PHONOLOGICAL RECODING AND ORTHOGRAPHIC LEARNING: TESTING THE SELF-TEACHING HYPOTHESIS IN ADULTS

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Submitted to the Graduate Faculty of the

Kenneth P. Dietrich School of Arts and Sciences in partial fulfillment

of the requirements for the degree of

Master of Science

University of Pittsburgh

2015

UNIVERSITY OF PITTSBURGH

DIETRICH SCHOOL OF ARTS AND SCIENCES

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December 15, 2014

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Share (1995) hypothesized that readers can use phonological recoding as a mechanism to self-teach the acquisition of orthographic word knowledge. Support for his theory has come from studies conducted in young children, but it has yet to be tested in adults. Experiment 1 tested the ability of adults to acquire orthographic representations of novel word forms via self-teaching. English-speaking adults (N = 18) read 16 pseudowords embedded within a lexical decision task. Posttests revealed that adults could acquire item-specific orthographic knowledge of novel word forms through the use of self-teaching. Experiment 2 tested the degree to which limiting phonological recoding affects orthographic learning in adults. English-speaking adults (N = 19) performed a lexical decision task while concurrently articulating. Participants in Experiment 2 exhibited evidence of orthographic learning. However, participants in Experiment 1, who had full overt access to phonological recoding, exhibited stronger evidence of orthographic learning. Collectively, adult patterns of orthographic learning are comparable to patterns observed in children, as predicted by Share's item-based account of reading skill.

Keywords: Self-teaching; adult orthographic learning; phonological recoding; concurrent articulation; word acquisition

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

A critical aspect of reading development is the fundamental ability to recognize a printed word both quickly and efficiently (Gough, 1984). Adults are capable of accomplishing this feat at an extremely high success rate, predominantly due to their robustly developed lexical knowledge of frequently encountered words (Kuhn & Stahl, 2003; Perfetti & Hart, 2002; Walley, 1993). However, even skilled adult readers encounter new words on a regular basis (Nagy & Anderson, 1984; Nation, 2006). Although it is understood that the capacity for orthographic learning must persist throughout the lifespan, the research on orthographic knowledge acquisition has been heavily focused on young beginning readers. For this reason, the mechanisms that allow adults to learn new printed word forms are poorly understood. Since orthographic knowledge continues to accrue well beyond childhood, this is an important gap in current knowledge.

Share's (Share, 1995) model of reading development posits that individuals can acquire orthographic knowledge for novels word forms without feedback from external sources (e.g., without direct instruction). His self-teaching hypothesis argues that phonological recoding (i.e., using knowledge of letter-to-sound correspondences) is a key mechanism that allows readers to acquire knowledge of the orthographic information for unfamiliar word form (Jorm & Share, 1983; Share, 1995). According to Share, readers are afforded a learning opportunity when confronted by an unfamiliar word: with each successful decoding experience readers are able to independently learn the orthographic representation of unfamiliar word forms, thereby accruing word-specific orthographic information. Eventually, readers can rely upon the acquired word-specific representation, while conversely reducing their reliance on phonological recoding, to yield more rapid automatic processing for familiar words.

Share evaluated his self-teaching hypothesis by developing an orthographic learning protocol and testing it in children. In these studies, children were instructed to independently recode (i.e., read aloud) novel words (pseudowords) embedded four to six times each within fictional stories. Three days later, the children were tested on their acquisition of the orthographic knowledge for each pseudoword. Results from an orthographic choice task demonstrated that the children chose the previously experienced orthographic word forms (targets) significantly more often than alternative spellings with the same pronunciations (homophones) or other orthographic distractors (foils). Results from a spelling task demonstrated that the children produced the orthographic form of the targets significantly more often than the homophone or any other spelling. Results from a naming task demonstrated that the children read aloud the target items more quickly and accurately than the homophone items. Share extended this study with an additional experiment designed to limit phonological recoding during pseudoword learning. Pseudowords were embedded within a lexical decision task with half of the stimuli being read out loud, and the remaining half being read covertly while children overtly repeated a non-sensible phrase (e.g., “la la la”). This additional experiment was found to produce an attenuated effect of orthographic learning. Collectively, these results provided evidence of children's ability to acquire orthographic knowledge of a novel word form without direct instruction, and implicates phonological recoding as a mechanism of self-teaching.

Additional support for Share’s (1995) self-teaching hypothesis has come from subsequent studies that adopted his orthographic learning methodology. These studies, all conducted in children, explored a variety of factors that may influence orthographic learning. The results indicate that similar findings of self-teaching can be found across writing systems that vary in transparency (e.g., Hebrew (Share, 1999, 2004) and English (Bowey & Muller, 2005; Cunningham, Perry, Stanovich, & Share, 2002; Cunningham, 2006; Kyte & Johnson, 2006; Ricketts, Bishop, Pimperton, & Nation, 2011)); when novel word forms are experienced within a semantic context (e.g., story (K. Nation, Angell, & Castles, 2007; Ricketts et al., 2011)), simply read aloud as part of a meaningless list (Bowey & Underwood, 1996), or experienced as part of a lexical decision task (Kyte & Johnson, 2006; Share, 1999); and when children are tested at different ages (K. Nation et al., 2007). Such results provide strong evidence for the generalizability of the self-teaching hypothesis.

