Orthographic Learning in Adults Through Overt and Covert Reading

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Orthographic learning is the basis of fluency in spoken and written communication. After achieving basic literacy, we continue to expand our orthographic knowledge, learning new words throughout our lifespan. Here, we provide an empirical foundation for the possibility that the processes of orthographic learning might differ in children and adults. Building on established literature, we map the behavioral patterns of adult word learning. In the first experiment, we compare the amount of orthographic learning attained following an independent story reading task with two modes of reading: overt and covert reading. In the second experiment, we add a concurrent articulation and concurrent finger tapping condition to assess if suppression of articulation reduces the amount of learning achieved in covert reading. We use a paradigm commonly employed in studies involving children to allow for cross-study comparisons and identify a critical departure in the behavioral phenotype of adult word learning. Our findings raise important questions about the nature of orthographic learning and the manner in which adult readers should learn the visual form of new words.

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Preface

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1.0 Introduction

Orthographic learning is fundamental to reading development throughout the lifespan (Share, 1995). For children in the early stages of acquiring an alphabetic writing system, most printed words are unfamiliar visual forms that can be decoded to access a known word in their spoken language. But even skilled adult readers regularly encounter new words (Ramscar, Hendrix, Shaoul, Milin, & Baayen, 2014). In most cases, these are new vocabulary words, in which the orthographic, phonological, and semantic knowledge is all unfamiliar. However, a likely phonological form can still be decoded using the alphabetic principle and comparison to visually similar known words. Individuals use their reading experience to build their capacity for skilled visual word identification, a fundamental ability that underlies skilled comprehension.

One prominent theory of how readers acquire visual word identification skill is the self-teaching hypothesis (Jorm & Share, 1983; Share, 1995). According to this theory, orthographic knowledge is acquired through phonological recoding, a process by which readers engage in print-to-sound translation to decode novel printed word forms to their spoken counterparts. Every time an unfamiliar printed word is successfully decoded, a reader is presented with an opportunity to learn the specific orthographic representations of the word without explicit instruction. Successful recoding allows a reader to independently identify novel words, acquire word-specific orthographic representations, and grasp orthographic regularities in the language.

A salient feature of self-teaching through phonological recoding is that it is considered to be an *item-based* process, as opposed to *stage-based* (Share, 1995). In a *stage-based* construct, word recognition of printed words is conceptualized as a process that changes in development from phonological to visual in nature. In contrast, an *item-based* view argues that the process of word recognition is determined by word exposure frequency. That is, regardless of the stage of reading development, more frequent items will be processed visually, while less frequent items will require involvement of phonology. For most reading ability levels, novel word forms and less familiar items should thus necessitate the use of phonological recoding, while more familiar items will likely make use of visual recognition (Share, 1995).

1.1 Orthographic Learning in Children

Most of the existing support for the self-teaching hypothesis comes from work on beginning readers who are children. There is evidence to suggest that orthographic knowledge is acquired independently (i.e., without explicit instruction) (Share, 1999, 2004; Nation, Angell & Castles, 2007; Ricketts, Bishop, Pimperton & Nation, 2011; Cunningham, Perry, Stanovich & Share, 2002;), and that phonological recoding plays a critical role in that process (Kyte & Johnson, 2006; Share, 1999). Many of these studies explored the self-teaching hypothesis using an experimental paradigm first developed by Share (1999). In this paradigm, children are asked to read aloud stories (overt reading) that contain pronounceable pseudowords. After some amount of time, posttests to assess orthographic learning are administered: an orthographic choice task, a spelling task, and a naming task. In a typical orthographic choice task, participants are instructed to identify the pseudoword they have seen from a set of four items. The choice set includes the orthographic form of the recently learned pseudoword (the target), its homophone (an alternative spelling of the same spoken word, e.g., *meep* and *meap*), and two visually similar items (e.g., *meeq* and *meaq*). The presence of the homophone is a critical manipulation as distinguishing the correct word from its homophone indicates that specific orthographic representation has been acquired. In a spelling task, target pseudowords are pronounced and participants are required to spell them. In the naming task, participants are asked to name the target pseudowords and their homophones, and both latency and accuracy are coded. Overall, past studies using variations of this basic protocol found that orthographic knowledge was acquired after independent reading of pseudowords with target spellings recognized more frequently and spelled more accurately than the homophones (e.g., Cunningham, Perry, Stanovich, & Share, 2002; Cunningham, 2006; Kyte & Johnson, 2006). The outcomes of the naming task have been inconsistent; some studies have found evidence of learning with targets named more quickly than their homophones (Bowey and Muller, 2005; Bowey and Miller, 2007), but others have not (Kyte & Johnson, 2006; Share, 2004).

A subset of these studies has also established the importance of phonological recoding in orthographic learning. For example, in their study of overt reading, Share and colleagues (1999) experimentally manipulated access to phonology with concurrent articulation, a technique thought to suppresses the use of inner speech to produce the phonological form of written stimuli (Baddeley, 1986; Baddeley & Hitch, 1974). They presented pseudowords to child readers of pointed Hebrew. One group of participants read short texts containing the unfamiliar pseudowords overtly while a second group was exposed to the items in the context of a lexical decision task with concurrent articulation. Afterwards, participants were assessed for orthographic learning. For the overt reading group, learning was observed on all three posttest measures. For the concurrent articulation group, some learning was evident in the choice and spelling task but not in the naming task. Compared to the overt reading group, participants in the concurrent articulation group exhibited reduced performance in the choice task. This finding was later replicated by Kyte & Johnson (2006) in a study that adopted matched learning conditions and a within-participant design.

Additional support for the importance of phonology in learning of visual word forms through independent reading comes from studies that have demonstrated a relationship between decoding accuracy and orthographic learning (Cunningham et al., 2002; Nation et al., 2007; Cunningham, 2006). In these studies, the proportion of target pseudowords correctly decoded during reading was found to be correlated to the degree of learning achieved. Work involving children with dyslexia also provides similar evidence where decoding success has been linked to the degree of orthographic learning (Share and Shalev, 2004).

