# THE ROLE OF MULTI-SCRIPTURALISM ON NOVEL ORTHOGRAPHY LEARNING

by

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Submitted in partial fulfillment of the

requirements for Departmental Honors in

the Department of Psychology

Texas Christian University

Fort Worth, Texas

May 3, 2021

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## ABSTRACT

Previous research has shown that multilingual individuals can learn to speak a new language more easily than those who are monolingual. However, no previous research has explored the relationship between existing orthography fluency, fluency within a print system, and letter-sound learning in a new alphabet. The present work explored the relationship between letter-sound learning ability and fluency in either one (mono-scripturalism) or multiple orthographies (multi-scripturalism). The grain size accommodation hypothesis suggests that it is easier to acquire a novel orthography that shares a similar grain size (length and complexity of smallest graphemes within an orthography) to the one an individual is fluent in. Thus, leading us to inquire if a multi-scriptural advantage exists. Young adult participants completed a background survey and battery of baseline assessments to determine eligibility, a self-paced training session to learn Hebrew consonants and vowels, a post-learning knowledge check, and a retention session seven days later. The ultimate goal of our research was to evaluate whether existing skill in reading more than one orthography provides an advantage for acquiring additional print systems. Our results demonstrate that multi-scripturalism may not provide an advantage in orthography learning, suggesting that despite overlapping brain networks, the mechanisms for acquiring language and reading function separately. Further, the grain size similarity between known and novel orthographies may have a stronger influence in orthography acquisition than the amount of orthographies one is fluent in. We plan to continue data collection to increase our sample size and evaluate grain size similarity and fluency in addition to scripturalism.

The Role of Multi-Scripturalism on Novel Orthography Learning

## Introduction

Over the past several decades, the United States has become increasingly diverse and multilingual. Between 1980 and 2009, the use of a language other than English at home increased by 148%, (Shin & Ortman, 2011). The U.S. Census Bureau estimates that approximately 22% of American citizens over the age of five years old speak a language other than English at home and predicts that lingual diversity in the United States will continue to rise based on current trends (U.S. Census Bureau, 2019). The increased rate of language learning may be attributed to the well-studied personal, professional, and cognitive benefits of multilingualism. Prior research suggests that multilingualism yields both personal and occupational benefits such as an increased salary (McMauns, 1983). Multilingualism allows individuals to communicate with a broader population which provides advantages in the job market, permits international business ventures, and extends additional opportunities to build personal relationships with others at home and abroad. Cognitively, research has demonstrated that multilingualism increases flexibility in problem solving and protects against cognitive decline. Bilinguals demonstrated increased divergent thinking and creativity when solving insight problems compared to monolinguals indicating an advantage in cognitive flexibility (Cushen & Wiley, 2011). Further, bilinguals developed dementia at an average of 4.5 years later than monolinguals, supporting that multilingualism protects against cognitive decline (Alladi et al., 2013). Multilingualism also provides advantages in executive functions. Specifically, bilingual adults responded faster than monolinguals on tasks that require response suppression or inhibitory control (Bialystok et al., 2004, Bialystok et al., 2006). Multilinguals exhibit cognitive superiority compared to monolinguals including reduced age-related cognitive decline, greater executive control, and increased creativity in problem solving (Alladi et al., 2013; Cushen & Wiley, 2011; Bialystok et al., 2004, Bialystok et al., 2006).

Importantly, bilingual individuals have an advantage in learning a new language compared to their monolingual peers. Multilingualism facilitated language acquisition among adults when learning phonologically unfamiliar words (pseudowords), and both English-Spanish and English-Mandarin bilingual groups recalled and recognized novel words at a higher rate than English monolinguals (Kaushanskaya & Marian, 2009). Further, Mandarin-Cantonese children performed more accurately on phonological awareness tasks and demonstrated superior tone and rime awareness when exposed to pseudowords, supporting that bilingualism produces a novel language acquisition advantage (Chen et al., 2004).

