arabic in the present study is the fact that standard letter names are the "preferred response" (p. 1) similar to what was reported by Abu Ahmad and Share (2021). Furthermore, the participants in the current study appear to be stronger than those in previous studies (Abu Ahmad & Share, 2021; Hassunah et al., 2017; Levin et al., 2008). Differences in letter knowledge may also be attributed to instructional practices. For example, in the current study, children are taught explicitly code-related skills with an emphasis on standard Arabic in all literacy materials. When Levin et al. (2008) intervention study was conducted, literacy instruction among their kindergarten population did not include emergent literacy skills. It is also important to note that the participants in Levin et al.'s study and Abu Ahmad and Share's study (2021) came from a middle to low SES background, whereas in our study the participants represented diverse SES as determined by parental education and employment. Future research that includes SES as a child-level factor in Arabic letter knowledge is warranted. Another possible explanation is that none of the previous studies on Arabic letters had investigated directly the effect of the different letter features, including letter frequency, on letter knowledge, nor used the method we used here by including all letter features simultaneously in one model. Therefore, replicating the current investigation with different Arabic-speaking populations, including all letter features, and with a younger age group (preschoolers) may shed light on divergence of the findings.

In summary, letter frequency, the late-developing phonemes, and diglossia were related to Arabic letter knowledge. However, when these features were included simultaneously, it was letter frequency alone that remained related to letter knowledge in Arabic.

Limitations and future directions

Although the present study provides new evidence on Arabic letter knowledge, some limitations need to be noted. For example, future research should include a larger sample size, draw samples from populations that speak different varieties of Arabic dialects, and include child-level factors such as phonological awareness, SES, and age. The age of our participants (M = 5.5), for example, may have affected performance on the letters that correspond to late-developing sounds. Future work may also compare the effect of letter knowledge as a function of the order taught by teachers (serial order vs. other methods such as grouping letters) particularly there seems to be no agreement about the preferred sequence of teaching letters. Furthermore, future research on Arabic letter knowledge may consider examining letter names separate from letter sounds and look into how the trajectories of these two aspects differ, or not. Another letter feature to be examined in future studies is the degree of allographic changes for each letter. Last, but not least, future research on Arabic letter knowledge can examine letters included in the child's name as a predictor of letter knowledge similar to what has been done in other studies (Justice et al., 2006; Treiman et al., 2006, Treiman et al., 2007, 2012).

Implications

Several instructional implications arise from the finding about later developing phonemes in Arabic. First, it is paramount to include the lower frequency letters in any Arabic letter screening tools. If screening tools focus only on the high-frequency letters, results might be misleading. Early screening and assessment should inform better instructional practices and early intervention. An assessment that is based on research evidence would provide teachers with a clearer picture as to differentiating instruction according to children's individual needs. Second, these results suggest that the letters that correspond to the late-developing sounds deserve more time for a deliberate and explicit teaching for an increased exposure to these letters and their corresponding sounds. Furthermore, formal and informal letter teaching of preschoolers, and younger children, should begin with the letters associated with early followed by intermediate phonemes because the early sounds have already been mastered by the age of five, if not earlier for some. The results also imply that teaching reading with words that contain the easy letters that have higher frequencies and early developed sounds are likely to facilitate development of word reading skill.

Conclusion

In conclusion, the current study contributes to our understanding of the letter features that may influence letter knowledge in Arabic, and found that letter frequency uniquely was related to letter knowledge, further supporting that letter frequency is a language-general mechanism as reported by Kim et al.'s cross-linguistic study on letter knowledge (2020). The present study also found that the late-developing sounds and diglossia each played a role in Arabic letter name knowledge when entered separately which underscores the importance of explicit and repeated instruction for those letters that have corresponding phonemes that are late-developing and diglossic.