These findings with overt reading extend to orthographic learning during covert (silent) reading, the more common mode in skilled readers. Bowey & Muller (2005) used Share's (1999) experimental paradigm involving children to show that independent orthographic learning does occur following covert reading. Further, they attributed the learning achieved to phonological recoding, arguing that the observed naming advantage for the target pseudoword over its homophone suggests that orthographic representation linking visual and phonological information has been formed. Such a link could not have been produced for the homophone as its orthography was not seen. Two studies have replicated these findings: Bowey and Miller (2007) with a similar design and de Jong & Share (2007) in a comparative study of overt and covert reading. Stronger evidence for phonological recoding in covert reading was later provided by de Jong et al. (2009) in another comparative study where they modified the experimental design to include naming speed for unexposed pseudowords. The prior design (which compared only targets and homophones naming latency) had produced mixed findings in studies of both overt and covert reading, mudding interpretations (Kyte & Johnson, 2006, and Share, 2004; de Jong and Share, 2005; Bowey and Miller, 2007; de Jong and Share, 2007). The authors reasoned that after exposure to target pseudowords, phonological representations would be formed for both targets and homophones (as they have the same pronunciation) resulting in a naming advantage over the unseen pseudowords. As predicted, they found a naming advantage for the targets and homophones over the unseen words, showing use of phonological recoding during covert reading. Then, in their second experiment, de Jong et al. (2009) limited access to phonological recoding by introducing a covert reading condition with articulatory suppression. Participants read pseudowords within a lexical decision task performed in silence, with concurrent articulation, and with concurrent finger tapping. The concurrent tapping condition was added to control for dual task effects and was not expected to have any consequence on recoding. As expected, performance in covert reading and concurrent tapping was virtually the same. Further, the findings revealed that concurrent articulation significantly reduced target recognition performance in the choice task. However, it had no effects on naming speed of targets and homophones. This along with the finding that concurrent articulation did not completely prevent orthographic learning in the recognition task led the authors to conclude that articulatory suppression might not fully hinder phonological recoding. As for the differential effects of articulatory suppression seen between the naming and recognition tasks, the researchers reasoned that the hindering effects of articulatory suppression were more apparent in the choice task because it requires more precise orthographic representations. In contrast, the naming task may be more dependent on phonological efficiency and so learning benefits might be seen with less precise orthographic representations.

One additional finding that emerged from these orthographic learning studies in children is that comparative assessments of overt and covert reading showed no difference in the amount of learning attained with the two modes of reading (de Jong & Share 2007; de-Jong et al., 2009). In their comparative study, de Jong and Share (2007) directly manipulated the speech production conditions under which children decoded novel monosyllabic pseudowords embedded in experimental stories: children either read stories overtly or covertly. Three or four days later, the children completed an orthographic choice test, a spelling test, and a naming test. In the choice test and spelling tests, de Jong and Share reported above chance recognition and spelling accuracy for the target items, which indicated orthographic learning occurred; with no significant performance differences observed between items learned under the overt or covert reading conditions.

In summary, most studies of orthographic learning in children have used Share's experimental paradigm. In this paradigm, participants were tested for orthographic learning with a choice, spelling, and/or a naming task after independently reading pseudowords in the context of a lexical decision or a story reading task. Overall, the studies have demonstrated that in children, independent orthographic learning of novel words occurs in both overt and covert modes of reading. The process is facilitated by phonological recoding in both modes as evidenced by the decline in performance seen in the choice and spelling tasks under conditions of articulatory suppression. Moreover, there is no difference in the amount of learning achieved with the two modes.

1.2 Orthographic Learning in Adults

Share posited that self-teaching is a phenomenon that persists into adulthood (Share, 1995). Given the item-based nature of phonological recoding, where reliance on phonology is contingent upon the degree of item familiarity, he argued that it should be possible to find instances of self-teaching among skilled readers. However, he also argued that the nature of phonological recoding changes with increasing orthographic knowledge. Children start learning to read with an initial set of simple spelling-sound correspondence rules that get modified with growing orthographic knowledge. Share referred to this process as “lexicalization” of phonological recoding, the outcome of which, he said, is a “skilled reader whose knowledge of the relationships between print and sound has evolved to a degree that makes it indistinguishable from a wholly lexical mechanism that maintains no sublexical spelling-sound correspondence rules” (Share, 1995, p. 156).

Orthographic learning studies in adults have varied in aim and experimental design from studies involving children. While there has been much interest in examining the role of phonology in the adult learning of new vocabulary words through reading, the specific role of self-teaching in orthographic learning has received little attention. Even when orthographic learning has been evaluated, many of the studies embedded pseudowords within the context of decision tasks (such as a rhyme judgement task) that create a learning environment that differs from naturalistic reading (e.g., Chalmers & Burt, 2008; Sandak et al., 2004). Others include feedback designed to aid learning – either during the learning or testing phase – which amounts to instructional guidance (e.g., Burt and Blackwell, 2008; Bartolotti and Marian, 2017). Thus, studies of orthographic learning in adults do not readily offer clean comparisons to prior work involving children.

Further, the research in adult readers has mostly examined the involvement of phonology as broadly defined. This has provided substantial evidence that the availability of phonological information enhances orthographic learning, though the specific effects of articulatory suppression on orthographic learning during covert reading are unknown. One line of evidence comes from studies that have compared learning outcomes in environments that favor the co-activation of phonology with those that do not (e.g., Chalmers & Burt, 2008; Sandak et al., 2004; Kaushanskaya & Yoo, 2011; Taylor, Plunkett, & Nation, 2011). Chalmers and Burt (2008), in their first experiment, investigated the role of phonology in learning to spell. They compared learning of pseudowords presented with and without recorded pronunciation in an encoding task that required a decision about the number of consonant clusters in the item. Past studies of beginning readers have mostly used monosyllabic pseudowords appropriate for the reading levels of children. In their study, Chalmers and Burt reasoned that literate adults have greater orthographic knowledge compared to children, and the new words they come across are often complex in sight and sound. For this reason, they used multisyllabic stimuli in their study. Learning was tested with an unexpected spelling recognition task. The findings revealed that participants showed better performance for items that they had learned with pronunciation, suggesting that phonology improves the learning of the visual forms. In their third experiment, Chalmers and Burt (2008) manipulated the conditions in which pseudowords were processed during learning. In an orthographic encoding condition, participants were instructed to count the consonant clusters. In a phonological encoding condition, participants were instructed to indicate whether the target letter was presented in the stressed syllable. The participants then read the pseudowords and their definitions covertly after encoding in both conditions and were tested with an orthographic choice task that included the target and homophone and a cued spelling task. The authors found better learning following the phonological encoding condition. In a similar design, Sandak et al. (2004) tested orthographic learning in covert reading by asking participants to perform either a rhyme judgment or orthographic structure task with monosyllabic pseudowords. They found that the rhyme judgment condition, which presumably favored phonological encoding, led to faster naming times relative to the orthographic structure condition.

