Gulf Education and Social Policy Review
Volume 4, Issue no. 1, DOI 10.18502/gespr.v4i1.13804
Production and Hosting by Knowledge E

Research Article

Influence of Enhanced Perceptual Features on Development of Neural Specialization for Arabic Print in Early Readers

تأثير الميزات الإدراكية المحسّنة على تطوير التخصص العصبي للطباعة العربية في القرّاء الأوائل

Roa'a Alsulaiman[1,2] and Tracy M. Centanni[3]

[1]Department of Psychology, King Saud University, Riyad, Saudi Arabia
[2]Division of Psychology and Language Sciences, University College, London, UK
[3]Department of Psychology, Texas Christian University, Fort Worth, TX, USA
ORCID
Tracy M. Centanni: https://orcid.org/0000-0002-9889-334X

Corresponding Author: Tracy M. Centanni; email: tmcentanni@gmail.com

Received: March 19, 2023
Accepted: April 13, 2023
Published: July 28, 2023

Production and Hosting by Knowledge E

Managing Editor: Natasha Mansur

Abstract

Reading in Arabic is challenging for many early learners. To improve Arabic reading fluency, a new textbook (IQRA) was designed to enhance the visual characteristics of Arabic and, thus, help children recognize the Arabic orthography. Despite promising behavioral improvement, it is unknown whether this improvement is associated with accelerated development of the brain's reading network, which develops over many years. Thus, the goal of this study was to measure brain responses to Arabic print in early readers enrolled in IQRA instruction. Reading was assessed and electroencephalography (EEG) responses were collected from 49 first-grade children in the UAE (*N* = 27 IQRA treatment, *N* = 22 control) while completing a single EEG task at the end of the school year. Behavioral measures of word identification revealed a slight improvement for IQRA children compared to their peers in control classrooms. EEG responses suggest improved familiarity with Arabic in IQRA children as well as increased print-specific response, though the latter finding did not survive correction for multiple comparisons. These findings suggest a modest effect of the IQRA curriculum on neural responses to print in young readers. Future work is needed to understand the long-term impact of IQRA on the reading brain.

الملخص

تعتبر القراءة باللغة العربية تحديًا للعديد من المتعلمين الأوائل. لتحسين طلاقة القراءة باللغة العربية، تم تصميم كتاب مدرسي جديد (اقرأ) لتعزيز الخصائص المرئية للغة العربية، وبالتالي مساعدة الأطفال على التعرف على قواعد الإملاء العربية. على الرغم من التحسن السلوكي الواعد، فمن غير المعروف ما إذا كان هذا التحسن مرتبطًا بالتطور المتسارع لشبكة القراءة في الدماغ، والتي تتطور على مدار سنوات عديدة. وبالتالي، كان الهدف من هذه الدراسة هو قياس استجابات الدماغ للمطبوعات العربية لدى القراء الأوائل المسجلين في تعليم "اقرأ". تم تقييم القراءة وجمع استجابات تخطيط كهربية الدماغ من ٤٩ طفلاً في الصف الأول في الإمارات العربية المتحدة (معالجة "اقرأ" = ٢٧، التحكم = ٢٢) أثناء إكمال مهمة تخطيط الدماغ واحدة في نهاية العام الدراسي. كشفت المقاييس السلوكية لتعريف الكلمات عن تحسن طفيف لأطفال "اقرأ" مقارنة بأقرانهم في الفصول الدراسية الضابطة. تشير استجابات مخطط كهربية الدماغ إلى تحسن الإلمام باللغة العربية لدى أطفال "اقرأ" بالإضافة إلى زيادة الاستجابة الخاصة بالطباعة، على الرغم من أن النتيجة الأخيرة لم تنجو من التصحيح لمقارنات متعددة. تشير هذه النتائج إلى تأثير متواضع لمنهج "اقرأ" على الاستجابات العصبية للطباعة في القراء الشباب. هناك حاجة إلى العمل المستقبلي لفهم التأثير طويل المدى لـ"اقرأ" على دماغ القراءة.

Keywords: *Reading, Intervention, Arabic language, EEG, Early readers, Literacy, Neural processing*

الكلمات المفتاحية: القراءة، المداخلة، اللغة العربية، تخطيط الدماغ، القراء الأوائل، محو الأمية، المعالجة العصبية

OPEN ACCESS

1. Introduction

Arabic is the most widely spoken Semitic language in the world, spoken by more than 250 million people as their first language in the Middle East (Watson, 2007). Despite its wide usage, learning to read in Arabic remains a challenge for many. Arabic is a complex orthography and may be challenging to learn for a variety of reasons, which has led to many efforts to improve reading instruction in the Middle East/North Africa (MENA) region. There have been several attempts to examine reading proficiency in Arabic children. In Jordan, for example, the Queen Rania Foundation (QRF) measured the average benefits achievable by having children attend early childhood care and education (ECCE; Fink et al., 2017). Children who participated in ECCE completed one year of preschool, followed by two years of kindergarten before starting their first year of school. Students who were exposed to ECCE had early grade reading and math scores 10–13 percentile ranks above children who entered their first year of school without this extra education (Fink et al., 2017). Moreover, the UAE participated in the Program for International Student Assessment (PISA) study (OECD, 2019). The PISA assessment program is a comprehensive one, and involves assessment of the proficiency of pupils in reading, science, and math at the age of 15. The latest reported data showed that students in the UAE scored lower than the mean OECD score (OECD, 2019). Among others, these data highlight the difficulty of acquiring fluency in reading Arabic and suggest new methods of instructions.

To improve Arabic reading fluency in children, a new textbook (IQRA) was designed to enhance the unique visual characteristics of Arabic and, thus, help children easily recognize the orthography of Arabic letters (Wilson et al., 2020). The IQRA textbook was designed to enhance the perceptual features of Arabic text by printing letters in a large font size and using increased spacing. In IQRA, letters are presented in order of visual complexity, with letters containing fewer standard forms presented first. The curriculum was tested in a large pilot project in the UAE that included 345 students in their first year of school (Wilson et al., 2020). The goal was to evaluate the effect of training in decoding and repeated exposure to modern standard Arabic (MSA) patterns on increasing reading performance (measured by speed and accuracy) in early-grade readers. After one year, students who used the IQRA textbook were able to accurately identify more letters and make fewer errors compared to a matched control group of children who received the standard curriculum. The students that received the IQRA curriculum were more accurate at recognizing printed words and read more words per minute than the business-as-usual control group (Wilson et al., 2020). However, it is currently unknown whether this improvement in behavioral reading performance is associated with accelerated development of the brain's reading network, which develops over a long trajectory. Because behavioral data collected from children using IQRA suggests that it is a promising educational intervention with positive effects on improving reading fluency, the goal of the present study was to measure brain responses to Arabic print in early readers enrolled in IQRA instruction.