Note

1. Some of the kindergartens in that region are housed within schools and share the same school principal.

Acknowledgments

- The Institution Review Board (IRB) at the Human Subjects Research Office at Florida State University approved this research on Oct. 10 2019 under the exempt category 1 (Approval) which conforms to the US Federal Policy recognized Standards.
-All children gave their assent prior to their inclusion in the study, and all parents gave their informed consent.
-No conflict of interest for any of the authors.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was funded by the Council on Research and Creativity (CRC) at Florida State University through The Committee on Faculty Research Support (COFRS) program award number 041761.

ORCID

Sana Tibi http://orcid.org/0000-0003-2121-5353
Ashley A. Edwards http://orcid.org/0000-0002-5268-4235
Young-Suk Grace Kim http://orcid.org/0000-0002-4328-3843
Christopher Schatschneider http://orcid.org/0000-0002-1700-7685
Sami Boudelaa http://orcid.org/0000-0002-1870-7202

References

Abdelhadi, S., Ibrahim, R., & Eviatar, Z. (2011). Perceptual load in the reading of Arabic: Effects of orthographic visual complexity on detection. *Writing Systems Research*, *3*(2), 117–127. doi:10.1093/wsr/wsr014

Abu Ahmad, H., & Share, D. (2021). Foundations of early literacy among Arabic-speaking pre-school children. *Applied Psycholinguistics*, *42*(5), 1195–1220. doi:10.1017/S0142716421000242

Adams, M. (1990). *Beginning to read: Thinking and learning about print*. Cambridge, MA: MIT Press.

Al-Hmouz, H. (2013). The relationship between letter fluency measures and Arabic GPA (Grade Point Average). *International Journal of Special Education*, *28*(3), 140–149.

Amayreh, M. M., & Dyson, A. (1998). The acquisition of Arabic consonants. *Journal of Speech, Language, and Hearing Research*, *41*(3), 642–653. doi:10.1044/jslhr.4103.642

Amayreh, M. M. (2003). Completion of the consonant inventory of Arabic. *Journal of Speech, Language, and Hearing Research*, *46*(3), 517–529. doi:10.1044/1092-4388(2003/042)

Aram, D., Korat, O., & Hassunah-Arafat, S. (2013). The contribution of early home literacy activities to first grade reading and writing achievements in Arabic. *Reading and Writing: An Interdisciplinary Journal*, *26*(9), 1517–1536. doi:10.1007/s11145-013-9430-y

Asaad, H., & Eviatar, Z. (2013). The effects of orthographic complexity and diglossia on letter naming in Arabic: Developmental changes. *Writing Systems Research*, *5*(2), 156–168. doi:10.1080/17586801.2013.862163

Asaad, H., & Eviatar, Z. (2014). Learning to read in Arabic: The long and winding road. *Reading and Writing: An Interdisciplinary Journal*, *27*(4), 649–664. doi:10.1007/s11145-013-9469-9

Ball, E. W., & Blachman, B. A. (1991). Ball and Blachman reply to Catterson. *Reading Research Quarterly*, *26*(4), 486. doi:10.2307/747900

Belkhouche, B., Harmain, M., Al Najjar, L., Taha, H., & Tibi, S. (2010). Analysis of primary school Arabic language textbooks. Paper presented at the 10th Arab conference on information technology, Benghazi, Libya. Retrieved from http://acit2k.org/ACIT/index.php/proceedings/acit-2010-proceedings

Blaiklock, K. (2004). The importance of letter knowledge in the relationship between phonological awareness and reading. *Journal of Research in Reading*, *27*(1), 36–57. doi:10.1111/j.1467-9817.2004.00213.x

Boudelaa, S., & Marslen-Wilson, W. D. (2001). Morphological units in the Arabic mental lexicon. *Cognition*, *81*, 65–92. https://doi.org/10.1016/S0010-0277(01)00119-6.

Boudelaa, S., & Marslen-Wilson, W. D. (2010). ARALEX: A lexical database for modern standard Arabic Behavior. *Research Methods*, *42*, 481–487. doi:10.3758/BRM.42.2.481.