Another strand of research that lends support to the continued role of phonology in adult orthographic learning comes from works on individual differences in phonological skills. There is evidence suggesting that individuals with better phonological skills achieve better learning (e.g., Brennan & Booth, 2015; Bartolotti & Marian, 2017; Chalmers & Burt, 2008; Ocal & Ehri, 2017; Service & Kohonen, 1995; Howland & Liederman, 2013). Yet more evidence comes from a series of studies that demonstrate better orthographic learning for pseudowords that offer ready access to phonology (Hamada & Koda, 2008; Howland & Liederman, 2013; McKague, Davis, Pratt, & Johnston, 2008; Bartolotti & Marian, 2019; Burt & Butterworth, 1996; McKay, Davis, Savage, & Castles, 2008; Brusnighan, Morris, Folk, & Lowell, 2014; Burt & Blackwell, 2008; Taylor et al.,2011). In these studies, the critical manipulation was the characteristics of the novel words being learned. For example, Taylor et al. (2011) trained participants on novel words that varied in their consistency of orthography-phonology mappings based on GPCs (Grapheme-Phoneme Correspondence) of an artificial orthography. Consistent words only had one possible pronunciation while inconsistent items could be mapped to two vowel sounds. The researched presented participants novel words visually and auditorily, after which participants then repeated the word aloud. Postexposure, participants showed better learning for the consistent rather than the inconsistent novel words.

On the issue of the relative amount of orthographic learning in overt and covert reading in adults, little is known. In children, there is no difference in the amount of learning achieved during overt and covert reading. In adults, however, tangential work suggests that this particular behavioral pattern might not hold true. Papagno, Valentine, & Baddeley (1991) investigated the role of the phonological loop system of working memory (which is posited to rely upon silent inner speech) in the acquisition of L2 vocabulary via paired word association. They compared two learning conditions – concurrent tapping and concurrent articulation. Participants were exposed to paired associates of L1 (Italian) and L2 (Russian) words. After some time, they were presented the L1 words and asked to write down the L2 words. Participants exhibited better accuracy for L2 words learned during concurrent tapping than for those learned during concurrent articulation. The authors concluded that the observed decline in performance in the concurrent articulation condition was because of the disruption of the phonological loop system. It is worth noting here that that participants were not assigned a specific mode of reading in the concurrent tapping condition; indeed, many read out the nonwords aloud in an attempt to better remember the sound of the words. Kaushanskaya and Yoo (2011) examined the effects of rehearsal strategy (overt vs. covert) on vocabulary learning in adults and found that the effectiveness of the adopted method was dependent on the phonological structure of the words. In their first experiment, participants were asked to learn phonologically familiar pseudowords (i.e., with English phonological structure) along with their English "translations". They learned half of them through overt rehearsal (speaking aloud), and half through covert rehearsal (silently through "inner" speech). The words were presented both visually and auditorily. Learning was then assessed with recall and recognition tasks. In the recall test, participants heard the novel word and were required to pronounce the English translation into a microphone. In the recognition task, participants heard the items and were required to choose the correct English translation from a set of choices. Findings showed better learning for the vocally rehearsed pseudowords. In a second experiment, the researchers gave participants phonologically unfamiliar novel words. They found that the outcomes reversed: there was better retrieval for items that were rehearsed silently. It is worth noting that this study does not equate to the comparative orthographic learning studies of overt and covert reading conducted in children as learning was mediated via visual and auditory media as opposed to just visually. Despite some concerns about interpretation, overall, there is suggestive evidence that reading mode (overt versus covert) is an important factor in the orthographic learning of adult skilled readers.

1.3 The Present Study

Currently, the complete behavioral profile of orthographic learning in adults is yet to be determined. There is evidence that orthographic learning occurs in both overt and covert reading within the context of experimental tasks or when guided with corrective feedback. However, there is no work on orthographic learning within the specific context of self-teaching. Also lacking is a comparative assessment of the amount of orthographic learning attained between the different modes of reading. In children, there is no difference in the learning achieved during overt and covert reading, but there is suggestive evidence this is not be true for adults. Another missing piece in the adult behavioral profile of orthographic learning is the effect of articulatory suppression. In children, learning is diminished with articulatory suppression in both modes of reading. In adults the specific effects of speech suppression have not been examined.

In the current study, we conduct two experiments to address the noted gaps in the literature. The primary goal of the experiments is to map the behavioral pattern of orthographic learning following independent reading in adults and to compare the degree of learning achieved through overt versus covert reading. A secondary goal is to explore the effect of articulatory suppression in the orthographic learning that occurs during covert reading. The experiments use a paradigm based on previous work in children, to facilitate comparisons to prior studies involving children.

In the first experiment, we compare orthographic learning of pseudowords after overt and covert story reading. Following the reasoning of Chalmer and Burt (2008) that literate adults have greater word knowledge than children, we include both monosyllabic and multisyllabic items. In the second study, we add a concurrent articulation and concurrent tapping condition to assess if articulatory suppression reduces the amount of learning achieved in covert reading.

2.0 Experiment 1

2.1 Methods

2.1.1 Participants

Eighteen undergraduate students enrolled in an Introduction to Psychology course at the University of Pittsburgh (11 males and 7 females; mean age = 18.82 years, SD = .81) participated in the study for course credit. All were native English speakers and provided informed consent on a University of Pittsburgh IRB reviewed form prior to their participation.

2.1.2 Materials

2.1.2.1 Pseudoword Corpus

A learning corpus of 12 pairs of pronounceable, monosyllabic homophonic pseudowords and 12 pairs of multisyllabic homophonic pseudowords was developed. The homophone pairs differed in spelling but shared the same target pronunciation (e.g., *meep* vs. *meap*). The monosyllabic pseudoword pairs were four to six letters in length and were drawn from the corpus used by Kyte and Johnson (2006) in their study of orthographic learning in children. This previous corpus had a total of 16 pairs of pseudowords. For the current study, three pseudoword pairs that contained both consonant and vowel manipulations were eliminated to keep the difference between each homophonic pair to a single letter change, and an additional pair with the same starting consonant as two other pairs was excluded.