Although acquiring fluency in a new language as an adult is a challenging feat, it is even more challenging to acquire an additional orthography, or print system, as an adult. Despite this challenge, reading in multiple orthographies provides additional opportunities in a variety of contexts including engagement in foreign affairs, immigration or travel, business ventures, and expansion of one's social or professional circle. Unfortunately, the period for optimal reading acquisition, the time in which one can fluently learn an alphabet, typically ends around 18-19 years old (Abadzi, 1996). While the difficulty of learning a new orthography increases in adulthood, it is still possible to acquire new orthographies, albeit with reduced fluency (Abadzi, 2012). A growing number of researchers are interested in understanding the reasons for this reduced capacity for orthography learning in adulthood.

One reason that orthography learning may decline in adulthood is reduced plasticity in the brain's reading network. While the brain's language network is optimized for learning at birth, the reading network must develop with experience and requires years of practice to fully specialize (Dehaene-Lambertz, 2018). One component of the reading network, the visual word form area (VWFA), develops with reading acquisition among typical developing readers (Cohen et al., 2002). The VWFA, located in the left occipitotemporal region of the brain, develops specificity for print based on the individual's native orthography, with sensitivity to print appearing within the first months of exposure to print in pre-readers (Kuhl et al. 2003).

As the VWFA develops with reading acquisition, neural pathways form between the reading and language networks. Neural imaging studies found that the VWFA is significantly more connected to language areas in the brain such as Broca's area, the superior and lateral temporal lobe, and posterior inferior parietal lobe compared to the fusiform face area (Chen et al., 2019). Additional fMRI imaging revealed increased activity and connectivity between the VWFA and Wernicke's area, a region responsible for language comprehension, during semantic classification tasks (Stevens et al., 2017). Neural pathways between the VWFA and language areas identified by neural imaging techniques indicate that the reading and language networks overlap, reinforcing that these integrated networks may develop and change with reading acquisition. Additional research assessing the process of reading acquisition demonstrates connections between the reading and language networks. In childhood, acquiring literacy results in increased neural connections between the language and reading networks. After one year of reading instruction, six- to nine-year-olds showed increased activation in the posterior superior temporal region, a region associated with phonological representation, and increased activation in the VWFA while listening to their native language (Monzalvo & Dehaene-Lambertz, 2013). Adults also develop changes in their reading and language networks upon acquiring a new orthography. Functional connectivity between the VWFA and left lateral and fronto-parietal regions increased and decreased respectively with literacy in adults (López-Barroso et al., 2020).

The previous studies highlight that the reading and language acquisition networks interact with one another and suggest that these two communication networks may function similarly during acquisition of new language or reading systems.

Both the language (Newport, 1990) and reading systems (Abadzi, 1996) exhibit a sensitive period, in which the brain is optimally prepared to acquire new languages or print systems, respectively. Once these sensitive periods end, it is difficult to add new expertise. Thus, learning a novel language or orthography is more challenging during adulthood, however, as previously discussed, bilingual adults possess a language acquisition advantage compared to monolinguals. Given the novel language learning advantage in those who are multilingual and the overlap between the brain's language and reading networks, it is possible that such an advantage also exists in reading. Just as multilingual adults have an advantage in acquiring spoken language compared to monolingual individuals, multi-scriptual adults may exhibit a similar advantage for novel print systems. Thus, the current study was designed to evaluate whether a multi-scripturalism advantage exists in reading acquisition. We hypothesized that multi-scriptural typical developing adults would have an advantage in novel orthography learning compared to mono-scriptural adults.

## Methods

### *Participants*

A total of 80 participants were recruited from an online participant pool in the Psychology Department at Texas Christian University and from the community through mutual contacts and social media posts. All participants provided informed consent prior to beginning the study. First, participants completed a background survey related to participants' demographics, language and reading development, and aspects of their home life such as socioeconomic status and parental education. Next, participants completed a standardized battery of baseline assessments designed to measure performance IQ and reading ability (Table 1). Due to the COVID-19 pandemic, this initial session was conducted via Zoom for participant and researcher safety and lasted approximately 30 minutes to an hour. The standardized battery included one non-verbal IQ assessment and four reading assessments. Nonverbal IQ was assessed with the KBIT-2 (Kaufman, 2004). Reading ability was assessed with two subtests from TOWRE-2 (Torgesen et al., 2012), Sight Word Efficiency and Phonemic Decoding Efficiency, and two subtests from the WRMT-3 (Woodcock, 2011), Word ID and Word Attack. In addition to this standard battery, participants also completed an oral fluency measure to measure words per minute in English and additional orthographies in which they indicated proficiency. All assessments were recorded with informed participant consent and de-identified audio was saved so that scores could be reviewed and verified by a second researcher. All procedures were reviewed and approved by the Texas Christian University Institutional Review Board. Participants recruited from the TCU participant pool received course credit for their participation, while community participants received a $20 Amazon gift card.