Subsequent studies have also adopted Share's (1999) methodology to test whether orthographic learning is mediated by phonological recoding, as hypothesized by Share. Consistent with Share's hypothesis, decoding skill has been found to be a significant predictor of children's orthographic learning (Cunningham et al., 2002; Cunningham, 2006; Kyte & Johnson, 2006; K. Nation et al., 2007). Furthermore, conditions that are assumed to limit phonological recoding (i.e., concurrent articulation of a meaningless utterance, such as "la") have also been examined within the self-teaching paradigm (Kyte & Johnson, 2006; Share, 1999). Kyte and Johnson (2005) found stronger orthographic learning when subjects performed a lexical decision task while also reading aloud each stimulus item, versus when they performed the lexical decision task with concurrent articulation demands. These studies provide notable support for Share's self-teaching hypothesis by revealing the importance of phonological recoding during the acquisition of orthographic knowledge.

While Share (1995) proposed the self-teaching hypothesis as the principle mechanism of ongoing reading development, evidence of this learning mechanism has yet to be tested within adult readers. This leaves unanswered whether or not adult readers acquire orthographic knowledge for new word forms using the same mechanisms as children. Share acknowledged that as readers acquire a growing body of orthographic knowledge, the mechanisms that support phonological recoding change. Consistent with this idea, as reading skill increases, phonological recoding becomes more automatic (Brown & Deavers, 1999; Garlock, Walley, & Metsala, 2001; Perfetti & Bell, 1991). Therefore, the profile of orthographic acquisition might differ substantially in adults than in children. However, Share posited that even though readers may exhibit differences in the representations and processes used to decode the phonological form of an unfamiliar printed word, orthographic knowledge acquisition nonetheless depends upon the successful recoding of the phonological form. If this is the case, then adults should exhibit behavioral signatures of orthographic learning that are similar to those exhibited by children, including reduced orthographic learning under conditions that limit phonological recoding.

2.0 EXPERIMENT 1

The current study investigates orthographic learning in adults by drawing upon behavioral tasks developed by Share (1999) and Kyte and Johnson (2006), which were designed to assess young children's orthographic learning of novel words. As a key feature of the design, the post-tests include stimuli that are either learned during a training phase (targets) or that have the same pronunciation but a different spelling (homophones). Accuracy and response time comparisons between targets and homophones are used as the primary measures of orthographic knowledge acquisition. The analyses will test whether orthographic learning effects previously documented in children can be observed in adults, and whether they are qualitatively similar in magnitude to those observed in children.

2.1 METHOD

2.1.1 Participants

Eighteen (11 female, 7 male) undergraduate students were recruited from the [redacted] Psychology department participant pool. All but one participant were right handed, with an age range of 18 to 22 years. Participants reported English as their spoken native language. Informed consent was provided using procedures approved by the [redacted] Institutional Review Board.

Upon completion of the entire study, participants were compensated with credit towards their Introduction to Psychology course.

2.1.2 Materials

The pseudoword pairs and real words fillers used in this experiment were borrowed from Kyte and Johnson (2006). The critical stimuli were a set of 16 pseudoword pairs with identical pronunciations but different spellings (i.e., words in each pair were homophones, such as meap and meep). Kyte and Johnson selected the pairs based on results from a pilot study that included 74 potential homophone pseudoword pairings. In their pilot study, participants were asked to guess the spelling of the phonological form for each pseudoword pair. The selected experimental pool of pseudowords displayed a spelling preference ratio of roughly 50:50 among the pilot group of the 22 fourth and fifth-grade students. An additional set of 32 real words was used as filler items in a lexical decision and naming task. Real word spelling length was matched to a specific pseudoword, and also shared at least 50% of its letters (e.g., meap and meat). Further details about the stimuli are described in Kyte and Johnson (2006).

Kyte and Johnson also made use of 32 orthographic pseudoword foil items that were matched to pseudowords for word length and number of syllables. These items were not included in their appendix materials. Therefore, orthographic foil items were created for the current study by following the letter substitution options described by Kyte and Johnson: (1) a consonant substitution of the target pseudoword, (2) and a consonant substitution of the homophone control. These foil items served as distractors in the orthographic choice task administered following training. Ten additional stimuli items (5 pseudowords and 5 real words) were created for exclusive use in the lexical decision and orthographic choice task practice trials.