The multisyllabic pseudowords were 9 to 11 letters in length and were drawn from the 64 pseudowords developed by Chalmers and Burt (2008). Because the authors only provided one spelling for each of their pseudowords, a homophone was created for each by manipulating either a consonant or a vowel or both to form pairs with the same target pronunciation (e.g., *descimand* vs. *dessimand*). Results from a preliminary naming study were used to select a final set of 12 pairs with the most consistent pronunciations and least similarity to real words. The homophones differed from one another by a single letter in all but one pair of pseudowords. In the remaining pair, they differed by two letters.

The final set consisted of 12 homophonic monosyllabic and 12 homophonic multisyllabic pseudoword pairs which were randomly split into two lists, so that one spelling from each pair was assigned to List 1 and the other was assigned to List 2. The use of the two lists was counterbalanced across participants.

2.1.2.2 Experimental Stories and Comprehension Questions

Twenty-four stories modeled after short expository texts used in a previous study of orthographic learning (Share, 1999) were created. The number of words in a given story was between 133 – 157 and each story was used to present one of the items within a pseudoword pair as a new vocabulary item (e.g., introduced within the story as a term describing a new color or new species) a total of six times. For each story, two comprehension questions were created, both regarding the subject matter of the story. In addition to the experimental stories, two practice stories (along with a comprehension question each) were created. These contained monosyllabic pseudowords similar to those included in the learning corpus.

The stories were split into four packets of six stories: two of the packets contained monosyllabic pseudowords while the other two comprised multisyllabic items. From each pseudoword pair, the item embedded in the stories alternated across participants, so that half of the participants read stories with one spelling of the pseudoword pairs (i.e., List 1) and the other half read stories with the other spelling (i.e., List 2). The embedded pseudoword spellings constituted the *target* items and the unseen spellings were the *homophone* items. One story was printed on a single page using double-line spacing and 12-point Times New Roman Font. The comprehension questions were printed on a separate page after each story.

2.1.2.3 Orthographic Choice Task

The orthographic choice task was modeled after the choice task used by Kyte and Johnson (2006). All 24 pseudowords in the learning corpus were included in this task. Two additional distractor pseudowords – called *foil 1* and *foil 2* – were created for each existing pair in the pseudoword corpus by substituting the final consonant of each pseudoword pair with another consonant letter. As a result, on a given trial of the orthographic choice task, participants were given a set of four choices: target, homophone, foil 1, and foil 2. The Mail Merge Manager plugin for Microsoft Word was used to randomize the order in which the participants were exposed to the pseudowords as well as the position of the four orthographic choices on each page. The four choices for each trial were printed on single page of paper using double-line space and 18-point Times New Roman font. To orient participants to the task, two practice trials were included in the beginning of the task.

2.1.2.4 Spelling Task

In this task, target word recordings were pronounced to participants and they were asked to write down the spellings of the pseudowords that they had previously read. Recordings of the target pronunciation were made for each of the 24 pseudoword pairs. The Mail Merge Manager plugin was used to generate randomized lists of the order in which to present the recordings. Two-page answer sheets were created with 12 numbered blank lines to a page.

2.1.3 Procedure

Participation in this experiment involved two sessions scheduled one week apart. The first session was a decoding session where participants were exposed to the set of pronounceable pseudowords in the context of a story-reading task. The second session was a posttest session where participants completed two tests of orthographic learning for the previously read pseudowords: an orthographic choice test and a spelling test.

2.1.3.1 Decoding Session

Each participant was assigned to a quiet testing room and asked to read the story packets under two reading conditions: overt and covert reading. First, to orient participants, the two practice stories with the embedded practice pseudowords were read (one aloud and one silently) at the beginning of the study. For both the reading conditions, participants had to overtly indicate when they began reading a story by saying “begin” and when they were finished reading by saying “end.” The participants answered a comprehension question about each practice story. They were instructed to answer the questions to their best ability and to leave a question blank if they could not answer. Then, participants read the four packets of experimental stories. One of the two reading conditions was randomly assigned to each packet. Participants read two packets aloud and two packets silently, in each case with one packet containing embedded multisyllabic targets and the other containing monosyllabic targets. The order of the reading conditions, story packets, and the items within the packets were counterbalanced across participants.

In the overt condition, participants read the stories out loud. Because the participants were forced to sound out the pseudowords, phonological recoding was always at play. In the covert condition, participants simply read the stories covertly. They were instructed to say ‘begin’ at the start of each story and say ‘end’ when they were finished reading the story. A desktop computer and the Adobe Audition software were used to record the session. At the end of each story, participants answered the two comprehension questions using pencil and paper. After giving the instructions, we did not provide further supervision of story reading and only periodically checked in on the participants’ progress.

2.1.3.2 Posttest Session

A week after the decoding session, participants were tested in groups ranging from one to four individuals. Testing was performed in a quiet conference room with sufficient spacing between each participant to avoid interactions during testing. Both the orthographic choice and spelling testing materials were distributed along with a pen. In the orthographic choice task, participants were prompted to circle the letter string they read previously. The participants first completed practice trials with the two practice pseudowords in the beginning of the task. After being oriented, they continued through the remaining 24 experimental trials and were prompted to stop and wait for every participant to finish. No time constraint was put on the participants.

After the entire group completed the orthographic choice task, the participants were instructed to use the answer sheets for the spelling task. The audio recording of each pseudoword pronunciation was played manually to the entire group via the Adobe Audition software with a speaker system. After hearing each item, participants were instructed to write down a spelling on the answer sheet. A practice trial was given at the beginning of the task.

2.2 Results

2.2.1 Decoding Assessments

2.2.1.1 Decoding Accuracy

Due to a technical error, audio files during the encoding session were not obtained for four participants. Decoding accuracy and story-reading time were measured for the remaining participants. For decoding accuracy, participants were given a score of 1 for correctly reading aloud a pseudoword during all six exposures; otherwise, they were given a score of ‘0’. Accuracy was determined by spelling-to-sound correspondence rules and confirmed by preliminary tests of preferred pronunciations for the pseudowords. Since pseudowords were not overtly named during covert reading, the decoding accuracy for the covert reading condition cannot be reported. Under the overt reading condition, participants decoded monosyllabic target pseudowords with a mean accuracy of .99 ($SD = .04$); they decoded multisyllabic target pseudowords with a mean accuracy of .69 ($SD = 0.17$). A t-test showed this difference was significant, $t(13) = 7.5$, $p < .01$.