To be eligible for the remaining study activities, participants were required to: a) be between the ages of 18-35, b) be a native English speaker, c) receive a standard score of 85 or more on the KBIT-2 assessment (Kaufman, 2004), d) receive a standard score of 90 or more on reading assessments, e) avoid medication that alters neurotransmitters, f) have no history of neurological disorders, and g) have no previous exposure to the Hebrew orthography. Finally, participants completed a Hebrew Letter ID pre-test to verify that they had no prior knowledge of the Hebrew orthography. Eligible participants scored below 5% correct on the Hebrew Letter ID pre-test ($0.00 \pm 0.00\%$). Of the 80 participants recruited, 1 was ineligible due to low non-verbal

IQ scores, 12 were ineligible due to low reading assessment scores, 37 were ineligible due to exclusionary medication, history of neurological disorders, or presence of neurological disorders, 1 was ineligible due to non-native English speaking, 1 was ineligible due to previous exposure to Hebrew, and 1 was ineligible due to age restrictions. Thus, 27 participants were eligible to participate in the remaining study activities including 16 mono-scriptural participants and 11 multi-scriptural participants. Of the 27 participants that were eligible, 8 were excluded due to scheduling issues or failure to complete the study resulting in a final sample of 10 mono-scriptural and 9 multi-scriptural participants.

*Training Program*

Eligible participants completed a 30-minute self-paced training session to learn a small set of four consonants and four vowels in Hebrew (Table 2). The module was custom coded and administered using Gorilla (Anwyl-Irvine et al., 2019). The training module was designed to mimic best practices in well-documented and marketed orthography training programs such as Duolingo (Duolingo, Inc., 2019) as well as previous orthography learning research in our lab (Thakkar et al., 2020). Participants completed six unique training blocks and each block consisted of an exposure section and a knowledge check section. During exposure, participants viewed a novel letter on the screen for three seconds, with simultaneous audio indicating the correct pronunciation. Audio recordings were made by a female, native English speaker and have been used in our prior studies of Hebrew orthography learning (Thakkar et al., 2020). Following five presentations of each letter, participants completed a short two-part knowledge check section to ensure learning and attention to the training. First, participants listened to an audio clip of a short speech sound and were instructed to choose the correct grapheme (letter symbol) from four possible options. Second, participants were shown a grapheme and instructed to type in the consonant phonetically. Participants experienced training on individual letters as well as consonant-vowel pairs.

*Learning and Retention Assessment*

Directly after participants completed the training session, participants completed the post-learning knowledge check (KC) which included three assessments to measure their acquired knowledge of Hebrew consonants and vowels (Thakkar et al., 2020). First, participants completed a Letter ID task, which was based on the Letter ID subtest of the WRMT-3 (Woodcock, 2011). In this task, participants were shown 16 Hebrew graphemes one at a time. They were instructed to select the correct consonant-vowel combinations from 8 options in a multiple-choice format. Correct answers were scored as 1 point and incorrect answers were scored as 0 points. The points were added together and translated into a percentage out of the 16 items. Participants next completed an Automaticity assessment (Figure 1) which was designed to mimic the Rapid Automatized Naming (RAN) subtest of the C-TOPP-2 (Wagner et al., 2013). In the Automaticity task, participants were presented with a nine-by-four grid of Hebrew graphemes. Participants were given 45 seconds to sound out as many consonant vowel combinations as they could. Performance was measured by the correct amount of consonant vowel combinations. Correct answers were scored as 1 point and incorrect answers were scored as 0 points. The points were added together and translated into a percentage out of the 36 total items. Finally, participants completed a Decoding assessment, which was designed to mimic the TOWRE-2 Phonemic Decoding Efficiency subtest (Torgesen et al., 2012; Figure 2). In the Decoding task, participants were shown a list of 16 Hebrew pseudowords and were instructed to sound out as many as they could. The list was presented for 45 seconds and this measure was scored based on the percent pseudowords pronounced correctly of the total 16 pseudowords.