One reason Arabic may be difficult for readers concerns the visual complexity of the Arabic orthography. The visual characteristics of written Arabic text, such as the use of vowel markings and whether the letters are connected to each other, slow the reading speed (Abdelhadi et al., 2011). The visual complexity of Arabic letters may increase perceptual load, thus slowing down the process of word identification. For example, some Arabic letters have up to four different writing shapes depending on where they appear within words. Moreover, some pairs or triplets of Arabic letters are identical in their basic shapes and can only be distinguished by the number of dots and their positions (above or below the letter; Saiegh-Haddad & Roitfarb, 2014). All of these complexities along with the mapping between similar graphemes and different phonemes may add to the cognitive demands while the brain is decoding the letters, which therefore increases reading difficulty in Arabic.

Another reason learning to read in Arabic is challenging is because Arabic is considered a Diglossic language (Ferguson, 1959), meaning there are multiple forms of the language in use. In Arabic, there is one standard form (the MSA) as well as many regional colloquial Arabic (CA) forms. MSA is used in most Arab countries in different situations and locations including on street signs, in newspapers, television news, and schoolbooks (Alsulaiman et al., 2022). In daily communication, individuals use their own CA dialect for speaking but use MSA for reading (although CA may be used in informal writing, such as text messaging). Moreover, the Arabic language has a dense morphology (Mahfoudhi et al., 2010), which requires increased cognitive effort by the reader to accurately recognize the printed words. (Elbeheri et al., 2006). In other words, Arabic exhibits a discontinuous morphology that is based on the combination of two abstract phonemes: the root and the word pattern (Boudelaa & Marslen-Wilson, 2005). The roots and word patterns are intertwined to form words across different lexical categories (e.g., nouns, verbs, and adjectives). For example, the root KTB (Table 1) carries the meaning of the word "writing" (Tucker, 2011), and various forms of this root, in combination with other verb and noun patterns, imply different aspects of "writing." These increased complexities of Arabic may impact the brain's ability to develop a fluent reading network in childhood.

Table 1

Words derived from the /ktb/ root. These examples are from different lexical categories and are supplied with vowels and prefixes.

English orthographic transcription	Arabic orthographic transcription	Word meaning in English
Kataba	كَتَبَ	He wrote
Kitaab	كِتَاب	Book
Maktaba	مَكتَبَة	Library; bookstore
Kaatib	كاتِب	Writer

Although reading is a critical skill, children are not born with a reading network. Rather, they rely on a dispersed neural network during reading acquisition before converging onto the adult reading network (Dehaene-Lambertz et al., 2018; Feng et al., 2020). Over the course of reading acquisition, the visual word form area (VWFA), a region on the fusiform gyrus, becomes sensitive and eventually specialized for print stimuli (Centanni et al., 2017; McCandliss et al., 2003; Van der Mark et al., 2009). The VWFA is functionally defined by its preferential response to printed words, compared to other visual stimuli such as faces, false fonts, checkerboards, scrambled visual stimuli, and line drawings (e.g., Centanni et al., 2017; Cohen et al., 2000; Stevens et al., 2017; Xiang et al., 2019). The development of this region is protracted, lasting into early adulthood (Centanni et al., 2017), and the trajectory of this process is guided by home literacy environment (Powers et al., 2016) and educational practices (Hruby & Goswami, 2011). The brain's response to print is detectable using electroencephalography (EEG), which is a noninvasive form of neural imaging that is well tolerated in young children (Bathelt et al., 2013). In EEG, print sensitivity is reflected by a negative-going event-related potential (referred to as the N1 or N170), and this component is usually absent in preschool children who do not read (Brem et al., 2013). Although the exact location of the VWFA is subject to individual variation (Baker et al., 2007; Brem et al., 2013; Centanni et al., 2017; Glezer & Riesenhuber, 2013; Vinckier et al., 2007), this region is most frequently located on the occipital–temporal cortex near the left occipital–temporal sulcus (Centanni et al., 2017; Hornickel & Kraus, 2013).

Although there is a large body of work characterizing the VWFA in a variety of orthographies and populations, research on reading in Arabic populations is still scarce. Most of the research on the VWFA has been conducted with English readers, or readers of Western languages in general (Feng et al., 2020). This is unfortunate, especially because of the visual complexity of Arabic orthography, which makes it difficult to draw or generalize conclusions across alphabetic systems. An event-related potential (ERP) investigation of the effects of Arabic orthographic complexity in fluent adults showed that the VWFA is activated during printed Arabic processing regardless of the connectivity of the words (Khateb et al., 2013). However, it is unknown whether the complexities of Arabic text require a longer trajectory for the VWFA to specialize in this alphabet. If so, it would explain the behavioral lag of children reading in Arabic compared to other orthographies. However, no study to date has investigated neural responses to print in early readers of Arabic to investigate the impact of this complex orthography on the VWFA development. Therefore, the present study was designed to examine whether the IQRA intervention, which enhances the perceptual features of the Arabic orthography, influences the development of neural specialization for print in early Arabic readers. Given prior evidence suggesting a significant improvement in reading fluency following this intervention, we hypothesized that we would observe a greater N1 amplitude in the group of children who have undergone the IQRA curriculum compared to a matching-control group.

2. Methods

2.1. Participants

Children in first grade were recruited from private and public primary schools in Ras Al Khaimah, United Arab Emirates and grouped based on their classroom's participation in the IQRA intervention. In brief, children received either the Ministry of Education curriculum (control) or the IQRA curriculum (treatment). The IQRA curriculum consists of two additional 45-min Arabic lessons per week utilizing a novel textbook designed to maximize salience of the perceptual features of Arabic letters by increasing letter size and spacing (Wilson et al., 2020). In total, 49 children (N = 27 treatment, N = 22 control) were enrolled. Informed consent was obtained from each parent, and verbal assent was given by each child prior to participating. All data were collected in a quiet room in the child's school or a dedicated space at the Sheikh Saud Saqr bin Al Qasimi Foundation for Policy Research. All study procedures were approved by the (anonymized) Institutional Review Board, and children received their choice of a small toy or book for their participation.

2.2. Behavioral testing

Children completed several measures in Arabic as part of their participation in the larger study (Wilson et al., 2020). In brief, children completed letter identification and

Table 2

Demographics and scores on all available Arabic reading measures reported as mean ± std. Note that there is only 1 child with both pre- and posttest data in the control group and only 15 children with both pre- and posttest data in the IQRA group.