2.2.1.2 Story Reading Time

The reading time for each story was computed by subtracting the time immediately after a participant said "begin" from the time the participant said "end." The mean reading times for each condition are provided in Table 1. A two-way ANOVA with repeated measures was performed where the independent variables were reading condition (overt and covert) and syllable length (monosyllabic or multisyllabic). The dependent variable was reading time. The mean reading times are presented in Table 1. Both main effects were significant: reading condition, $F(1, 13) = 71.01$, $p < .001$, $\eta p2 = .84$, with faster reading times for the covert reading as compared to overt reading condition, and syllable length, $F(1, 13) = 14.05$, $p = 0.002$, $\eta p2 = .52$, with faster reading times for stories containing monosyllabic as compared to multisyllabic pseudowords. We did not observe an interaction between reading condition and syllable length ($F(1, 13) = 0 .03$, $p = .86$).

Table 1 Decoding session assessments: Mean and standard deviations (in parentheses) by reading condition and syllable length.

	Overt		*Covert*	
	Monosyllabic	*Multisyllabic*	*Monosyllabic*	*Multisyllabic*
Decoding (Proportion Correct)	.9 (.0)	.6 (.2)		
Reading time (s)	48.0 (6.4)	50.9 (8.2)	35.7 (9.6)	39 (7.9)
Comprehension (Proportion Correct)	.9 (.1)	.9 (.1)	.9 (.1)	.9 (.1)

2.2.1.3 Comprehension

After each story, two questions were asked to assess comprehension. The accuracy was scored as a '1' if both questions were correct, '0.5' if only one was correct, '0' if neither was correct. Participants performed similarly on the comprehension questions under both reading conditions (Table 1). An ANOVA with repeated measures was performed on the mean portion of correct responses with reading condition and syllable length as the independent variables. No significant effects were observed for either condition ($F(1, 17) = 0.32$, $p = .58$; $F(1, 17) = .26$, $p = .41$, respectively). Furthermore, no interaction between the two independent variables was observed ($F(1, 17) = .26$, $p = 62$).

2.2.2 Orthographic Learning Assessments

2.2.2.1 Choice Task

Performance on the orthographic choice task was scored as the proportion of correctly chosen target items for each of the two reading conditions. The first question of interest is whether adults demonstrate evidence of significant orthographic learning. This was tested using a strict measure of orthographic learning, namely the difference in Target versus Homophone selection (Cunningham et al., 2002; Share 1999, 2004). Using this measure, a paired-samples t-test provided evidence of significant learning, $t(17) = 2.58$, $p = .02$.

To explore differences in learning across our experimental factors, an ANOVA with repeated measures was performed with reading condition and syllable length as the predictors, and the proportion of target choice responses as the dependent measure. The descriptive statistics for all orthographic learning measures are provided in Table 2. For the choice task, a significant effect was observed for reading condition, $F(1, 17) = 5.39$, $p < 0.033$, $\eta_p^2 =.24$ with participants selecting the target items decoded under the overt reading condition more often ($M = .55$, $SD = .23$) as compared to items decoded under the read silently condition ($M = .43$, $SD = .12$). No main effect was observed in the syllable length variable ($F(1, 17) = 2.13$, $p = .16$) and no significant reading condition x syllable length interaction was observed ($F(1, 17) = .79$, $p = .39$).

2.2.2.2 Spelling Task

In studies involving children, performance on the spelling task was scored in two ways: whole word and target letter accuracy (e.g., de Jong and Share, 2007). In whole word scoring, only pseudoword spellings that completely matched the target spellings would be scored as correct responses. In the target letter scoring, any spellings that included the target letters would be scored as correct responses. The target letter was the one letter (with the exception of *stranoose* and *strannuce*) that differentiated the target and homophone spellings in each pseudoword pair. Because we included multisyllabic pseudowords in our study, we reasoned that increasing item length by itself should result in more spelling errors, and so to hone in on orthographic learning effects more specifically we report only target letter scoring as a measure of spelling accuracy.

Table 2 Orthographic learning assessments: Mean accuracy with standard deviation (in parenthesis) by reading condition and syllable length.

	Overt		*Covert*	
Task	*Monosyllabic*	*Multisyllabic*	*Monosyllabic*	*Multisyllabic*
Choice Task	.5 (.2)	.6 (.3)	.4 (.2)	.4 (.2)
Spelling (Target Letter)	.6 (.2)	.6 (.3)	.5 (.2)	.5 (.3)

We first assessed evidence of significant orthographic learning. We again used the strict measure of orthographic learning, namely the difference between target and homophone spelling production. Using this measure, a paired-samples t-test showed evidence of significant learning, $t(17) = 2.86$, $p = .011$.

Then, we compared the amount of learning with the two modes of reading. A two-way repeated measures ANOVA was performed with spelling accuracy as the dependent measure. No significant main effects were observed for either reading condition ($F(1, 17) = 2.38$, $p = .14$) or syllable length ($F(1, 17) = .42$, $p = .52$), nor was there an interaction effect ($F(1, 17) = .68$, $p = .42$).

2.2.2.3 Relationship Between Decoding and Orthographic Learning

We examined the relationship between the participants' target decoding accuracy and their level of orthographic learning, as measured by the orthographic choice task and the spelling task. Only the overt reading condition was included in the analysis, the two participants from whom audio recordings were not obtained. A linear regression was performed with target decoding accuracy as the independent variable and the target choice accuracy as the dependent variable. Surprisingly, we observed a significant negative correlation between target decoding accuracy and the participants' ability to choose target items over the homophone and distractor items, $r(12) = .49$, $p = .005$. A similar linear regression was performed with the spelling accuracy as the dependent variable. We did not observe a significant correlation between decoding accuracy and spelling accuracy.

2.3 Discussion

This study used a well-established experimental protocol to compare behavioral patterns of orthographic learning in overt and covert reading in adults. Share's self-teaching hypothesis predicts that both children and adults use phonological decoding to acquire orthographic knowledge about unfamiliar printed words (Share, 1995). Studies in children have provided substantial support for Share's theory and mapped out the behavioral patterns of orthographic learning in both modes of reading (e.g., Bowey & Muller, 2005 and de Jong et al., 2009). In adults, the behavioral profile of orthographic learning remains incomplete, and it is unknown whether the amount of learning achieved during overt and covert reading varies.