Correct answers were scored as 1 point and incorrect answers were scored as 0 points. The points were added together and translated into a percentage. Participant audio was recorded using Gorilla for both the Automaticity and Decoding tasks.

Seven days after completing the training session, participants completed the retention (RT) session which lasted approximately 15 minutes. In the retention session, participants completed the same three Hebrew assessments they completed at post-learning knowledge check (Letter ID, Automaticity, and Decoding).

*Statistical Analysis*

All analyses were conducted using custom MATLAB programming. All descriptive statistics related to standardized assessments are reported as mean ± the standard deviation (SD). In our primary analysis, one-way ANOVA was used to evaluate the main effects of group (multi- x mono-scriptural) and time (KC x RT) on performance. Post-hoc *t*-tests were utilized to further investigate any significant main effects and interactions.

**Results**

All 19 participants completed the Letter ID measure of Hebrew performance; however, 1 mono-scriptural participant was removed from the Automaticity dataset and 2 participants were removed from the Decoding dataset due to inaudible recordings. We ran both ANOVA and post-hoc *t*-tests on each assessment task.

*Letter ID*

In the Letter ID measure, there was no main effect of group ($F$ (1,17) = 12.2, $p$ = 0.81). However, there was a significant main effect of time between post-learning knowledge check and retention ($F$ (1,17) = 0.06, $p$ = 0.003). Post-hoc *t*-tests demonstrated a significant decrease in Hebrew performance in mono-scriptural participants between knowledge check and retention on

Letter ID (KC: 86.25% ± 9.51%; RT: 63.75% ± 9.51%; $t$ (9) = 3.14, $p$ = 0.01) while there was no significant difference in performance across timepoints in multi-scriptural participants (KC: 85.42% ± 8.77%; RT: 70.14% ± 10.47%; $t$ (8) = 1.83, $p$ = 0.10; Figure 3A). There were no differences between mono-scriptural and multi-scriptural groups at post-learning knowledge check (Mono: 86.25% ± 9.51%; Multi: 85.42% ± 8.77%; $t$ (17) = 0.07, $p$ = 0.95) and retention (Mono: 63.75% ± 9.51%; Multi: 70.14% ± 10.47%; $t$ (17) =0.48, $p$ = 0.64; Figure 3A) on the Letter ID task.

*Automaticity*

In the Automaticity task, there was no main effect of group ($F$ (1,16) = 0.08, $p$ = 0.78), but there was a significant main effect of time ($F$ (1,16) = 9.31, $p$ = 0.007). After running post-hoc $t$-tests, mono-scriptural participants exhibited increased Hebrew performance between post-learning knowledge check and retention on the Automaticity task (KC: 36.42% ± 4.60%; RT: 50.31% ± 6.12%; t (8) = 4.47, $p$ = 0.002; Figure 3B). There was no significant difference in performance between post-learning knowledge check and retention for multi-scriptural participants on the Automaticity task (KC: 37.96% ± 7.86%; RT: 43.21% ± 10.96%; $t$ (8) = 0.96, $p$ = 0.36). There were no significant differences between mono- and multi-scriptural groups within time points at post-learning knowledge check (Mono: 36.42% ± 4.60%; Multi: 37.96% ± 7.86%; $t$ (16) = 0.18, $p$ = 0.86) and retention (Mono: 50.31% ± 6.12%; Multi: 43.21% ± 10.96%; $t$ (16) = 0.60, $p$ = 0.56; Figure 3B).

*Decoding*

In the Decoding task, there were no main effects of group ($F$ (1,15) = 0.31, $p$ = 0.59) or time ($F$ (1,15) = 4.25, $p$ = 0.06; Figure 3C).