Measure	IQRA (N = 21, 1 female)	Control (N = 19, 7 female)	t-value	P-value
Age	6.81 ± 0.47	6.84 ± 0.57	0.19	0.85
Letter identification (pretest)	41.14 ± 42.66	11.00 ± 16.03 (*N* = 5)	1.49	0.15
Words per minute (pretest)	12.86 ± 17.96	0.60 ± 1.20 (*N* = 5)	1.47	0.16
Letter identification (posttest)	34.56 ± 8.23	41.71 ± 8.17	0.55	0.59
Words per minute (posttest)	13.63 ± 3.36	11.29 ± 3.63	0.42	0.68

fluency tests. During the letter identification task, children were asked to identify as many Arabic letters and short letter combinations as possible within 1 min. During the reading fluency task, children were given 1 min to read a 49-word paragraph in Arabic, and the child was stopped after five errors were made. Children were tested on these measures once at the beginning of the academic year (pretest) and again at the end of the academic year (posttest). Accuracy and reading speed were calculated for each child on each measure. Participant demographics and scores for the final sample are reported in Table 2. Unfortunately, there was significant data loss due to rates of online school in the fall semester and absences in the spring (full pre- and posttest data available for 15 children in the IQRA group and 1 child in the control group). Thus, for all subsequent analyses reported, we only analyzed posttest reading data with respect to neural responses for all group comparisons.

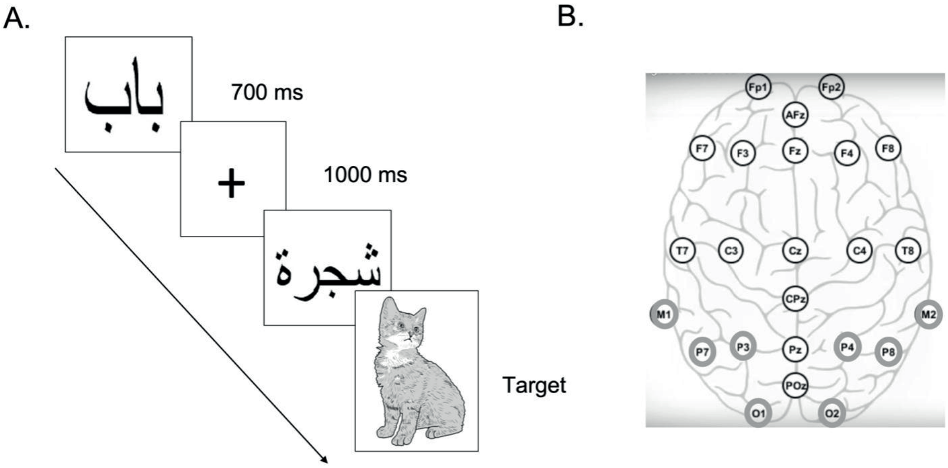
2.3. EEG data collection and task

All children completed a single EEG task at the end of the school year lasting no longer than 20 min. Of the 49 children enrolled in the study, 4 withdrew prior to the EEG portion of the study and data could not be collected from 1 child due to an equipment malfunction. The remaining children were fitted with a 24-channel semi-dry portable EEG system (smarting mobi, mBrainTrain, Belgrade, Serbia) by a trained researcher and impedances were lowered <30 kΩ. Data were acquired at a sampling rate of 500 Hz and referenced to the vertex using the smarting Streamer 3.4.3 software (mBrainTrain, Belgrade, Serbia).

A practice block consisted of common objects while the researcher provided instruction and feedback, followed by test blocks containing connected Arabic words and

Figure 1

Study design. (A) Example of a test block containing connected Arabic words. Each stimulus was presented for 700 ms followed by a 1000 ms fixation delay. The presentation of a cat was the vigilance target, at which time children pressed a button. (B) Electrodes of interest are highlighted in grey and include O1/O2, P3/P4, P7/P8, and M1/2.



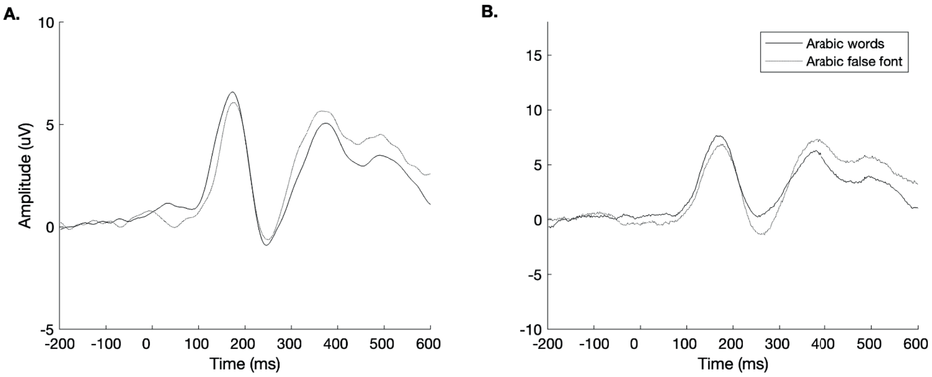
disconnected Arabic false font strings (Figure **1**A). Children viewed images on a screen and completed a vigilance task in which they pressed a button when a picture of a cat appeared (10% of trials). Each test stimulus category contained 10 unique items that were repeated 10 times each. Items were presented for 700 ms with a 1000 ms fixation cross between each item. Items were presented in pseudorandom order over four blocks, with each block lasting 3 min. Between blocks, children were given a break to stretch, move around, and prepare for the next block. The entire task lasted approximately 15 min. Stimuli were presented and responses were recorded using custom Python programming (PsychoPy; Peirce et al., 2019).

2.4. EEG preprocessing and analysis

All EEG data were preprocessed in Matlab (The Mathworks, Natick, MA) using a combination of EEGLab (Brunner et al., 2013) and custom code. Data were filtered with cut-offs of 0.1 – 30 Hz and then re-referenced offline to an average reference. Eye blink artifacts were identified through independent components analysis and regressed out of the signal. Data were then cleaned to remove movement artifacts and bad channels using the Clean Rawdata plugin (transition band [0.25 0.75], bad channels defined as a channel exhibiting a flat line of at least 5 s and/or correlation to their robust estimate based on other channels <0.8). Interpolation was used as needed to replace

Figure 2

Grand average across all 8 electrodes to Arabic words and disconnected false font in the IQRA group (A) and the Control group (B). The P1 time window was defined as 175 to 195 ms post-stimulus onset. The N1 time window was defined as 215 to 235 ms post-stimulus onset.



bad channels, which impacted mostly frontal electrode sites. Epochs were then created for each stimulus category (–500 to 600 ms with respect to stimulus onset) with baseline correction using the 500 ms prior to stimulus onset. Neural data for each participant were included when there were >10 good trials available within a stimulus condition. Given this criterion, data from four children were excluded (*N* = 2 IQRA, *N* = 2 control). The final EEG sample thus contained data from 21 children in the treatment group (IQRA curriculum) and 19 children in the control group (standard instruction). In left hemisphere, data were analyzed from electrodes M1, P3, P7, and O1, and complementary electrodes were analyzed in the right hemisphere (M2, P4, P8, and O2; Figure **1**B).