2.1.3 Procedure

The experimental procedures were also modeled closely upon Kyte and Johnson (2006; see also Share, 1999). Participants completed two sessions conducted in a laboratory setting. During the first session participants completed a self-teaching phase. During the second session (seven days later), participants were tested on their acquisition of the previously exposed orthographic information. This was accomplished through the administration of three orthographic-learning posttests: an orthographic choice posttest, a spelling posttest, and a naming posttest. The time to complete each session ranged from 12-15 minutes.

All tasks were designed and executed using the E-prime software (Schneider, Eschman, & Zuccolotto, 2002). Participants sat roughly 15 inches in front of the computer screen, with the keyboard placed near the edge of the table. Trial items were displayed in black lowercase bold Arial 30-point font on a Dell computer screen. Trial items were presented in the center of the screen with a white background. Participant keypress responses were recorded using the keyboard, a microphone placed directly in front of the screen to acquire spoken responses, and pen and paper to acquire written responses. An audio recording of each session was collected using a digital audio program (Adobe Audition 2.0). Spoken responses were recorded and reviewed at a later time point to determine pronunciation accuracies.

Session 1: self-teaching phase. The self-teaching phase exposed participants to the target pseudowords by embedding them within a lexical decision task. Prior to performing the lexical decision task, 10 practice trials were completed to familiarize participants with the vocal procedures of the task and the keyboard correspondences. The experimental portion of the task involved 16 pseudoword targets and 32 real words. The pseudoword homophone pairs were divided into two lists, and the assignment of each list to a target or homophone condition was counterbalanced across participants. For instance, the first participant was exposed to List A spellings for the 16 pseudoword homophones (e.g., meap), while the second participant was exposed to List B spellings (e.g., meep). Counterbalancing was done to avoid item-level confounds that could affect responses to the pseudoword targets and their homophones.

For each trial, participants were exposed to either an English word or pseudoword target (one of the 16 items in the assigned pseudoword list). They were instructed to first pronounce each item aloud once into a microphone, and then to decide whether or not it was a real word. A fixation-cross (+) appeared on the screen for 1000 ms to alert participants to an upcoming orthographic item. Each item appeared directly after the fixation-cross for 400 ms, followed by the presentation of a letter mask (XXXXX) for 800 ms. A blank screen replaced the letter mask, which prompted participants to pronounce the item and then indicate their lexical decision via a keypress response, by selecting 1 for “word” or 2 for “nonword” on the number-pad extension of the keyboard.

Collectively, participants were exposed to a total of 192 randomized experimental trials. The 32 real words were displayed three times each (96 trials) and the 16 pseudowords were displayed six times each (96 trials). Participants were told that accuracy and not speed was essential for this task. No feedback was given to participants concerning correct responses to any of the displayed items.

Session 2: orthographic learning posttests. Three orthographic learning posttests were administered seven days after participants completed the self-teaching phase.

Orthographic choice. Participants completed an orthographic choice task in which they were asked to identify the previously experienced target pseudoword from a set of four choice items. Each target pseudoword (e.g., meap) was presented simultaneously with its homophonic spelling (e.g., meep) and two orthographic distractors (e.g., meab and meeb). A total of 16 experimental trials were administered (one for each pseudoword item experienced during the self-teaching phase), along with 10 practice trials (which involved the practice items experienced during the self-teaching phase).

For each trial, participants were exposed to four randomly positioned pseudowords presented vertically atop one another. A fixation cross (+) was presented on the screen for 800 ms to alert participants to the upcoming trial. Following the offset of the fixation-cross, the four pseudoword arrays appeared on screen until a participant's response was recorded. Responses were indicated by pressing the corresponding key on the number-pad: "9" for the top choice, "6" for the second choice, "3" for the third choice, or "." for the fourth choice. It was stressed that accuracy and not speed was important for this task.

Spelling. Participants were provided with a pen and paper and asked to correctly spell each of the pseudowords they experienced during the self-teaching phase. For each trial, a letter mask (XXXXX) appeared on the screen for 800 ms to alert participants to listen for the next trial. Pseudowords were then verbally pronounced once through the computer's audio speakers, and participants provided a written spelling of the heard item. Upon completion of the written response, the experimenter pressed the spacebar to advance the trial.

Naming. The final measure of orthographic learning required participants to verbally pronounce a set of items. For each trial, the item was either one of the 16 pseudowords experienced during the self-teaching phase (i.e., a target), one of the 16 homophone controls, or one of the 32 real word filler items. Each stimulus was presented three times to provide a stable reaction time (RT) measurement for each participant. For each trial, a letter mask (XXXXX) appeared on the screen for 1500 ms to alert participants to the upcoming item. Trial items appeared in the center of the screen for 1000 ms. Participants were instructed to read the item aloud once as soon as it appeared on screen. It was stressed that both speed and accuracy in pronouncing the item were important.

2.2 RESULTS

2.2.1 Lexical Decision

Participants demonstrated proficiency in phonological decoding and lexical status judgments by correctly pronouncing and classifying stimuli as words or pseudowords. Participants displayed a high degree of accuracy at phonological decoding (M = .99, SD = .02). Participants also achieved 99% accuracy in successfully deciding whether or not the item was a pronounceable English word (SD = 1, range = 96–100). Thus, as expected, adults were able to successfully decode and make lexical judgments at near ceiling levels (Table 1).