*Impact of participant errors on orthography learning*

Due to concerns related to exclusionary factors among the initial data set, we excluded additional participants and re-analyzed the data set with ANOVA and post-hoc *t*-test analyses. We removed one participant who demonstrated a low reading score once their assessment was second scored, and removed an additional three participants who did not follow specific instructions on the Automaticity task (i.e. read from left to right rather than from right to left as one is instructed to in Hebrew). The results upheld previous conclusions. There was an effect of time ($F\ (1,12) = 11.2$, $p = 0.006$) but not group ($F\ (1,12) = 1.70$, $p = 0.22$; Figure 4) in Automaticity. Mono-scriptural participants demonstrated an increase in performance from post-learning knowledge check to retention (KC: 39.24% ± 3.99%; RT: 54.86% ± 4.30%; $t\ (7) = 5.35$, $p = 0.001$) while there was no significant difference between multi-scriptural participants over time (KC: 31.94% ± 6.37%; RT: 40.28% ± 13.05%; $t\ (5) = 1.05$, $p = 0.34$). There was no difference between mono- and multi-scriptural groups at post-learning knowledge check (Mono: 39.24% ± 3.99%; Multi: 31.94% ± 6.37%; $t\ (12) = 1.10$, $p = 0.29$) or at retention (Mono: 54.86% ± 4.30%; Multi: 40.28% ± 13.05%; $t\ (12) = 1.30$, $p = 0.22$). After removing the additional participants who did not follow specific directions, the mono-scriptural group increased Hebrew performance from KC to RT and there was no main effect of time on the multi-scriptural group. Overall, there were no group differences between mono- and multi- scriptural participants. These findings replicate our previous results. Thus, participant error did not impact our findings.

**Discussion**

The current study tested the hypothesis that a multi-scriptural advantage exists in novel orthography acquisition. Our current results suggest that multi-scripturalism may not influence novel orthography learning, as there were no significant differences between mono and multi-scriptural groups at either time point. Interestingly, while test performance did not change over time in multi-scriptural participants, mono-scriptural performance varied across time points based on the assessment given, such that performance decreased over time on Letter ID and increased over time on Automaticity. Overall, there were no differences between mono and multi-scriptural groups suggesting that fluency in multiple scripts may not provide an advantage in novel orthography acquisition. As previously discussed, research illustrates that bilinguals have an advantage in language acquisition in adulthood compared to monolinguals (Kaushanskaya & Marian, 2009). We hypothesized that this advantage might carry over to orthography acquisition, however, our current results suggest multi-scripturals do not have an advantage in reading acquisition, and that reading and language acquisition mechanisms may function separately. This leads us to question what additional factors may influence orthography learning.

*Effect of time on mono-scriptural performance*

The mono-scriptural differences in Hebrew performance at various tasks may be attributed to the differing format of the dependent measures. With respect to the Letter ID task, performance in the mono-scriptural group decreased over time while the opposite pattern was observed for the Automaticity task. The Letter ID assessment was given in a multiple-choice format while the Automaticity assessment required participants to read and produce Hebrew consonant-vowel pairs out loud. This difference in format drastically altered the level of difficulty for participants. While Letter ID assessed recognition, Automaticity assessed recall. Research has shown that recall recruits more brain activation and is therefore more challenging than recognition (Cabeza,1997). However, these prior findings would suggest that participants should have performed better on Letter ID compared to Automaticity, in contrast to our actual findings. There are two possible explanations for this finding. First, participants may have clicked through the Letter ID task with less focus to save time while they were forced to participate in the Automaticity task due to the audio recording. Since we did not observe our participants during testing, we cannot evaluate this possibility. Second, the differences in mono-scriptural performance over time at both Letter ID and Automaticity may be attributed to the small sample size. We are currently altering the KC and RT protocol so that participants are more directly supervised and to remove the difficulty differences across tasks to further probe this curious finding.