2.5. Statistical plan

Repeated measures ANOVA was used to evaluate the effects of group, hemisphere, and stimulus type on neural response amplitudes (the P1 and N1). Time windows for each component were identified by visual inspection of the average neural response across all participants (Figure **2**). The P1 was quantified as the average amplitude 175 to 195 ms post-stimulus onset. The N1 was quantified as the average amplitude 215 to 235 ms post stimulus onset. These time windows are in line with prior reports of these peak latencies in early readers (Brem et al., 2013; Eberhard-Moscicka et al., 2016; Maurer et al., 2006). Post-hoc *t*-tests were used to probe any significant effects and interactions. All *t*-tests were two-tailed unless otherwise stated. Spearman's rho was used to evaluate correlations between brain activation and reading scores, given the non-Gaussian distribution of reading scores in this sample. The Bonferroni correction was applied to analyses including multiple comparisons.

3. Results

3.1. No differences in reading across groups

There were no reading differences across groups in either letter identification or in the word reading tasks at the posttest time point (*ps* > 0.59; Table 2). Although we only had pre- and posttest data from one control child, we were able to collect pre- and posttest data from 15 IQRA children. In these children, no improvement was observed in letters (posttest – pretest, 4.87 ± –0.79 letters; paired *t*-test; *t* [14] = 0.86, *P* = 0.40), however, a modest improvement was observed in words of 6.33 ± 0.22 over the course of the academic year (*t* [14] = 2.03, *P* = 0.06). This improvement is approximately half of what was reported in a much larger study of the IQRA curriculum (Wilson et al., 2020), perhaps reflecting challenges due to the COVID-19 pandemic during our data collection period.

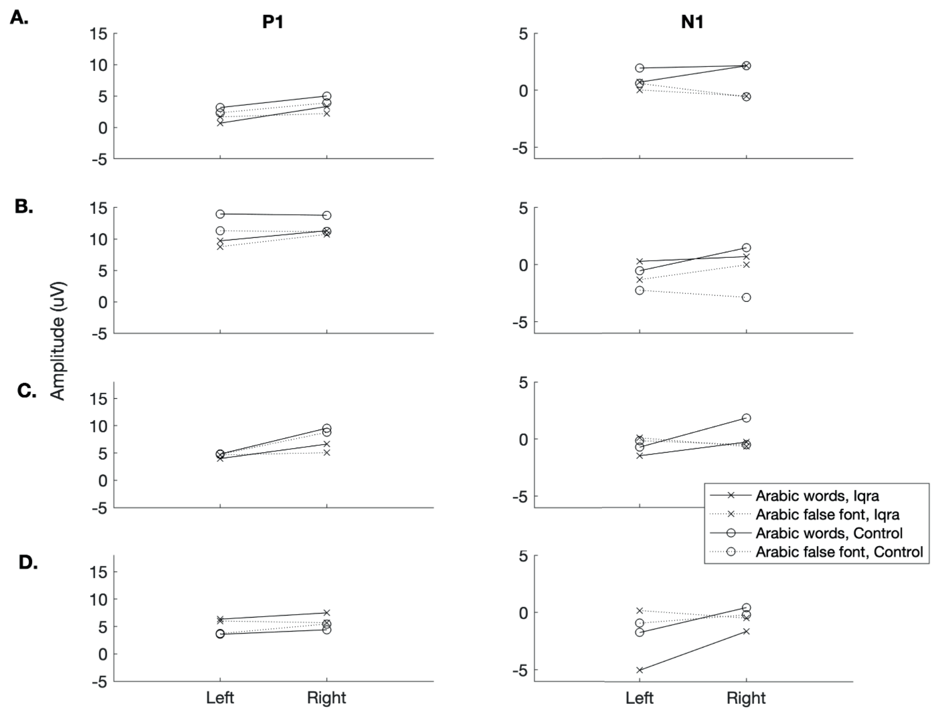
3.2. Effect of IQRA pilot on neural responses to print

We first conducted repeated measures ANOVA on each ERP component (stimulus condition x group x electrode; Figure **3**). With respect to P1, there was a main effect of group (F [1, 614] = 3.98, *P* = 0.047) and a main effect of electrode (F [1, 614] = 25.5, *P* < 0.0001). No significant main effect of stimulus type (F [1, 614] = 2.12, *P* = 0.15) was observed. There was one significant interaction between electrode and group (F [1, 614] = 2.5, *P* = 0.015). No other interactions were significant (*ps* > 0.78). With respect to the N1, there was no main effect of group (F [1, 614] = 1.04, *P* = 0.31) and no main effect of stimulus type (F [1, 614] = 2.05, *P* = 0.15). There was a significant main effect of electrode (F [1, 614] = 2.86, *P* = 0.006). There was no interaction between electrode and group (F [1, 614] = 0.72, *P* = 0.66). Significant interactions were observed between stimulus type and electrode (F [1, 614] = 3.27, *P* = 0.002) and between stimulus and group (F [1, 614] = 4.85, *P* = 0.028). Given the main effect of electrode, we evaluated the N1 responses to each electrode individually for additional analyses.

Next, we investigated whether participation in the IQRA program impacted the P1 and N1 responses to print and false font string stimuli at the O1 and O2 electrode sites, which are commonly used in studies of print perception, including studies in Arabic (Taha et al., 2013; Figure **3**B). At the O1 electrode, there was a marginally significant group difference in the P1 response to Arabic words such that control children exhibited a stronger response (*t* [40] = 1.73, *P* = 0.046), but no difference in the response to Arabic false font strings (*P* = 0.16). At the O2 electrode, no group differences were observed

Figure 3

Average ERP component amplitudes by electrode and stimulus category. Left column corresponds to P1 amplitudes and right column corresponds to N1 amplitudes in P3/P4 (A), O1/O2 (B), P7/P8 (C), and M1/M2 (D). Control children exhibited a stronger P1 response to Arabic words at the O1 (B-left) and P3 electrodes (A-left) and IQRA children exhibited a stronger N1 response to Arabic words at the M1 electrode (D-left).



in the P1 response to Arabic words (*P* = 0.19) or Arabic false font strings (*P* = 0.77). At the O1 electrode, there were no group differences in the N1 response to Arabic words (*P* = 0.38) or Arabic false font strings (*P* = 0.77). At the O2 electrode, there was also no group difference in the N1 response to Arabic words (*P* = 0.90) but there was a trend for Arabic false font strings (*t* [34] = 1.64, *P* = 0.055).