Table 1

Summary of performance (SD) on experimental tasks

Self-teaching phase	Target	Real Word	
Lexical decision percentage	99 (2)	99 (0)	
Lexical decoding percentage	98 (2)	99 (1)	
Orthographic learning posttests	Target	Homophone	Other
Choice task percentage	67 (15)	27 (15)	6 (7)
Spelling task percentage	63 (13)	28 (13)	9 (5)
Naming accuracy percentage	99 (2)	99 (1)	
Naming latency (ms)	547 (48)	551 (43)	

2.2.2 Orthographic Learning Posttests

For the orthographic choice task, participants demonstrated learning of the orthographic word form by successfully choosing the target pseudoword, presented among three distractor items, that they were exposed to one week earlier. If no learning occurred, then participants should select each of the four orthographic spellings at roughly the same rate (25%). However, item recognition for each of the word forms were not evenly distributed (Table 1). Moreover, target items were chosen significantly beyond chance, $t(17) = 12.15$, $p < .001$, suggesting that participants' preference of the target item was not a product of random selection.

To further investigate the acquisition of the orthographic word form, a paired-samples t-test compared the selection percentages of the orthographically correct spelling (target) and its phonological counterpart (homophone control). There was a significant difference between these two selection percentages, $t(17) = 5.89$, $p < .001$. These results indicated that on average, participants chose the target item ($M = .67$, $SD = .15$) more consistently than its homophone control ($M = .27$, $SD = .15$).

Exclusion of all orthographically correct trials (i.e., selection of target items) allowed for an analysis of error patterns. For this analysis, selection of the homophone item indicated participants' phonological accuracy. The other orthographic spellings (distractors) served as the phonologically incorrect choices. Of the 95 orthographically incorrect choices, participants selected the phonologically correct item ($M = .79$, $SD = .28$) more consistently than the other orthographic distractors' combined selection ($M = .21$, $SD = .28$). Participants' significant preference for selecting the phonologically correct item above the phonologically incorrect items is indicative of the occurrence of phonological learning during self-teaching in adults, $t(17) = 4.29$, $p < .001$.

For the spelling task, successful acquisition of the orthographic information was demonstrated by spelling the spoken form of the target pseudoword. Accuracy was measured on the spelling of the whole word. If no orthographic learning occurred then participants will show no preference for spelling the target word over its homophone control.

As displayed in Table 1, participants achieved 63% accuracy in producing the orthographically correct spelling (*SD* = 13, range = 38–88). Of the remaining orthographically incorrect spellings, 28% were homophone controls (*SD* = 13, range = 06–56), and 9% were neither of the phonologically correct pseudoword items (*SD* = 5, range = 0–19). Most notable of these results was the significant advantage that target spellings had over the homophone controls, with target pseudowords being spelled more than twice as often as the homophones, $t(17) = 5.86$, $p < .001$.

An investigation of errors patterns is also reported for the spelling task. Of the 106 incorrect spellings, participants spelled the phonological control item more often ($M = .74$, $SD = .15$) than spellings that did not preserve the correct pronunciation ($M = .26$, $SD = .15$). Performance results for error trials are indicative of participants' significant ability in reading skill $t(17) = 6.88$, $p < .001$. That is, when adults orthographically misspell a word, they would be expected to produce a spelling that preserves the phonology of the spoken stimulus.

For the naming task, successful acquisition of orthographic learning would be demonstrated by pronouncing the target pseudoword faster than its homophone control. Only RTs in which participants provided a correct pronunciation of the word form were included in the analysis. One participant consistently pronounced each item at an exceedingly slower pace than the group average. Further inspection revealed that this participant's latency scores were well above the outlier threshold (above 2.5 SD of the group mean). Accordingly, this participant's naming data were excluded from further naming task analyses.

As shown in Table 1, participants displayed no significant difference between correctly pronouncing the target (*M* = .99, *SD* = .02) and homophone controls (*M* = .99, *SD* = .01). Further examination of the item type differences revealed faster latency scores for pseudowords learned during the self-teaching phase (*M* = 547, *SD* = 48) over their homophone controls (*M* = 551, *SD* = 43), however this difference was not significant $t(16) = -1.49$, $p = .175$. In general, an investigation between target and homophone pseudoword latencies revealed no significant preference for pronouncing the target item more accurately or faster than its homophone control.

3.0 EXPERIMENT 2

A second experiment was conducted to explore the assumption that adults rely upon phonological recoding to independently acquire specific orthographic knowledge of unfamiliar words. More precisely, Experiment 2 investigated orthographic learning under conditions that limit phonological recoding. Phonological recoding was restricted during the self-teaching phase by having participants concurrently articulate a nonsense syllable while encountering the target pseudowords and filler word items. In addition, this experiment tested the degree to which limiting phonological recoding can influence orthographic learning by comparing the results from participants in Experiment 2 (Concurrent Articulation group) to those from participants in Experiment 1 (Read Aloud group).