*Differences in language and orthography acquisition*

Language acquisition is innate to human development. From infancy, humans utilize statistical learning to pick up phonemes and distinguish which phonemes pair together to form words (Kuhl et al., 1992; Maye et al., 2002; Kuhl, 2004). By 9 months of age, proficiency in distinguishing native and nonnative speech sounds predicts future language performance (Kuhl et al., 2005; Kuhl et al., 2008), and 8-month-old infants are able to distinguish phonetic probability cues in an unfamiliar language (Pelucchi, et al. 2009). These studies demonstrate that humans are neurologically primed to acquire language and have designated neurons allocated to language comprehension (Wernicke's area) and production (Broca's area) from birth. Language acquisition is an innate process. In contrast, reading acquisition is relatively new in terms of evolution. Scholars estimate that the first writing system was developed between 3200 to 3400 B.C., which is relatively recent in terms of evolution (Ewan, n.d.). Since reading is an evolutionarily new skill, our brains are not equipped with neurons designated for reading from birth. As children learn to read, the brain reallocates neurons from the left face fusiform gyrus to become the visual word form area (Cohen et al., 2002). While language acquisition has been largely studied in neuroscience, researchers are just beginning to explore the mechanisms of reading acquisition. Since our current results suggest multi-scriptural readers may not have the same orthography acquisition advantage as multilinguals in language acquisition, this suggests that while the reading and language networks are connected, they may function differently. The present work builds on the limited literature addressing orthography learning to suggest that despite overlapping neural networks, the mechanisms for reading and language acquisition are separate.

*The role of grain size on reading*

An alternative explanation for advantages or disadvantages in reading acquisition may be attributed to the grain size accommodation hypothesis. This hypothesis posits that the ability to pick up a new orthography is dependent on the similarity between the grain size, the complexity or length of the smallest graphemes within an orthography, of the known orthography and the novel orthography (Lallier & Carreiras, 2018). Orthographies fall onto a spectrum from shallow (fine) to deep (course), where shallow orthographies consist of short and simple grain sizes and deep orthographies consist of long, complex, or irregular grain sizes (Ziegler & Goswami, 2005). Research has shown that within fine grain orthographies, individuals identify phonemes by directly mapping graphemes to phonemes within each word. In contrast, those fluent in coarse orthographies examine combinations of letters or even the whole word, rely on learned patterns, and reference their developed lexicon to guess the phoneme (Grainger & Ziegler, 2011). In other words, shallow orthographic readers break down each word into parts to sound it out while deep orthographic readers view larger portions of each word or the entire word as a unit to determine the correct pronunciation. With these differences in reading tactics, readers in various orthographic depths may approach reading differently when acquiring a new orthography. The grain size accommodation hypothesis suggests it is easier to learn a novel orthography if the grain size is similar to one's familiar orthography due to the similar approach of visual attention skills (covert spatial visual attention shifting and visual attention span) needed for phonological decoding. All of our participants were native English speaker and readers. English is defined as a deep orthography due to the long grain size and irregular grapheme-to-phoneme patterns (Seymour et al., 2003). Our multi-scriptural group included Spanish, Italian, and German readers, which are all shallow orthographies (Seymour et al., 2003). The present work trained participants in diacritic Hebrew. There are two forms of Hebrew, diacritic (vowelized) Hebrew which is shallow and undiacritic (unvowelized) Hebrew which is deeper (Schiff, 2012). All multi-scriptural participants in the present work were fluent in reading both a deep and shallow orthography. According to the grain size accommodation hypothesis, the multi-scriptural group could have an advantage in novel reading acquisition due to the similar grain size between their shallow orthography (Spanish, German, or Italian) and diacritic Hebrew. Our results did not demonstrate this effect; however, a larger sample size is needed to evaluate the role of grain size in orthography learning.

*Limitations*

It is important to note the limitations of this study. First, we had a small sample size. Only 19 participants completed all three parts of the study. Many participants were ineligible due to exclusionary medications including SSRIs for anxiety or depression and stimulants for ADHD. Participants taking medication that alter neurotransmitters were removed from the study based on the impact neurotransmitters have on learning. By excluding these participants, we reduce false conclusions on reading acquisition attributed to medications that alter learning rather than the effects of scripturalism. The GAPP Lab plans to continue data collection and recruit at least 40 participants before finalizing our data set and drawing firm conclusions from this study.

Second, due to the nature of the COVID-19 pandemic, our research was adapted to an online format to protect our participants and lab members, which introduced some errors in data collection. Research assistants were not present to administer the dependent measures in person, therefore, some participants missed specific instructions and made errors while completing the Automaticity task including reading from right to left instead of left to right. As we continue data collection in the future, we will host live sessions to ensure that participants follow specific directions on dependent measures.