To confirm that small differences in child head size and EEG cap placement did not impact these results, we also evaluated additional electrodes in left hemisphere (electrodes M1, P3, and P7) vs right hemisphere (electrodes M2, P4, and P8; Figure **3**). In response to words, there was one significant group difference in the P1 response at electrode P3 (*t* [40] = 1.76*, P* = 0.04) such that control children exhibited a stronger response. There was also one trend in P8 (*t* [40] = 1.39, *P* = 0.085) in the same direction. No other comparisons were significant (*ps* > 0.15). In response to false fonts, no group differences were observed at any electrode (*ps* > 0.22) other than one marginal difference at electrode P8 (*P* = 0.06) such that control children exhibited a stronger response. With respect to the N1 response to words, only one significant difference was observed in electrode M1 (t [40] = 2.29, P = 0.014) such that children in the IQRA group exhibited a stronger response than control children (all other $ps > 0.11$). No differences were observed in the N1 response to false font ($ps > 0.44$). Importantly, neither of the two significant comparisons survived the correction for multiple comparisons.

Since prior work has suggested that specificity for print (a greater response to print compared to other stimuli) is associated with better reading performance, we evaluated whether the IQRA program increased the N1 response to print versus the response to false font strings. We analyzed electrodes O1–O2 for their common use in studies of print perception, as well as electrodes M1–M2 since they exhibited a group effect in the hypothesized direction. No significant group difference was observed in specificity for Arabic print in O1 (P = 0.74) or O2 (P = 0.20). A significant difference was observed in M1 (t [33] = 2.32, P = 0.027) but not in M2 (t [33] = 0.80, P = 0.43). The significant difference in M1 did not survive the correction.

3.3. Right but not left N1 correlates with reading performance

We next evaluated whether neural specificity for Arabic print was associated with reading performance. We ran these analyses across the entire sample to increase statistical power. There were no correlations between O1 specificity (Arabic words > Arabic false font strings) and letter identification or word reading ($ps > 0.16$). There was no correlation between specificity at O2 and letter identification (r = 0.16, P = 0.48). There was a significant positive correlation with word reading (r = 0.41, p = 0.037), but it did not survive correction. At M1, there was no relationship between specificity and letter identification (r = 0.02, P = 0.94) but there was a trend toward a negative correlation with word reading (r = –0.36, p = 0.075). There were no correlations at M2 ($ps > 0.26$).

4. Discussion

4.1. Summary of the main results

The aim of the present study was to examine the influence of enhanced perceptual features of Arabic print on the development of neural specialization in early readers. In particular, the study was aimed at evaluating whether one year of participation in the IQRA curriculum would improve neural responses to Arabic words in first-grade children. Behavioral measures of word identification revealed a slight but nonsignificant improvement for IQRA children following exposure to the curriculum compared to their peers in control classrooms. In addition, we found that IQRA children exhibited reduced P1 responses to words in two left-hemisphere electrodes (O1 and P3) as well as a stronger N1 response to words and a stronger specificity for print at M1. Across the entire sample, there was a significant correlation between specificity and word reading in O2, with a trend at M1. It is important to note that none of the N1 findings survived correction, likely due to the small sample size. In general, our results suggest a modest effect of the IQRA curriculum on neural responses to print in young readers.

4.2. Task demand impact on electrical activation in the early reading brain

We found that P1 amplitude was larger for control children relative to IQRA children. This electrophysiological difference between the two groups could reflect additional resources needed by the brains of control children to process less fluent stimuli. Increased amplitude of this component is associated with tasks that require higher cognitive loads (Bullock et al. 2015) and is affected by participants' attention to the stimulus and the task demand, with smaller amplitudes generally associated with better cognitive skills (Hileman et al., 2011). For example, the P1 amplitude in children was reduced while playing a memory card game; an indication of greater working memory load during task performance (Debnath & Wetzel, 2022). Further, work by Taroyan and Nicolson (2009) showed increased P1 amplitude in response to words for adolescents with reading difficulty, compared to a matched control group of adolescents. The results were interpreted as an indication of abnormalities in the occipitotemporal areas of the experimental group with reading difficulties. The findings reported from those studies concern reading English print; thus, it remains unknown whether the brain's development for Arabic reading acquisition in Arabic follows the same developmental trajectory. In our study, the reduced P1 associated with children in the IQRA group may indicate accelerated familiarity with Arabic letters. However, we do not know whether these differences were due to baseline differences in letter perception, perhaps due to a better home literacy environment. Future work is needed to quantify the P1 prior to the start of the intervention itself and follow the brain's development for reading over time.

Developmental studies showed that as children acquire reading English, they develop an N1 specialization for print, particularly over the left inferior occipitotemporal sites (Brem et al., 2013; Maurer et al., 2006). The N1 amplitude peaks rapidly with reading training and continues to increase until adulthood. By the age of eight, children have completed several years of reading instruction, and their N1 specialization to words is already measurable. In English readers, left hemisphere specificity for print increases as reading skills are acquired (Brem et al., 2013; Maurer et al., 2006), demonstrating the relationship between brain specialization and reading skill. However, the nature of developmental trajectory of Arabic has not received wide attention. In the current study, we observed a stronger left occipital N1 to print in IQRA as well as increased specificity for print compared to the control group. This could be interpreted as an indication that the IQRA program accelerated brain processes specializing for print during reading training. However, this result could also indicate that the N1 specialization has simply not yet been present in the matching control group of children, who were not exposed to IQRA curriculum. These differences could also be due to variation in the home literacy environment of children, with some parents spending more time on reading instruction and practice than others. Longitudinal studies are desirable in future work to trace the development of neural network of brain in early readers of Arabic.

4.3. Right but not left N1 correlates with reading performance

Prior work on early reading acquisition in English showed that at the earlier stage of pre-literacy development, five-year-old children exhibit a bilateral recruitment of the tempo-parietal sites during letter processing (Yamada et al., 2012). This bilateral recruitment then shifts to left lateralized as children mature and start learning pre-literacy skills (Maurer et al., 2005). In the current study, despite the increased left ventral print responses observed, only right hemisphere specificity was correlated with reading in our sample. There is some evidence from studies in reading Arabic on the involvement of the right hemisphere in identifying Arabic words in adult skilled readers (Eviatar & Ibrahim, 2000, 2014), however, it is unknown whether this early right involvement represents accelerated development of the adult-like Arabic reading network and whether right lateralization is to be expected in fluent Arabic readers. Thus, future longitudinal or cross-sectional work is needed to better characterize the reading network's development for Arabic specifically.

4.4. Bilingualism impact on neural processing

Given that our participants were conversational in at least two languages, Arabic and English, we must consider the effect of bilingualism on the brain's reading network.