3.1 METHOD

3.1.1 Participants

Nineteen (7 female and 12 male) undergraduate students were recruited from the [redacted] psychology department participant pool. Sixteen of the participants were right handed, with an age range of 18 to 22 years. All participants reported English as their spoken native language. Informed consent was provided using procedures approved by the [redacted] Institutional

Review Board prior to their participation. Upon completion of the entire study, participants were compensated with credit towards their Introduction to Psychology course.

3.1.2 Materials

All task stimuli, and measures of orthographic knowledge acquisition were adopted and replicated from Experiment 1.

3.1.3 Procedure

All task procedures were adopted and replicated from Experiment 1, with the addition of a concurrent articulation task during the self-teaching phase.

Session 1: self-teaching phase. The lexical decision task procedures and stimuli from Experiment 1 were used in Experiment 2. The sole variation in Experiment 2 was the inclusion of concurrent articulation during trial-item exposures. Rather than reading the word or pseudoword overtly during lexical decisions, participants had to repeatedly articulate the irrelevant syllable “la” during the lexical decision process. For each trial, participants were instructed to repeatedly speak the syllable “la,” at their normal conversational speed, from the onset of the fixation-cross (fixation-trial-mask) until the onset of the blank screen (decision).

Session 2: orthographic learning posttests. All of the stimuli and procedures from the orthographic posttests in Experiment 1 were used in Experiment 2.

3.2 RESULTS

3.2.1 Lexical Decision

Overall, participants were 97% accurate in successfully deciding whether or not the task-item is an English word (*SD* = 4, range = 84–100). This result suggests that limiting explicit decoding does not disturb the ability of most adults to proficiently judge the lexical status of a novel word (Table 2).

Table 2

Summary of performance (SD) on experimental tasks

Self-teaching phase	Target	Real Word	
Lexical decision percentage	96 (6)	97 (2)	
Orthographic learning posttests	Target	Homophone	Other
Choice task percentage	52 (13)	24 (8)	24 (13)
Spelling task percentage	51 (11)	30 (11)	19 (11)
Naming accuracy percentage	99 (3)	99 (3)	
Naming latency (ms)	543 (46)	550 (46)	

3.2.2 Orthographic Learning Posttests

For the orthographic choice task, evidence of orthographic learning was also confirmed for the concurrent articulation group. As indicated in Table 2, target items were recognized significantly beyond chance levels, $t(18) = 9.37$, $p < .001$. Furthermore, there was a significant difference between target and homophone item recognition, $t(18) = 7.29$, $p < .001$. That is, target items (*M*

= .52, *SD* = .13) were recognized more frequently than their homophone controls (*M* = .24, *SD* = .08). These results suggest that the acquisition of the orthographic word form is still achievable even under conditions that limit phonological recoding.

An examination of error patterns revealed no indication of phonological learning. Participants made a total of 143 orthographic errors, distributed more or less evenly between the homophone and the other orthographic distractors. When visually presented amongst other orthographic distractors, concurrent articulation seems to restrict adults' ability to select the phonologically plausible spelling (*M* = .54, *SD* = .04) of a newly learned word $t(18) = .989$, $p = .336$.

For the spelling task, as shown in Table 2, participants achieved 51% accuracy in spelling the whole-word target item (*SD* = 11, range = 31–69). Of the remaining orthographically incorrect spellings, 30% were homophone controls (*SD* = 11, range = 6–50), and 18% were neither of the phonologically correct spellings (*SD* = 11, range = 0–38). As anticipated, participants were able to successfully demonstrate orthographic learning by spelling the target item significantly more often than its homophone control, $t(18) = 4.52$, $p < .001$.

Error patterns were also analyzed for the spelling task results. Of the 149 incorrect spellings, participants that learned target pseudowords under concurrent articulation spelled the phonological control item more often (*M* = .62, *SD* = .21) than spellings that do not adhere to the correct phonological form (*M* = .38, *SD* = .21). These results suggest that when orthographically misspelling a word, concurrent articulation during learning does not significantly influence an adult's tendency to generate a homophone of the correct orthographic word form, $t(18) = 2.55$, $p < .05$.

For the naming task, participants under concurrent articulation were able to successfully pronounce both target (M = .99, SD = .03) and homophone controls (M = .99, SD = .03) at a near perfect rate, displaying no significant difference in accuracy between item types (Table 2). A latency analysis showed that participants read target items (M = 543, SD = 46) faster than their homophone controls (M = 550, SD = 46), however this difference was not significant $t(18) = -1.79$, $p = .09$. Similar to findings in Experiment 1, in Experiment 2 no evidence was found for naming the target items faster or more accurately than the homophone controls.