Finally, our multi-scriptural participant pool included a limited range of orthographies. This study only included English, Italian, German, and Spanish readers. In the future, we hope to examine a wider range of orthographies to determine how grain size may influence reading acquisition. For example, it would be interesting to determine if orthographies that are similar in grain size or reading direction, such as Arabic, would show higher Hebrew performance compared to multi-scriptural individuals fluent in deep orthographies or accustomed to reading left to right.

*Future Directions*

Moving forward, the GAPP Lab will continue data collection and investigate the role of multi-scripturalism on novel orthography learning. We will also run secondary analyses in addition to ANOVA and post hoc t-tests to evaluate correlations between pre-training assessments (English reading assessments, IQ assessments, and oral fluency) and the single outcome measure of Hebrew performance. Previous research has examined the effects of multilingualism on language acquisition, however, there was a gap in the literature on scriptural fluency and orthography learning. The present work indicates that multi-scripturalism may not provide a learning advantage in reading acquisition, revealing that the reading and language acquisition mechanisms are inherently different. Reading acquisition is difficult but beneficial in adulthood, and we plan to examine grain size, fluency, and scripturalism to uncover variables that provide an advantage in novel orthography learning.

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**Tables**

Table 1. Summary of participant demographics and standard scores (M ± SD) from baseline English assessments (N = 19). *p< 0.05.

| Group | Mono-scriptural | Multi-scriptural | *t*-values |
|---|---|---|---|
| Number of Participants | 10 | 9 | N/A |
| Number of Females | 8 | 8 | N/A |
| Age | 21.41 ± 0.94 | 20.09 ± 0.44 | 1.23 |
| KBIT-2 | 105.89 ± 4.12 | 110.89 ± 4.64 | 1.52 |
| TOWRE-2 SWE | 105.78 ± 4.21 | 104.22 ± 3.38 | 0.28 |
| TOWRE-2 PDE | 111.33 ± 2.58 | 110.56 ± 2.24 | 0.26 |
| WRMT-3 Word ID | 104.78 ± 2.82 | 107.44 ± 2.62 | 0.87 |
| WRMT-3 Word Attack | 103.56 ± 3.67 | 106.6 ± 4.04 | 0.32 |
| WRMT-3 Oral Fluency | 225.78 ± 2.48 | 246.44 ± 6.63 | 2.57* |
| WRMT-3 Oral Fluency Orthography #2 | N/A | 128.11 ± 8.60 | N/A |
| Hebrew Pre-Test | 0.00 ± 0.00% | 0.00 ± 0.00% | N/A |

Table 2. Hebrew consonants and vowels learned during the training session and their corresponding sounds in English.

| Hebrew Letter | ה | י | ל | ר | ָ | ֶ | ֻ | ִ |
|---|---|---|---|---|---|---|---|---|
| Approximate English Translation | h | y | l | r | ah | eh | oo | ee |

**Figures**

Figure 1. Automaticity assessment in Hebrew based off of the English Rapid Automatized Naming (RAN) subtest.

| | |
|---|---|
| הָרָ | הִלָ |
| יִלָרֻ | יֶרָ |
| יֶהָלִ | לָרֶיָ |
| יָל | הִלֶרָ |
| הֶלֻ | רֻיָל |
| הָיֶ | יָרֶיָל |
| יָרִ | הִלָיֶרִ |
| יֻלֶ | רִלִהָ |

Figure 2. Decoding assessment in Hebrew based off of the English TOWRE-2 Phonemic Decoding Efficiency subtest.