Boudelaa, S., Perea, M., & Carreiras, M. (2020). Matrices of the frequency and similarity of Arabic letters and allographs. *Behavior Research Method*, *52*(5), 1893–1905. doi:10.3758/s13428-020-01353-z

Bowey, J. A. (2005). Predicting individual differences in learning to read. In J. Margaret (Ed.), *The science of reading: A handbook* (155–172 pp.). Oxford, UK: Blackwell. doi:10.1002/9780470757642.ch9

Bowles, R. P., Pentimonti, J. M., Gerde, H. K., & Montroy, J. J. (2014). Item response analysis of uppercase and lowercase letter name knowledge. *Journal of Psychoeducational Assessment*, *32*(2), 146–156. doi:10.1177/0734282913490266

Burgess, S. R., & Lonigan, C. J. (1998). Bidirectional relations of phonological sensitivity and prereading abilities: Evidence from a preschool sample. *Journal of Experimental Child Psychology*, *70*(2), 117–141. doi:10.1006/jecp.1998.2450

Burgess, S. R. (2002). The influence of speech perception, oral language ability, the home literacy environment, and pre-reading knowledge on the growth of phonological sensitivity: A one-year longitudinal investigation. *Reading and Writing: An Interdisciplinary Journal*, *15*(7/8), 709–737. doi:10.1023/A:1020954606695

Byrne, B., & Fielding-Barnsley, R. (1991). Evaluation of a program to teach phonemic awareness to young children. *Journal of Educational Psychology*, *83*(4), 451–455. doi:10.1037/0022-0663.83.4.451

Caravolas, M., & Bruck, M. (1993). The effect of oral and written language input on Children′s phonological awareness: A cross-linguistic study. *Journal of Experimental Child Psychology*, *55*(1), 1–30. doi:10.1006/jecp.1993.1001

Caravolas, M., Hulme, C., & Snowling, M. J. (2001). The foundations of spelling ability: Evidence from a 3-year longitudinal study. *Journal of Memory and Language*, *45*(4), 751–774. doi:10.1006/jmla.2000.2785

Dai, J., Ibrahim, R., & Share, D. L. (2013). The influence of orthographic structure on printed word learning in Arabic. *Writing Systems Research*, *5*(2), 189–213. doi:10.1080/17586801.2013.827563

Evans, M., Bell, M., Shaw, D., Moretti, S., & Page, J. (2006). Letter names, letter sounds and phonological awareness: An examination of kindergarten children across letters and of letters across children. *Reading and Writing: An Interdisciplinary Journal*, *19*(9), 959–989. doi:10.1007/s11145-006-9026-x

Eviatar, Z., Ibrahim, R., & Ganayim, D. (2004). Orthography and the hemispheres: Visual and linguistic aspects of letter processing. *Neuropsychology*, *18*(1), 174–184. doi:10.1037/0894-4105.18.1.174

Ferguson, C. A. (1959). Diglossia. *WORD*, *15*(2), 325–340. doi:10.1080/00437956.1959.11659702

Foulin, J. N. (2005). Why is letter-name knowledge such a good predictor of learning to read? *Reading and Writing: An Interdisciplinary Journal*, *18*(2), 129–155. doi:10.1007/s11145-004-5892-2

Georgiou, G. K., Torppa, M., Manolitsis, G., Lyytinen, H., & Parrila, R. (2012). Longitudinal predictors of reading and spelling across languages varying in orthographic consistency. *Reading and Writing: An Interdisciplinary Journal*, *25*(2), 321–346. doi:10.1007/s11145-010-9271-x

Gordon, R. G. (Ed.). (2005). Ethnologue: Languages of the world (15th ed.). Dallas, TX: SIL International.