3.2.3 Between Subjects Analyses

An examination of posttest performance differences between the Read Aloud (Experiment 1) and Concurrent Articulation (Experiment 2) group's posttest performances provided a means to further explore the effect of limiting phonological access during reading. An independent-samples t-test was conducted, for each of the posttests, to compare the target mean values between the read aloud and concurrent articulation groups.

Self-teaching performances. Overall, both groups achieved proficient levels of performance in their judgments of lexicality. The concurrent articulation group displayed a slightly reduced lexical decision accuracy percentage (M = .96, SD = .04) with more variability than their read aloud counterpart (M = .99, SD = .01). Although the concurrent articulation group were still able to consistently classify the orthographic word form at a near ceiling level, these group percentages, using Welch statistic due to unequal variances across the two group means, were found to be statistically significant $F(1, 19.896) = 9.775$, $p < 01$. This difference may reflect the potential utility of phonological recoding as a source of information for lexical decisions (Parkin, 1982).

Orthographic learning performances. Orthographic learning results between the two experiments were analyzed to examine the degree to which accurate phonological recoding affects self-teaching in adults (Figure 1). The overall performance of the orthographic posttests indicated that having complete access to phonological recoding during self-teaching allows for greater orthographic learning.

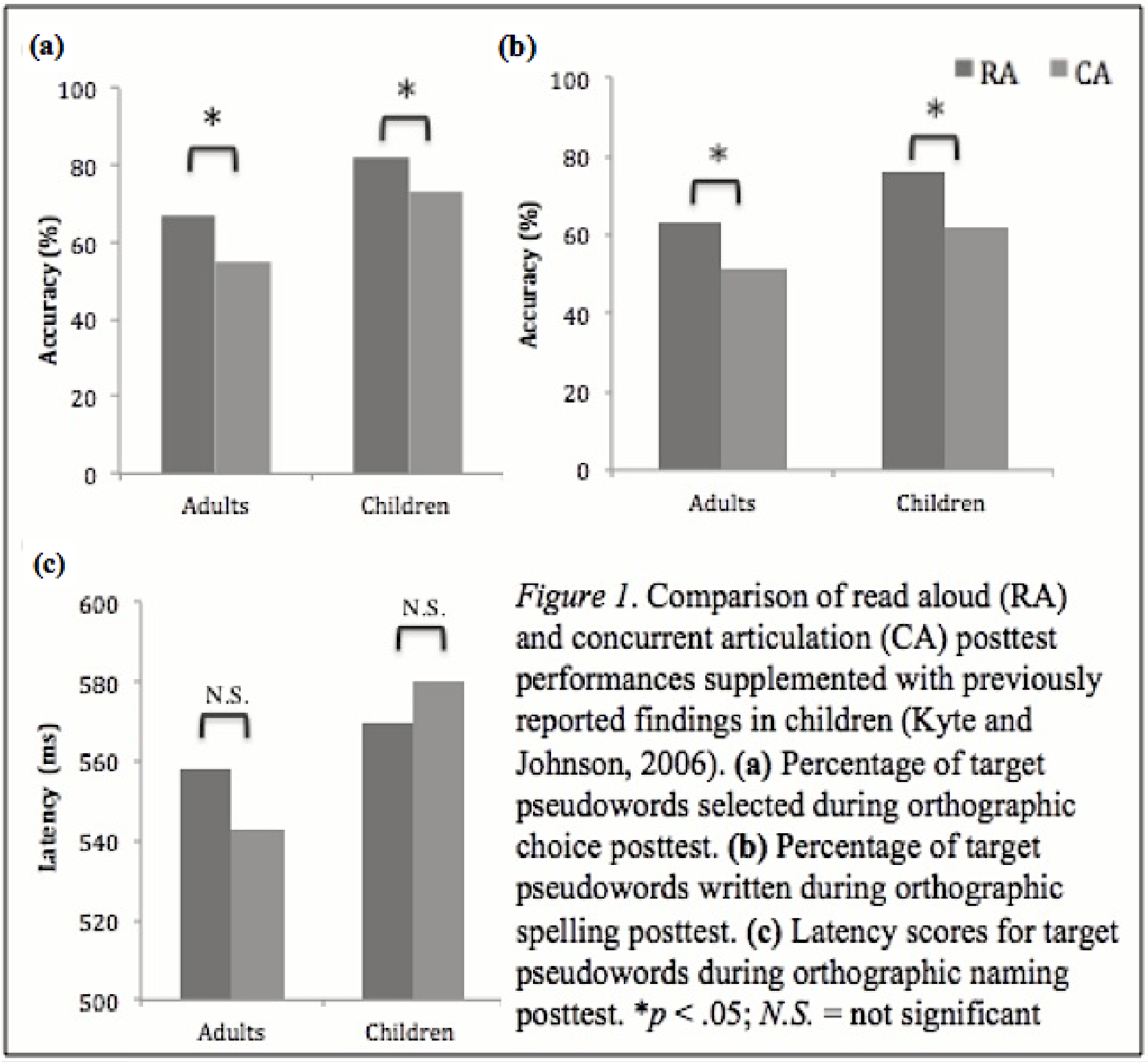

Figure 1. Comparison of read aloud (RA) and concurrent articulation (CA) posttest performances supplemented with previously reported findings in children (Kyte and Johnson, 2006). **(a)** Percentage of target pseudowords selected during orthographic choice posttest. **(b)** Percentage of target pseudowords written during orthographic spelling posttest. **(c)** Latency scores for target pseudowords during orthographic naming posttest. $^*p < .05$; *N.S.* = not significant