Learning to read in those additional languages may impact the laterality of the N1 (Ibrahim et al., 2002; Proverbio et al., 2002; Simon et al., 2006). As indicated earlier in this paper, Arabic is a disglossic language and there is a wide agreement that reading in Arabic is slower than reading in several other languages including English and French (Abdelhadi et al. 2011). In a study that compared French to Arab readers, the N1 amplitudes elicited by Arabic words from Arabic speakers were lower than the N1 elicited by French words from French speakers (Simon et al., 2006). In a study of Italian and Slovenian bilingual children, it was found that the N1 was leftward lateralized for Slovenian words in the occipito–temporal regions, but a bilateral activation for the same areas was found for Italian words (Proverbio et al., 2002). These findings suggest that: (1) bilingualism may be associated with different brain activation patterns in response to print and (2) those patterns are not consistent across languages of different orthographic systems. In addition, the linguistic experiences for children in both languages tend to be very heterogeneous at this age. The rate at which these bilinguals use Arabic varies considerably depending on several factors including school teaching system and parental support. Along with the diverse regional dialects used by children tested, the heterogeneity could explain the lack of overall differences between IQRA and control on N1 response. While we did not collect data on home language environment and prior language exposures, future work should include variables such as the fluency level of each language and the age of acquisition.

4.5. Limitations and future directions

There are two main limitations to consider in the present work that may have affected the results and the interpretation. First, the study was limited by missing data and the fact that many children were still learning online during the IQRA intervention. We also noted that the improvements are smaller than that reported in prior reports (e.g., Wilson et al., 2020). This may suggest that the curriculum may not have been as effective behaviorally with the disruptions to the current sample. Second, the study was limited by an overall small sample size given the amount of variability in home language exposure and literacy help that likely existed in our dataset. Future work should include a larger number of participants and potentially children at different stages of reading. Further information may also be obtained on language usage, possibly using a language history questionnaire. Finally, the integration of multi-modal measures from different methods such as detailed behavioral measures, ERP, and fMRI data, where possible, may assist in better assessing the role of enhanced visual characteristics of Arabic print on increasing

N1 response. FMRI data can provide subtle details on the development of the reading brain at submillimeter spatial resolution, which cannot be achieved using EEG data alone (Warbrick, 2022).

5. Conclusion

Results of the current study suggest that the IQRA curriculum is a promising intervention that has the potential to improve neural responses to Arabic print in young Arabic readers. It is important to emphasize here that research on the effect of enhancing the unique visual features of Arabic on improving reading fluency is still in its infancy. However, the effect of IQRA on neural responses to print observed in the current study is promising and justifies future research on the implementation of such programs to improve reading fluency in students in the UAE.

Acknowledgments

The authors would like to thank Hanadi Mohammed and Gehad Al Najjar for assistance with logistics and recruitment and Batool Mohsin for assistance with translation and data entry.

Funding Information

This work was supported by a Faculty Research Grant awarded to TMC by the Sheikh Saud bin Saqr Al Qasimi Foundation for Policy Research and a generous private donation to TMC from Dr. Helen Abadzi.

Competing Interests

None.

Author Biography

Tracy Centanni (Twitter: @tmcentanni) is an assistant professor at Texas Christian University with a PhD in Cognition and Neuroscience. Her research focuses on the neural and genetic underpinnings of reading development, causes of and deficits in dyslexia, and novel methods for improving reading.

Roa'a Alsulaiman (Twitter: @ roaaalsulaiman) is currently an assistant professor in the college of education at King Saud University. She is generally interested in speech production and disfluencies. A major focus of her research is on the unique characteristics of the Arabic language and their association with speech disorders such as stuttering.

References

[1] Anderson, R. C., Bousselot, T., Katz-Buoincontro, J., & Todd, J. (2021). Generating buoyancy in a sea of uncertainty: Teachers creativity and well-being during the covid-19 pandemic. *Frontiers in Psychology, 11*, 614774. https://doi.org/10.3389/fpsyg.2020.614774

[2] Balkar, B. (2015). The relationships between organizational climate, innovative behavior and job performance of teachers. *International Online Journal of Educational Sciences, 7*, 39–67. https://doi.org/10.15345/iojes.2015.02.007

[3] Barza, L. (2017). Empowering culturally foreign teachers by fostering cultural competence. In *Teacher professional knowledge and development for reflective and inclusive practices* (pp. 126–134). Routledge. https://doi.org/10.4324/9781315397702-11

[4] Beltman, S., Mansfield, C., & Price, A. (2011). Thriving not just surviving: A review of research on teacher resilience. *Educational Research Review, 6*(3), 185–207. https://doi.org/10.1016/j.edurev.2011.09.001

[5] Beltman, S. (2015). Teacher professional resilience: Thriving not just surviving. In N. Weatherby-Fell (Ed.) *Learning to teach in the secondary school* (pp. 20–38). Cambridge University Press.

[6] Bryan, C., O'Shea, D., & MacIntyre, T. (2019). Stressing the relevance of resilience: A systematic review of resilience across the domains of sport and work. *International Review of Sport and Exercise Psychology, 12*(1), 70–111. https://doi.org/10.1080/1750984X.2017.1381140

[7] Carson, L. D. (2013). *Teacher motivation: A case study on what motivates expatriate teachers at an English medium private school in Sharjah* [Doctoral dissertation, The British University in Dubai (BUiD)].

[8] Campbell-Sills, L., & Stein, M. B. (2007). Psychometric analysis and refinement of the Connor-Davidson Resilience Scale (CD-RISC): Validation of a 10-item measure of resilience. *Journal of Traumatic Stress, 20*(6), 1019–1028.

https://doi.org/10.1002/jts.20271

[9] Dawson, C., & Heylin, C. (2022). Reflecting on the distance learning provision in Dubai private schools. *Gulf Education and Social Policy Review, 2*(2), 193–210. https://doi.org/10.18502/gespr.v2i1.10049

[10] De Jonge, J., Dormann, C., Van Vegchel, N., Von Nordheim, T., Dollard, M., Cotton, S., & Vanden Tooren, M. (2007). *DISQ 2.0: The DISC Questionnaire English Version 2.0*. Eindhoven University of Technology.

[11] DeLongis, A., Folkman, S., & Lazarus, R. S. (1988). The impact of daily stress on health and mood: Psychological and social resources as mediators. *Journal of Personality and Social Psychology, 54*(3), 486–495. https://doi.org/10.1037/0022-3514.54.3.486

[12] Demerouti, E., Bakker, A. B., Nachreiner, F., & Schaufeli, W. B. (2001). The job demands-resources model of burnout. *The Journal of Applied Psychology, 86*(3), 499–512. https://doi.org/10.1037/0021-9010.86.3.499

[13] Dorn, E., Hancock, B., Sarakatsannis, J., & Viruleg, E. (2020). *COVID-19 and student learning in the United States: The hurt could last a lifetime*. McKinsey & Company.