Hamdan, J. M. & Amayreh, M. M. (2007). Consonant profile of Arabic-speaking school-age children in Jordan. *Folia Phoniatr Logop*, *59*, 55–64. doi: 10.1159/000098338

Hamdan, J. M., & Amayreh, M. M. (2007). Consonant profile of Arabic-speaking school-age children in Jordan. *Folia Phoniatrica Et Logopaedica*, *59*(2), 55–64. doi:10.1159/000098338

Hammill, D. D. (2004). What we know about correlates of reading. *Exceptional Children*, *70*(4), 453–468. doi:10.1177/001440290407000405

Hassunah Arafat, S., Korat, O., Aram, D. et al. Continuity in literacy achievements from kindergarten to first grade: a longitudinal study of Arabic-speaking children. *Reading and writing: An interdisciplinary journal*, *30*, 989–1007 (2017). doi:10.1007/s11145-016-9709-x

Huang, F. L., & Invernizzi, M. A. (2012). Factors associated with lowercase alphabet naming in kindergartners. *Applied Psycholinguistics*, *35*(6), 943–968. doi:10.1017/S0142716412000604

Justice, L. M., Pence, K., Bowles, R., & Wiggins, A. K. (2006). An investigation of four hypotheses concerning the order by which 4-year-old children learn the alphabet letters. *Early Childhood Research Quarterly*, *21*(3), 374–389. doi:10.1016/j.ecresq.2006.07.010

Kim, Y.-S. G. (2011). Considering linguistic and orthographic features in early literacy acquisition: Evidence from Korean. *Contemporary Educational Psychology*, *36*(3), 177–189. doi:10.1016/j.cedpsych.2010.06.003

Kim, Y.-S. G., Petscher, Y., Foorman, B., & Zhou, C. (2010). The contributions of phonological awareness and letter-name knowledge to letter sound acquisition—A cross-classified multilevel model approach. *Journal of Educational Psychology*, *102*(2), 313–326. doi:10.1080/10888438.2020.1830406

Kim, Y.-S. G., Petscher, Y., Treiman, R., & Kelcey, B. (2020). Letter features as predictors of letter-name acquisition in four languages with three scripts. *Scientific Studies of Reading, 25*(6), 453–469. doi:10.1080/10888438.2020.1830406

Kim, Y.-S., & Petscher, Y. (2013). Language general and specific factors in letter acquisition: Considering child and letter characteristics in Korean. *Reading and Writing: An Interdisciplinary Journal*, *26*(2), 263–292. doi:10.1007/s11145-012-9367-6

Levin, I., Saiegh-Haddad, E., Hende, N., & Ziv, M. (2008). Early literacy in Arabic: An intervention study among Israeli Palestinian kindergartners. *Applied Psycholinguistics*, *29*(3), 413–436. doi:10.1017/S0142716408080193

Levin, I., Shatil-Carmon, S., & Asif-Rave, O. (2006). Learning of letter names and sounds and their contribution to word recognition. *Journal of Experimental Child Psychology*, *93*(2), 139–165. doi:10.1016/j.jecp.2005.08.002

Lonigan, C. J., Burgess, S. R., & Anthony, J. L. (2000). Development of emergent literacy and early reading skills in preschool children: Evidence from a latent-variable longitudinal study. *Developmental Psychology*, *36*(5), 596–613. doi:10.1037/0012-1649.36.5.596

Lonigan, C. J., Schatschneider, C., & Westberg, L. & The National Early Literacy Panel. (2008). *Results of the National Early Literacy Panel research synthesis: Identification of children's skills and abilities linked to later outcomes in reading, writing, and spelling*. Developing early literacy: Report of the National Early Literacy Panel. Washington, DC: National Institute for Literacy.

Maamouri, M. (1998, September). Language Education and human Development: Arabic Diglossia and its Impact on the Quality of Education in the Arab Region. Paper presented at the Mediterranean Development Forum of the World Bank. Marrakech, Morocco.