Our results from both the choice and spelling posttests provide evidence of orthographic learning in adults following the reading of unfamiliar pseudowords embedded within a story context. Importantly, we found that for one of our two posttest measures, the choice task, participants showed higher recognition for items read overtly than covertly. This is a departure from the behavioral profile of children where overt and covert reading yield equivalent amounts of learning (de Jong and Share, 2007; de Jong et al, 2009).

One potential explanation for the learning difference between the two modes of reading could be that participants paid less attention in the covert reading condition and therefore learned the pseudowords to a lesser degree. Consistent with this explanation, reading speed was significantly faster when participants read covertly than when they read out loud. However, de Jong and collaborators (2007, 2009) reported that children showed no difference in learning between the two modes of reading despite also demonstrating a faster reading time during covert reading. This along with the finding in the current study that reading comprehension was equivalent for the two reading conditions makes it unlikely that a simple lack of attention caused the difference in orthographic learning.

Another possible explanation for the difference could be that learning in overt reading was reinforced because participants could hear themselves pronouncing the pseudowords. However, this too seems unlikely based on parallels to studies involving children (e.g. de Jong et al, 2009), where orthographic learning achieved with the two modes of reading was equivalent despite the possible contributions of auditory reinforcement in overt reading.

A third explanation, which lies in Share's claim that the nature of phonological recoding changes in the course of development, is most compelling. The beginning reader's decoding is dependent on simple letter-to-sound rules that aid in breaking down unfamiliar words into segments. As reading skill develops, the rules are modified, and decoding is said to become 'lexicalized' (Share, 1995). The observed learning difference between overt and covert reading in adults is likely a consequence of this change. At the core of this explanation is the claim that, in adults, the two modes of reading support different types of decoding. During covert reading, skilled readers use the efficient lexicalized decoding, whereas in overt reading, the extra constraint of articulation necessitates the use of speech planning and production processes that likely involve representations with phonemic and articulatory elements (Shuster and Lemieux, 2005). This account can easily explain the findings observed in children. Novice readers only make use of beginner phonological recoding as they have yet to develop lexicalized decoding. That is, for the beginning reader, decoding in covert and overt reading are mechanistically the same. As for why overt reading yielded better learning in adults, it could be that overt reading (assisted by articulation) supports a superior decoding process that leads to more precise orthographic representations.

In overt reading, we found the decoding accuracy to be negatively correlated with choice accuracy. This is in contrast to what is seen in children where decoding accuracy is positively correlated with performance in the choice task (e.g., Cunningham et al., 2002; Nation et al., 2007). This difference in the relationship between the decoding accuracy and performance in the choice task could be further evidence of a change in the nature of decoding over the course of development. It is also possible that it is a reflection of the pseudoword corpus used. In children, the relationship between decoding and choice task accuracy was established using monosyllabic items. In this experiment, while we use both monosyllabic and multisyllabic items, it is the latter that accounts for most of the variability seen in decoding.

Syllable length had no effects in orthographic learning in either of our learning measures. This is surprising as it is plausible to think that the more complex and less familiar multisyllabic structures might be harder to learn; that is, longer words present greater opportunity for error as they have more individual units. However, there is suggestive evidence that the effects of word length might depend on morphological legality of the pseudowords being learned and might only be apparent for morphologically illegal items (Callahan, 2011). In the present study, all pseudowords were morphologically legal.

Beyond tests of orthographic learning, adults also differed from children in one more behavioral profile: reading comprehension. In studies involving children, reading condition has been shown to affect comprehension during the learning session. For example, De Jong et al. in their original work (2007) and then in a follow-up study (2009) found that children comprehended stories that were overtly read significantly better than stories read covertly. We did not find this pattern in our study of adult orthographic learning. Participants showed similar comprehension for stories read overtly and covertly. This suggests that adults might have superior comprehension skills that allow them to equally access semantic information of texts read overtly or covertly. It might also indicate a developmental change in the decoding process. That is lexicalized decoding might be more efficient in mapping of familiar orthographic forms to their corresponding meanings.

In sum, the findings of this experiment establish that orthographic learning is achieved in adults following independent reading. Further, they highlight the difference between overt and covert reading in adults: In contrast to what we see in children, these two processes result in different amounts of learning. The results also show that the overall behavioral pattern of orthographic learning in adults deviates from what is seen in children.

3.0 Experiment 2

The purpose of Experiment 2 was to determine whether the findings of Experiment 1 can be replicated and to further explore the nature of orthographic learning in covert reading in adults. The experimental design was similar to Experiment 1 in that participants were exposed to pseudowords though story reading, and orthographic learning was measured a week later. As a point of difference, it introduces two additional reading conditions (concurrent articulation and concurrent finger tapping) to assess if articulatory suppression reduces the amount of learning achieved in covert reading. In addition, we included a naming task as the third measure of orthographic learning. And finally, all tasks in this experiment were designed and executed using computer-based test administration.

3.1 Method

3.1.1 Participants

A total of 48 participants (6 males and 18 females; mean age = 22.67 years, SD = 3.82) took part in this experiment. All were native English speakers with no history of learning disability. As in Experiment 1, participants came in for two sessions. In the decoding session, they read stories that contained pronounceable pseudowords under four separate reading conditions. In the second session, which took place a week later, they completed three orthographic learning tests.

3.1.2 Materials

3.1.2.1 Pseudoword Set

In this experiment, two more levels were added to the independent variable reading condition (concurrent articulation and finger tapping). To maintain the number of pseudowords allotted per condition same as in Experiment 1 (i.e., six), we added 24 more pseudoword pairs. Furthermore, we improved our existing corpus by ensuring that all the homophone pairs only differed by a single letter and restricting the letter differences to vowels only. The new corpus was developed from a larger pool of 139 pseudowords tested on pilot participants. A subset of these items was newly created, and the rest were borrowed from previous studies (Bowey and Muller, 2005; Kyte and Johnson, 2006; Chalmers and Burt, 2008). Each pair had a single correct pronunciation in English grapheme–phoneme correspondence rules (Ziegler, Stone, & Jacobs, 1997). We eliminated items in which the pairs were pronounced differently by more than two pilot participants. We also eliminated items for which homophone spelling ratio was not roughly 50/50. The final corpus comprised 24 pairs of pronounceable, monosyllabic homophonic pseudowords and 24 pairs of multisyllabic, homophonic pseudowords. Six of the monosyllabic pairs were previously used by Kyte and Johnson (2006), 3 were used by Bowey and Muller (2005), and 13 of the multisyllabic pairs were employed by Chalmers and Burt (2008); the rest were newly created.