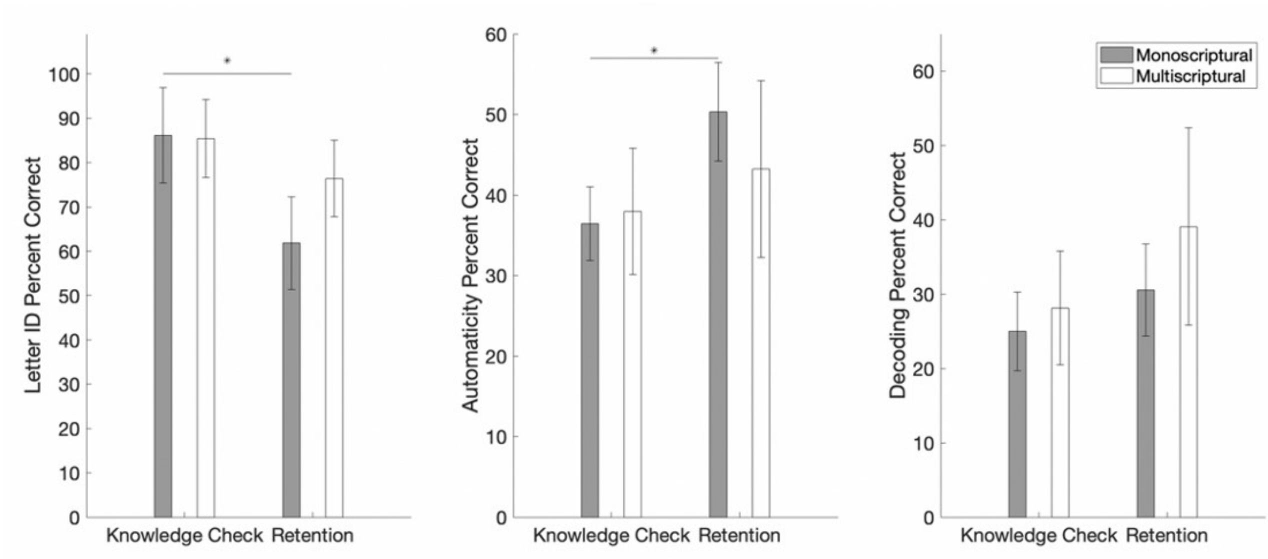


Figure 3. Hebrew Performance in both mono- and multi-scriptural participants on the Letter ID (A.), Automaticity (B.), and Decoding (C.) assessments. *p<0.05.

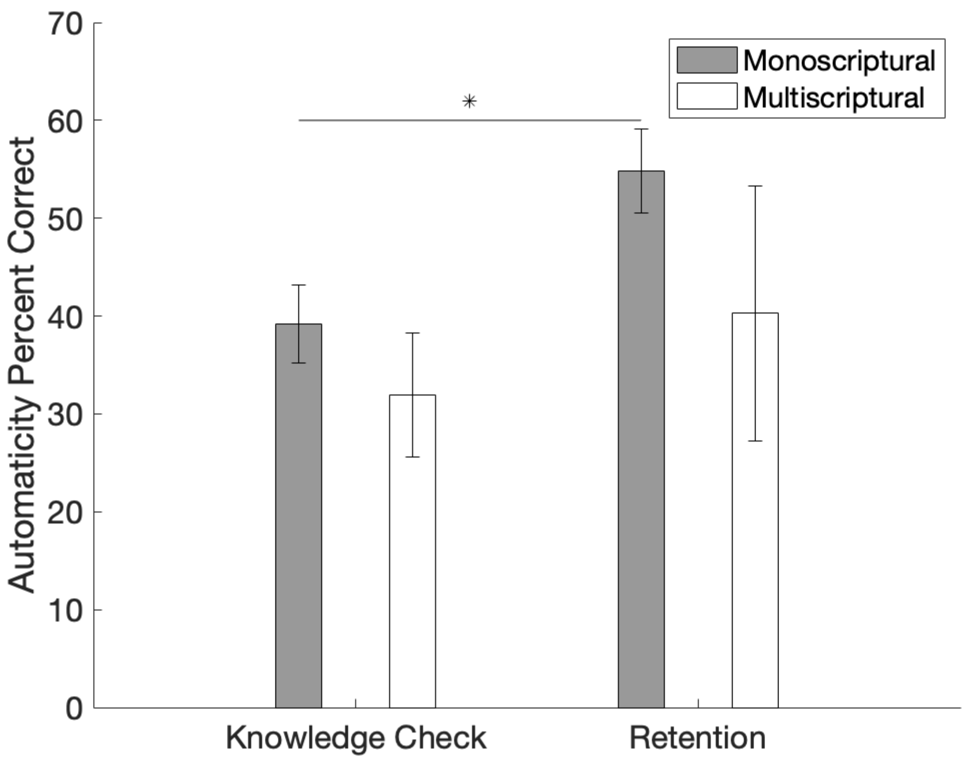


Figure 4. Hebrew performance on the Automaticity assessment excluding participants who read from left to right and excluding participants with low reading scores after second scoring. *p<0.05.