McBride-Chang, C. (1999). The ABCs of the ABCs: The development of letter-name and letter-sound knowledge. *Merrill-Palmer Quarterly*, *45*(2), 285–308. Retrieved from https://www.jstor.org/stable/23093679

Mirdehghan, M. (2010). Persian, Urdu, and Pashto: A comparative orthographic analysis. *Writing Systems Research*, *2* (1), 9–23. doi:10.1093/wsr/wsq005

Muter, V., & Diethelm, K. (2001). The contribution of phonological skills and letter knowledge to early reading development in a multilingual population. *Language Learning*, *51*(2), 187–219. doi:10.1111/1467-9922.00153

Perea, M., Abu Mallouh, R., Mohammed, A., Khalifa, B., & Carreiras, M. (2016). Do diacritical marks play a role at the early stages of word recognition in Arabic? *Frontiers in Psychology*, *7*, 1255. doi:10.3389/fpsyg.2016.01255

Perea, M., Abu Mallouh, R., Mohammed, A., Khalifa, B., & Carreiras, M. (2018). Does visual letter similarity modulate masked form priming in young readers of Arabic? *Journal of Experimental Child Psychology*, *169*, 110–117. doi:10.1016/j.jecp.2017.12.004

Phillips, B. M., Piasta, S. B., Anthony, J. L., Lonigan, C. J., & Francis, D. J. (2012). IRTs of the ABCs: Children's letter name acquisition. *Journal of School Psychology*, *50*(4), 461–481. doi:10.1016/j.jsp.2012.05.002

Piasta, S. B., & Wagner, R. K. (2010a). Developing emergent literacy skills: A meta-analysis of alphabet learning and instruction. *Reading Research Quarterly*, *45*(1), 8–38. doi:10.1598/RRQ.45.1.2

Piasta, S. B., & Wagner, R. K. (2010b). Learning letter names and sounds: Effects of instruction, letter type, and phonological processing skill. *Journal of Experimental Child Psychology*, *105*(4), 324–344. doi:10.1016/j.jecp.2009.12.008

Saiegh-Haddad, E. (2003). Linguistic distance and initial reading acquisition: The case of Arabic diglossia. *Applied Psycholinguistics*, *24*(3), 431–451. doi:10.1017/S0142716403000225

Saiegh-Haddad, E., & Haj, L. (2018). Does phonological distance impact quality of phonological representations? Evidence from Arabic diglossia. *Journal of Child Language*, *45*(6), 1377–1399. doi:10.1017/S0305000918000302

Saiegh-Haddad, E., & Henkin-Roitfarb, R. (2014). The structure of Arabic language and orthography. In E. Saiegh-Haddad, and M. Joshi (Eds.), *Handbook of Arabic literacy: Insights and perspectives* (pp. 3–28). The Netherlands, Springer: Dordrecht.

Saiegh-Haddad, E., Shahbari-Kassem, A., & Schiff, R. (2020). Phonological awareness in Arabic: The role of phonological distance, phonological-unit size, and SES. *Reading and Writing: An Interdisciplinary Journal*, *33*(6), 1649–16741–26. doi:10.1007/s11145-020-10019-3

Schatschneider, C., Fletcher, J. M., Francis, D. J., Carlson, C. D., & Foorman, B. R. (2004). Kindergarten prediction of reading skills: A longitudinal comparative analysis. *Journal of Educational Psychology*, *96*(2), 265–282. doi:10.1037/0022-0663.96.2.265

Share, D. (2008). On the Anglocentricities of current reading research and practice: The perils of overreliance on an "outlier" orthography. *Psychological Bulletin*, *134*(4), 584–615. doi:10.1037/0033-2909.134.4.584

Snowling, M. J., & Hulme, C. (2011). Evidence-based interventions for reading and language difficulties: Creating a virtuous circle. *British Journal of Educational Psychology*, *81*(1), 1–23. doi:10.1111/j.2044-8279.2010.02014.x

Storch, S. A., & Whitehurst, G. J. (2002). Oral language and code-related precursors to reading: Evidence from a longitudinal structural model. *Developmental Psychology*, *38*(6), 934–947. doi:10.1037/0012-1649.38.6.934