3.1.2.2 Experimental Stories and Comprehension Question

Using simple language, we created 24 more stories along with comprehension questions. Stories were split into four packets of twelve, each to be read in one of the four reading conditions. The 24 monosyllabic item pairs were randomly divided into four lists counterbalanced in bigram frequencies and orthographic neighbor statistics. The 24 multisyllabic item pairs were similarly divided into four lists. One monosyllabic and one multisyllabic list of pseudowords was then randomly embedded in one of the 4 story packets. The order of the reading condition and the stories were counterbalanced across participants, as was the order of the items within the stories. Half of the participants were exposed to one spelling of the homophone pair, while the other half saw the alternate spelling.

3.1.3 Procedure

The experiment had two phases. The decoding phase was administered under four reading conditions: read overtly, read covertly, read covertly with concurrent articulation, and read covertly with concurrent finger tapping. The testing phase included three parts: an orthographic choice task, a spelling task, and a naming task.

3.1.3.1 Decoding Session

Participants were asked to read the four packets of 12 stories in the four reading conditions. The overt and covert reading conditions were similar to Experiment 1. In the concurrent articulation condition, participants said the syllable ‘‘la’’ out loud repeatedly at normal conversational speed for the entire time it took them to read the 12 stories under this condition. In comparison with the overt reading condition, the concurrent articulation condition limited access to phonological decoding because participants’ speech system was otherwise engaged while reading the stories. In the finger tapping condition, which was included to control for dual task effects of concurrent articulation, participants were asked to tap their fingers while reading covertly. For the duration of this condition, participants used their thumb to tap the other fingers on one hand in a sequential order.

3.1.3.2 Posttest Session

A week after the initial exposure to the pseudowords, participants were tested for orthographic learning with three post-tests: orthographic choice, spelling, and naming task. 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).

Participants first completed 48 trials of orthographic choice task in which they were asked to identify the previously experienced target pseudoword from a set of four choice items. All item pairs were imbedded in arrays with a set of four choices consisting of the target item (e.g. keam), its homophonic control (e.g., keem), and two orthographic foils (e.g., kean and keen). The foils were created by substituting the final consonant of all pseudoword pairs with a visually confusing consonant letter using the visual confusion matrices for lowercase letters by Geyer (1977). They were matched in pronunciation. All items within an array had the same number of letters. The task was executed using E-prime software (Schneider, Eschman, & Zuccolotto, 2002). In each trial, participants saw four randomly positioned pseudowords presented vertically atop one another. A fixation cross (+) was presented on screen for 800 ms after which, the choice array appeared vertically until a participant's response was recorded. Responses were indicated by pressing keys on the number-pad. The Mail Merge Manager plugin for Microsoft Word was used to randomize the order of the four orthographic choices on the computer screen. Participants' responses were recorded using the keyboard.

In the spelling task, participants were provided with a pen and paper and asked to correctly spell each of the pseudowords they experienced during the self-teaching phase. Recordings of the 48 target items were pronounced once through the computer's audio speakers and participants wrote down their responses. Upon writing a response, the experimenter pressed the spacebar to advance the trial. The Mail Merge Manager plugin was used to generate randomized lists of the order to play the recordings.

In the naming task, the final measure of orthographic learning, participants were required to verbally pronounce a set of items. In each trial, the item was either one of the 48 pseudowords experienced during the self-teaching phase (i.e., the target), one of the 48 homophone controls, or one of the 96 real word filler items. A 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. We used the Mail Merge Manager plugin for Microsoft Word to randomize the order in which the participants were presented with the pseudowords. Participants were instructed to read the items overtly.

3.2 Results

3.2.1 Decoding Assessments

3.2.1.1 Decoding Accuracy

The story-reading audio file was incomplete for one participant and was excluded from the decoding accuracy and reading speed analyses. Decoding accuracy was measured in the same manner as Experiment 1. Under the overt reading condition, monosyllabic target pseudowords were decoded with a mean accuracy of .9 (SD = .1) (Table 3) while multisyllabic target pseudowords were decoded with a mean accuracy of .5 (SD = .2). This difference was significant: $t(22) = 7.65$, $p < 0.001$.

Table 3 Decoding session assessments: Mean and standard deviations (in parenthesis) by reading condition and syllable length.

	Overt		Covert		CA		CT	
	Mono	Multi	Mono	Multi	Mono	Multi	Mono	Multi
Decoding Accuracy	.9 (.1)	.54 (.2)						
Reading time	48.5 (5.3)	54.3 (7.0)	36.2 (8.5)	39.5 (10.4)	36.2 (8.5)	39.5 (10.4)	36.9 (11.8)	39.2 (12.4)
Comprehension Accuracy	.9 (.2)	.8 (.1)	.9 (.1)	.8 (.2)	.9 (.1)	.8 (.2)	.8 (.1)	.8 (.1)

Mono: monosyllabic; multi: multisyllabic; CT: concurrent articulation; CT: concurrent tapping

3.2.1.2 Story Reading Time

The mean reading times for each reading condition are provided in Table 2. Analysis was conducted in two parts. First, we compared overt and covert reading. A two-way analysis of variance (ANOVA) with repeated measures was performed on reading time with reading condition and syllable length as the predictor variables. Similar to Experiment 1, main effects of reading condition and syllable length were observed, $F(3, 22) = 68.41$, $p < .001$, $\eta_p^2 = .76$ and $F(1, 22) = 63.49$, $p < .001$, $\eta_p^2 = .74$, respectively). Reading speed was faster for stories read covertly than overtly. It was also faster for stories containing monosyllabic than monosyllabic items. Unlike in Experiment 1, an interaction effect was observed: $F(1, 22) = 5.34$, $p = .03$, $\eta_p^2 = .15$). Then, we compared covert reading to the concurrent articulation and finger tapping conditions. There was only a main effect of syllable length, $F(2, 44) = 31.06$, $p < .001$, $\eta_p^2 = .59$), with reading speed faster for stories containing monosyllabic than multisyllabic items.