[14] Drew, S. V., & Sosnowski, C. (2019). Emerging theory of teacher resilience: A situational analysis. *English Teaching, 18*(4), 492–507. https://doi.org/10.1108/ETPC-12-2018-0118

[15] Erfurth, M., & Ridge, N. (2020). *The impact of COVID–19 on education in the UAE* (Report No. 1). Sheikh Saud bin Saqr Al Qasimi Foundation for Policy Research. http://dx.doi.org/10.18502/aqf.0143

[16] Fletcher, D., & Sarkar, M. (2013). Psychological resilience. *European Psychologist, 18*(1), 12–23. https://doi.org/10.1027/1016-9040/a000124

[17] Fletcher, D., & Sarkar, M. (2016). Mental fortitude training: An evidence-based approach to developing psychological resilience for sustained success. *Journal of Sport Psychology in Action, 7*(3), 135–157. https://doi.org/10.1080/21520704.2016.1255496

[18] Fredrickson, B. L., & Branigan, C. (2005). Positive emotions broaden the scope of attention and thought-action repertoires. *Cognition and Emotion, 19*(3), 313–332. https://doi.org/10.1080/02699930441000238

[19] Gillani, A., Dierst-Davies, R., Lee, S., Robin, L., Li, J., Glover-Kudon, R., Baker, K., & Whitton, A. (2022). Teachers' dissatisfaction during the COVID-19 pandemic: Factors contributing to a desire to leave the profession. *Frontiers in Psychology, 13*, 940718. https://doi.org/10.3389/fpsyg.2022.940718

[20] Gillet, N., Morin, A. J. S., Sandrin, É, & Fernet, C. (2022). Predictors and outcomes of teachers' burnout trajectories over a seven-year period. *Teaching and Teacher Education, 117*, e103781. https://doi.org/10.1016/j.tate.2022.103781

[21] Gouthier, M. H., & Rhein, M. (2011). Organizational pride and its positive effects on employee behavior. *Journal of Service Management, 22*(5), 633–649. https://doi.org/10.1108/09564231111174988

[22] Gu, Q., & Day, C. (2013). Challenges to teacher resilience: Conditions count. *British Educational Research Journal*, *39*(1), 22–44. https://doi.org/10.1080/01411926.2011.623152

[23] Hammerstein, S., König, C., Dreisörner, T., & Frey, A. (2021). Effects of COVID-19-related school closures on student achievement—A systematic review. *Frontiers in Psychology, 12*, 746289. https://doi.org/10.3389/fpsyg.2021.746289

[24] Hilger, K. J. E., Scheibe, S., Frenzel, A. C., & Keller, M. M. (2021). Exceptional circumstances: Changes in teachers? work characteristics and well-being during COVID-19 lockdown. *School Psychology, 36*(6), 516–532. https://doi.org/10.1037/spq0000457

[25] Hobfoll, S. E. (2001). The influence of culture, community, and the nested-self in the stress process: Advancing conservation of resources theory. *Applied Psychology, 50*(3), 337–421. https://doi.org/10.1111/1464-0597.00062

[26] Khan, F., Yusoff, R., & Khan, A. (2014). Job demands, burnout and resources in teaching a conceptual review. *World Applied Sciences Journal, 30*(1), 20–28. https://www.idosi.org/wasj/wasj30(1)14/4.pdf

[27] Kormos, E. M. (2018). The unseen digital divide: Urban, suburban, and rural teacher use and perceptions of web-based classroom technologies. *Computers in the Schools, 35*(1), 19–31. https://doi.org/10.1080/07380569.2018.1429168

[28] Koys, D. J., & DeCotiis, T. A. (1991). Inductive measures of psychological climate. *Human Relations, 44*(3), 265–285. https://doi.org/10.1177/001872679104400304

[29] Kraemer, T., & Gouthier, M. H. (2014). How organizational pride and emotional exhaustion explain turnover intentions in call centers: A multi-group analysis with gender and organizational tenure. *Journal of Service Management, 25*(1), 125–148. https://doi.org/10.1108/JOSM-07-2013-0173

[30] Kristensen, T. S., Borritz, M., Villadsen, E., & Christensen, K. B. (2005). The Copenhagen Burnout Inventory: A new tool for the assessment of burnout. *Work and Stress, 19*(3), 192–207. https://doi.org/10.1080/02678370500297720

[31] Kyriacou, C. (2001). Teacher stress: Directions for future research. *Educational Review, 53*(1), 27–35. https://doi.org/10.1080/00131910120033628

[32] Lilja, J., Fladmark, S., Nuutinen, S., Bordi, L., Larjovuori, R.-L., Innstrand, S. T., Christensen, M., & Heikkilä-Tammi, K. (2022). COVID-19-related job demands and resources, organizational support, and employee well-being: A study of two Nordic countries. *Challenges, 13*(10), 10. https://doi.org/10.3390/challe13010010

[33] Maceda, C. (2015, August 11). UAE is top expat destination in the world. Study report. *Gulf News*, https://gulfnews.com/business/uae-is-top-expat-destination-in-the-world-study-1.1564550

[34] MacIntyre, P. D., Gregersen, T., & Mercer, S. (2020). Language teachers' coping strategies during the Covid-19 conversion to online teaching: Correlations with stress, wellbeing and negative emotions. *System, 94*, 102–352. https://doi.org/10.1016/j.system.2020.102352

[35] Mansfield, C. F., Beltman, S., Broadley, T., & Weatherby-Fell, N. (2016). Building resilience in teacher education: An evidenced informed framework. *Teaching and Teacher Education, 54*, 77–87. https://doi.org/10.1016/j.tate.2015.11.016

[36] Mas-Machuca, M., Berbegal-Mirabent, J., & Alegre, I. (2016). Work-life balance and its relationship with organizational pride and job satisfaction. *Journal of Managerial Psychology, 31*(2), 586–602. https://doi.org/10.1108/JMP-09-2014-0272

[37] Masten, A. S., & Reed, M.-G. J. (2002). Resilience in development. In *Handbook of positive psychology* (pp. 74–88). Oxford University Press.