Tangel, D. M., & Blachman, B. A. (1992). Effect of phoneme awareness instruction on kindergarten children's invented spelling. *Journal of Reading Behavior*, *24*(2), 233–261. doi:10.1080/10862969209547774

Taouk, M., & Coltheart, M. (2004). The Cognitive processes involved in learning to read in Arabic. *Reading and Writing: An Interdisciplinary Journal, 17*, 27–57. doi:10.1023/B:READ.0000013831.91795.ec

Tibi, S., Edwards, A. A., Schatschneider, C., Lombardino, L. J., Kirby, J. R., & Salha, S. H. (2021). IRT analyses of Arabic letter knowledge in kindergarten. *Reading and Writing: An Interdisciplinary Journal*, *34*, 791–816. Retrieved from https://doi.org/10.1007/s11145-020-10086-6

Tibi, S., & Kirby, J. R. (2018). Investigating phonological awareness and naming speed as predictors of reading in Arabic. *Scientific Studies of Reading*, *22*, 70–84. https://doi.org/10.1080/10888438.2017.1340948

Tibi, S., Tock, J. L., & Kirby, J. R. (2019). The development of a measure of root awareness to account for reading performance in the Arabic language: A development and validation study. *Applied PsychoLinguistics*, *40*, 303–322. https://doi.org/10.1017/S0142716418000589

Treiman, R., Kessler, B., & Pollo, T. C. U. (2006). Learning about the letter name subset of the vocabulary: Evidence from US and Brazilian preschoolers. *Applied Psycholinguistics*, *27*(2), 211–227. doi:10.1017/S0142716406060255

Treiman, R., & Kessler, B. (2003). The role of letter names in the acquisition of literacy. In R. Kail (Ed.), *Advances in child development and behavior* (Vol. 31, pp. 105–135). San Diego, Ca: Academic Press.

Treiman, R., Levin, I., & Kessler, B. (2007). Learning of letter names follows similar principles across languages: Evidence from Hebrew. *Journal of Experimental Child Psychology*, *96*(2), 87–106. doi:10.1016/j.jecp.2006.08.002

Treiman, R., Levin, I., & Kessler, B. (2012). Linking the shapes of alphabet letters to their sounds: The case of Hebrew. *Reading and Writing: An Interdisciplinary Journal*, *25*(2), 569–585. doi:10.1007/s11145-010-9286-3

Treiman, R., Tincoff, R., & Richmond-Welty, E. D. (1997). Beyond zebra: Preschoolers' knowledge about letters. *Applied Psycholinguistics*, *18*(4), 391–409. doi:10.1017/S0142716400010900

Treiman, R., Tincoff, R., Rodriguez, K., Mouzaki, A., & Francis, D. J. (1998). The foundations of literacy: Learning the sounds of letters. *Child Development*, *69*(6), 1524–1540. doi:10.1111/j.1467-8624.1998.tb06175.x

Turnbull, K. L. P., Bowles, R. P., Skibbe, L. E., Justice, L. M., & Wiggins, A. K. (2010). Theoretical explanations for preschoolers' lowercase alphabet knowledge. *Journal of Speech, Language, and Hearing Research*, *53*(6), 1757–1768. doi:10.1044/1092-4388(2010/09-0093)

Wagner, R. K., Torgesen, J. K., Rashotte, C. A., Hecht, S. A., Barker, T. A., Burgess, S. R., Donahue, J., & Garon, T. (1997). Changing relations between phonological processing abilities and word-level reading as children develop from beginning to skilled readers: A 5-year longitudinal study. *Developmental Psychology*, *33*(3), 468–479. doi:10.1037/0012-1649.33.3.468

Whitehurst, G. J., & Lonigan, C. J. (1998). Child development and emergent literacy. *Child Development*, *69*(3), 848–872. doi:10.1111/j.1467-8624.1998.tb06247.x