For the orthographic choice posttest, participants that had explicit access to phonological recoding (Read Aloud group) during the self-teaching phase were more accurate in recognizing the target word form seven days later, $t(35) = 3.26$, $p < .01$. The effect size of this difference ($d = 1.07$) was found to exceed Cohen's (Cohen, 1988) convention for a large effect ($d = .80$), suggesting a very high practical value in adult's reading aloud a newly encountered word to enhance their acquisition of the orthographic word form. Furthermore, the addition of concurrent articulation demands affected participants' phonological recall of the experienced pseudowords. For the Read Aloud group, 79% of the orthographic choice errors were phonologically accurate (homophones). In contrast, a mere 54% of the Concurrent Articulation group's orthographic choice errors were phonologically accurate. These orthographic error patterns were found to be significantly different $t(35) = 3.21$, $p < .01$, with the Read Aloud group having a clear advantage in recognizing the phonologically correct word form.

For the spelling posttest, participants that read the word aloud during the learning phase were 12% more accurate in spelling the correct pseudoword than those who learned the pseudoword while concurrently articulating. This difference was significant $t(35) = 3.02$, $p < .01$, with an observed large effect size ($d = .99$) according to Cohen (1988). In addition, learning conditions under concurrent articulation affected participants' orthographic spelling errors. In comparison to the read aloud group, participants under concurrent articulation displayed a 12% decrease in spelling the phonologically correct form of the heard pseudowords, $t(35) = 2.07$, $p < .05$.

For the naming posttest, no distinguishable group differences were found between the Read Aloud and Concurrent Articulation groups. The average latencies for target pseudowords were 4 ms slower for the Read Aloud group, however this small difference was not significant, $t(34) = .227$, $p = .822$. Adults from both groups achieved a naming accuracy score of at least 91%, demonstrating their high degree of proficiency in pseudoword naming. Target naming errors were not significantly different between the Read Aloud 1% (*SD* = 2) and Concurrent Articulation group 2% (*SD* = 3).

4.0 CONCLUSION

An individual's mental lexicon continues to expand well past childhood, when literacy is typically first acquired. Despite this fact, orthographic learning in adults has received little attention. Our study explored this issue by conducting two experiments that were motivated by Share's (1995) self-teaching model of reading development. Experiment 1 applied the methodology developed by Share (1999) and modified by Kyte and Johnson (2005) to characterize the orthographic learning profile of adult readers. Experiment 2 investigated how limiting phonological recoding influences adult's ability to acquire new word forms. By characterizing the profile of orthographic learning in adults, we aimed to provide critical insights into the mechanisms that support the "lifespan development" of orthographic knowledge (Alexander, 2005).

Overall, evidence of orthographic learning was found in both experiments, which is indicative of adults' ability to acquire orthographic knowledge of a new word form through the self-teaching mechanism of phonological recoding. Orthographic learning was most robustly observed for two of the posttests (choice and spelling), with stronger patterns of acquired word-specific knowledge for participants who had complete access to phonological recoding during word learning. That is, concurrent articulation during the phonological recoding of a new word reduced adults' orthographic learning, but did not completely abolish their ability to acquire new word forms. There was no significant evidence of orthographic learning in naming posttest for either experiment. Previous studies using similar methods have reported inconsistent findings for the naming task (Kyte & Johnson, 2006; Share, 1999, 2004; for opposing results see Cunningham et al., 2002). Intralist priming (i.e., choice and spelling posttests primed adults for the un-encountered homophone control), sample size power, and considerable variability in participant reading pace have all been noted as probable sources of the unreliable naming task results (Kyte & Johnson, 2006; Share, 1999, 2004).