[38] Masudi, F. (2020, June 21). UAE premium schools most at risk of losing students, experts warn. *Gulf News*. https://gulfnews.com/uae/education/uae-premium-schools-most-at-risk-of-losing-stud ents-experts-warn-1.72153597

[39] McCarthy, C. J., Lambert, R. G., Lineback, S., Fitchett, P., & Baddouh, P. G. (2016). Assessing teacher appraisals and stress in the classroom: Review of the classroom appraisal of resources and demands. *Educational Psychology Review, 28*(3), 577–603. https://doi.org/10.1007/s10648-015-9322-6

[40] McKinnon, M., Barza, L., & Moussa-Inaty, J. (2013). Public versus private education in primary science: The case of Abu Dhabi schools. *International Journal of Educational Research, 62*, 51–61. https://doi.org/10.1016/j.ijer.2013.06.007

[41] Metrailer, G. M., & Clark, K. N. (2022). Returning to school: Teachers' occupational and COVID-19-related stress and their perceptions of school climate. *Contemporary School Psychology*. https://doi.org/10.1007/s40688-022-00428-2

[42] Montes, F. J. L., Moreno, A. R., & Fernàndez, L. M. M. (2004). Assessing the organizational climate and contractual relationship for perceptions of support for innovation. *International Journal of Manpower, 25*(2), 167–180. https://doi.org/10.1108/01437720410535972

[43] Montgomery, C., & Rupp, A. (2005). A meta-analysis for exploring the diverse causes and effects of stress in teachers. *Canadian Journal of Education, 28*(3), 458–486. https://doi.org/10.2307/4126479

[44] Näring, G., Vlerick, P., & van de Ven, B. (2012). Emotion work and emotional exhaustion in teachers: The job and individual perspective. *Educational Studies, 38*(1), 3–72. https://doi.org/10.1080/03055698.2011.567026

[45] Ng, K., Klavina, A., Ferreira, J. P., Barrett, U., Pozeriene, J., & Reina, R. (2021). Teachers' preparedness to deliver remote adapted physical education from different European perspectives: Updates to the European Standards in Adapted Physical Activity. *European Journal of Special Needs Education, 1*(1), 1–16. https://doi.org/10.1080/08856257.2021.1872848

[46] Nicola, M., Alsafi, Z., Sohrabi, C., Kerwan, A., Al-Jabir, A., Iosifidis, C., Agha, M., & Agha, R. (2020). The socio-economic implications of the coronavirus pandemic (COVID-19): A review. *International Journal of Surgery, 78*, 185–193. https://doi.org/10.1016/j.ijsu.2020.04.018

[47] Nisa, C. F., Bélanger, J. J., Faller, D. G., Buttrick, N. R., Mierau, J. O., Austin, M. M. K., Schumpe, B. M., Sasin, E. M., Agostini, M., Gützkow, B., Kreienkamp, J., Abakoumkin, G., Abdul Khaiyom, J. H., Ahmedi, V., Akkas, H., Almenara, C. A., Atta, M., Bagci, S. C., Basel, S., . . . Leander, N. P. (2021). Lives versus Livelihoods? Perceived economic risk has a stronger association with support for COVID-19 preventive measures than perceived health risk. *Scientific Reports, 11*(1), 9669. https://doi.org/10.1038/s41598-021-88314-4

[48] OECD. (2019). *Teaching in the United Arab Emirates: 10 lessons from TALIS.* https://www.oecd.org/education/talis/Teaching_in_the_UAE-10_Lessons_from_TALIS.pdf

[49] Ridge, N., Kippels, S., & Shami, S. (2015). Private education in the United Arab Emirates and Qatar: Implications and challenges. *Sheikh Saud bin Saqr Al Qasimi Foundation for Policy Research.* https://doi.org/10.18502/aqf.0113

[50] Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software, 48*(2), 1–36. https://doi.org/10.18637/jss.v048.i02

[51] Russell, D. W. (1996). UCLA Loneliness Scale (Version 3): Reliability, validity, and factor structure. *Journal of Personality Assessment, 66*(1), 20–40. https://doi.org/10.1207/s15327752jpa6601_2

[52] Rutter, M. (2012). Resilience as a dynamic concept. *Development and Psychopathology, 24*(2), 335–344. https://doi.org/10.1017/S0954579412000028

[53] Schaufeli, W. B., Leiter, M. P., & Maslach, C. (2009). Burnout: 35 years of research and practice. *Career Development International, 14*(3), 204–220. https://doi.org/10.1108/13620430910966406

[54] School Education Gateway. (2020, June 8). *Survey on online and distance learning – Results*. European School Education Gateway. https://www.schooleducationgateway.eu/en/pub/viewpoints/surveys/survey-on-online-teaching.htm

[55] Sharif, T., Upadhyay, D., & Ahmed, E. (2016). Motivational factors influencing teaching (FIT) as a career: An empirical study of the expatriate teachers in the Emirates. *Journal of Developing Areas, 50*(6), 209–225. https://www.jstor.org/stable/10.2307/26415662 https://doi.org/10.1353/jda.2016.0148

[56] Skaalvik, E. M., & Skaalvik, S. (2010). Teacher self-efficacy and teacher burnout: A study of relations. *Teaching and teacher education*, *26*(4), 1059-1069. https://doi.org/10.1016/j.tate.2009.11.001

[57] Skaalvik, E. M., & Skaalvik, S. (2011). Teacher job satisfaction and motivation to leave the teaching profession: Relations with school context, feeling of belonging, and emotional exhaustion. *Teaching and Teacher Education, 27*(6), 1029–1038. https://doi.org/10.1016/j.tate.2011.04.001

[58] Sokal, L., Trudel, L. E., & Babb, J. (2020). Supporting teachers in times of change: The job demands-resources model and teacher burnout during the COVID-19 pandemic. *International Journal of Educational Research Open, 1*, 2666–3740. https://doi.org/10.1016/j.ijedro.2020.100016

[59] Sokal, L., Trudel, L. E., & Babb, J. (2021). I've had it! Factors associated with burnout and low organizational commitment in Canadian teachers during the second wave of the COVID-19 pandemic. *International Journal of Educational Research Open*, *2*(2), 2666–3740. https://doi.org/10.1016/j.ijedro.2020.100023

[60] Thomas, J., Raynor, M., & Bahussain, E. (2016). Stress reactivity, depressive symptoms, and mindfulness: A Gulf Arab perspective. *International Perspectives in Psychology: Research, Practice, Consultation, 5*(3), 156–182. https://doi.org/10.1037/ipp0000055

[61] Tschannen-Moran, M., & Hoy, A. W. (2001). Teacher efficacy: Capturing an elusive construct. *Teaching and Teacher Education*, *17*(7), 783-805. https://doi.org/10.1016/S0742-051X(01)00036-1

[62] World Health Organization (WHO). (2019). *Burnout as an occupational phenomenon: International classification of diseases*. www.who.int/mental_health/evidence/burn-out/en/ (accessed 30 June 2021).

[63] Yang, G., Badri, M., Rashedi, A. A., & Almazroui, K. (2018). The social and organizational determinants of school commitment of expatriate teachers. *Journal of Research in International Education*, *17*(1), 33–48. https://doi.org/10.1177/147524091876898 28