In addition to learning the orthographic representations of the novel words, participants in Experiment 1 displayed proficient learning of their phonological representations, supporting the notion of phonology's irrepressibility (Harm & Seidenberg, 1999; Perfetti & Bell, 1991; Perfetti, 1992; Share, 1999). Contrastingly, participants in Experiment 2 displayed a loss of phonological learning, suggestive of concurrent articulation's practical use in limiting phonological processing during novel word learning. For the choice task, participants did not exhibit a phonological preference in their errors, suggesting that their decisions were primarily guided on the basis of orthographic similarity. For the spelling task, adults under concurrent articulation were able to successfully spell the phonological form (homophone) of the word more consistently than any other incorrect spelling. However, their success at reproducing the phonological representation of the word form can be attributed to their advanced proficiency in spelling (Garlock et al., 2001). That is, advanced readers can rely on phoneme-grapheme correspondences to successfully spell a heard item despite having been visually exposed to that word under conditions that limit phonological recoding. Collectively, the differences between these two groups provide evidence for the benefits in adults' reading a novel word aloud to aid in the strengthening of that word's phonological traces. Furthermore, concurrent articulation produced a loss of phonological learning concomitant with a reduction in orthographic learning, providing support for Share's theory in that phonological recoding is indeed a mechanism of self-teaching.

Despite clear differences in reading skill level (Carroll & White, 1973; Grosjean & Frauenfelder, 1996; Kruidenier, 2002), adults' orthographic learning of a novel word form is intriguingly of similar magnitude to that observed in children. Figure 1 shows a comparison of the current study's primary orthographic posttests' measures for adults to that of Kyte and Johnson's (2006) study with children. Of the three orthographic posttests, both adults and children display strong evidence of orthographic learning for the choice and spelling posttests. Moreover, adults seem to show similar effects of concurrent articulation, in terms of the magnitude in disruption of orthographic learning (Figure 1a,b), and the loss of phonological learning. This comparability between adults and children is of critical importance because it sheds light upon the role of phonological processing in reading development across the lifespan.

Share (1995) argued that phonological recoding is a critical mechanism of self-teaching and that this mechanism is beneficial throughout all ages. However, he also argued that this process may change as reading skill develops. That is, it is possible that skilled readers may use different mechanisms of phonological recoding that are not interrupted by speech-based processes. For instance, phonological recoding might be done by analogy to preexisting words that are known (e.g., Tath & Math), rather than a serial letter-by-letter strategy. To this extent, it might be thought that advanced readers, such as adults, may not rely as heavily upon a speech-based mechanism for phonological recoding as do children. If this were indeed the case, then in comparison to findings in children, adults' pattern of orthographic learning should be different, or at least less disrupted by concurrent articulation. However, our comparisons between the patterns and effect sizes of orthographic learning for adult and child readers illustrates otherwise.

As early-stage readers, children are indeed working harder and spending more intentional resources towards phonological recoding, but it seems that for both children and adults, some kind of speech-based mechanism is significantly beneficial for orthographic learning. More generally, the similarities between children and adults indicate that differences in decoding skill can be decoupled from the orthographic learning that ensues when an unfamiliar printed word is correctly identified. Accordingly, the primary challenge faced by most individuals who are less skilled at decoding may be word identification, not orthographic learning.

This study possesses a number of limitations that should be addressed in future investigations. Individual differences in learning or even reading skill may be a factor of orthographic learning above and beyond phonological recoding in adult readers. Cunningham and colleagues (2002) used regression-based approaches to examine possible factors of children's orthographic learning. Their findings revealed a strong relationship between orthographic processing ability and orthographic learning and, most notably, that this relationship was not mediated by decoding skill. The self-teaching hypothesis proposes phonological recoding as an important mechanism of orthographic learning, while acknowledging that there are additional lexical principles that may contribute to a reader’s acquisition of whole word information. Future studies may want to consider these factors by employing a within-participant design with the inclusion of additional cognitive and reading skill measures as predictors of orthographic learning in adults. Another caveat with the current study concerns the issue of whether or not adults will display evidence of self-teaching when phonological recoding is not required. To address this issue in children, Bowey and Muller (2005) had third graders silently read stories, and they found strong evidence of orthographic learning when they later tested the children’s orthographic acquisition of the novel words embedded within each story. Since phonological recoding occurs more automatically in adults as compared to children, it is possible that adults would not draw upon speech-based decoding mechanisms under silent reading conditions, which could in turn reduce their orthographic learning of novel words. By comparing orthographic learning differences between covert, overt, and concurrent articulation conditions in adults, the boundary conditions of phonological recoding during self-teaching could be explored more fully. Finally, the observed similarities between adults and children's orthographic learning were not statistically assessed, and should therefore be regarded as qualitative observations.

The findings from this research offer sound contributions towards understanding an individual's continued development as a reader. This development is not finished during the early years of learning, as individuals continuously encounter new words throughout their lifespan. Our findings provide clear evidence of orthographic learning via self-teaching in adult readers of English. Under conditions that limit phonological recoding (concurrent articulation), we observed reduced effects of orthographic learning, and a loss of phonological learning. Not only did adults demonstrate the ability to independently acquire word-specific orthographic information and their phonological representations, but they also showed effects similar in size to those observed in children. This study suggests that adults exhibit a pattern of orthographic and phonological learning that parallels the patterns observed in young children, due to the fact that both adults and children utilize speech-based phonological recoding as a mechanism that supports orthographic learning.

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