3.2.1.3 Comprehension

A two-way ANOVA with repeated measures was performed on the mean proportion of correct responses comparing overt to covert reading. Neither reading condition nor syllable length had an effect: $F(1, 23) = .68$, $p = .42$ and $F(1, 23) = 2.11$, $p = .16$. No interaction effect was observed, $F(1, 23) = 0.04$, $p = 0.84$). When comparing covert reading to the concurrent articulation and finger tapping, we found there was a main effect of condition, $F(2, 46) = 16.16$, $p < .001$, $\eta_p^2 = .44$. Follow up tests revealed that the proportion of correct answers was significantly lower in the concurrent articulation condition than in the covert reading ($t(23) = 4.93$, $p < .001$) and finger tapping condition ($t(23) = 4.48$, $p < .001$). There was no main effect of syllable length ($F(1, 23) = 3.67$, $p = 0.07$) or interaction effect ($F(2,46) = 1.27$, $p = 0.29$).

3.2.2 Orthographic Learning Assessments

3.2.2.1 Choice Task

In this task, as in Experiment 1, orthographic learning was indicated by the correct identification of the target pseudoword in each trial where participants were presented with four choices that included the target, its homophone, and two foils. Orthographic learning was assessed by comparing target versus homophone selection. A paired-samples t-test showed evidence of significant learning, $t(23) = 5.39$, $p < .001$.

Descriptive statistics for the mean accuracy by reading condition and syllable length are outlined in Table 4. Comparative analysis was conducted in two parts. First, we compared overt to covert reading. We conducted a two-way repeated measures ANOVA. The proportion of target responses was taken as a dependent measure. Reading condition and syllable length were the within-subject factors. We found a significant effect of reading condition, $F(1, 23) = 5.94$, $p = 0.02$, $\eta_p^2 = .21$. The proportion of correct responses was significantly higher for pseudowords read in the overt condition than those read covertly. No main effect of syllable length was observed ($F(1,23) = .74$, $p = .40$), nor was there an interaction effect ($F(1,23) = 1.37$, $p = .25$). Next, the amount of learning after covert reading was compared to concurrent articulation and finger tapping. Learning was virtually the same for the three reading conditions across the word types. There were no significant main effects, nor was an interaction effect observed (syllable length: $F(1,23) = .37$, $p = .55$; reading condition: $F(2.46) = 1.48$, $p = .24$; interaction: $F(2,44) = .56$, $p = .57$).

3.2.2.2 Spelling Task

In this task, orthographic learning was demonstrated by participants correctly spelling target letters of pseudowords seen during the learning phase. One participant’s file was lost and so was not included in the analysis. We used the difference between target and homophone spelling production as a measure of learning and a paired-samples t-test revealed significant learning, $t(23) = 4.50$, $p < .001$.

Comparative assessment was then conducted. First, we compared covert to overt reading. The mean proportion correct on the spelling task were subjected to a two-way repeated measures ANOVA. A main effect of reading condition was observed with participants showing higher accuracy for pseudowords read in the overt than the covert condition $F(1, 22) = 5.71$, $p = .03$, $\eta_p^2 = .21$. Neither a main effect of syllable length nor an interaction effect was observed $F(1, 22) = 1.49$, $p = .23$; $F(1, 22) = .03$, $p=.87$, respectively. Then, we compared performance in covert reading condition to concurrent articulation and concurrent tapping. A main effect of syllable length was observed, $F(1, 22) = 6.82$, $p = .02$, $\eta_p^2 = .24$. Participants showed higher accuracy for monosyllabic than multisyllabic items. Neither a main effect of reading condition nor an interaction effect was observed, $F(2, 44) = .81$, $p = .45$; $F(2, 44) = 2.97$, $p = .06$, respectively.

3.2.2.3 Naming Task

For the naming task, successful acquisition of orthographic learning would be demonstrated by pronouncing the target pseudoword faster than its homophone control. For this reason, we use difference scores in our analyses (target minus homophone), which has the benefit of controlling for overall differences in naming accuracy and latency that we expect for multisyllabic as compared to monosyllabic items. For 6 participants, due to software failure, audio files were either not created or incomplete. These subjects were excluded from the analysis.

The descriptive statistics for the various conditions are presented in Table 4. A paired-sample t-test for naming accuracy was not significant $t(15) = 0.25$, $p = .81$). However, a paired-sample t-test revealed significant difference in the latency, $t(15) = -2.13$, $p = .048$ with faster naming times for targets.

Comparative assessment of the amount of learning achieved in different conditions was conducted in two analyses. First, a comparison of covert and overt reading was performed. A two-way ANOVA with naming accuracy difference for target and homophone items as the dependent variable was conducted. The independent variables were syllable length and reading condition. There was no main effect of reading condition ($F(1,16) = .47$, $p = .50$) or syllable length ($F(1,16) = .66$, $p = .43$), nor was there an interaction effect ($F(1,16) = .94$, $p = .35$). Similarly, for naming latency, there were no main or interaction effects (reading condition: $F(1,16) = .73$, $p = .41$; syllable length: $F(1,16) = .38$, $p = .54$; interaction: $F(1,16) = .41$, $p = .53$).

Table 4 Orthographic learning assessments: Mean accuracy and standard deviations (in parenthesis) for the choice and spelling tasks, and naming accuracy and latency difference between targets and homophones for the naming task.

	Overt		*Covert*		*CA*		*CT*	
	Mono	*Multi*	*Mono*	*Multi*	*Mono*	*Multi*	*Mono*	*Multi*
Choice Task Accuracy	.6 (.3)	.7 (.2)	.5 (.3)	.5 (.2)	.5 (.3)	.5(.2)	.5 (.3)	.4 (.2)
Spelling Accuracy (Target Spelling)	.7 (.2)	.6 (.3)	.6 (.2)	.5 (.2)	.5 (.2)	.5 (.3)	.6 (.3)	.5 (.3)
Naming Accuracy (Difference score)	.0 (.0)	.0 (.1)	.0 (.0)	.0 (.1)	.0 (.0)	.0 (.1)	.0(.0)	.0 (.1)
Naming Latency (Difference score)	.0 (.1)	.1 (.1)	.0 (.0)	.0 (.1)	.0 (.1)	.0 (.2)	.0 (.1)	.1 (.1)

Then, covert reading was compared to concurrent articulation and concurrent tapping. Participants showed similar naming accuracy for words in the different reading conditions, i.e., no significant difference was observed ($F(2, 32) = .96$, $p = .39$). There was no effect of syllable length ($F(1,16) = .02$, $p = .88$), and the interaction term was not significant ($F(1,16) = .44$, $p = .65$). For latency, participants showed a significant effect of reading condition: $F(2, 32) = 5.48$, $p = .009$, $\eta_p^2 = .26$. Follow up tests revealed a greater difference score for items learned in the covert reading ($t(16) = -2.34$, $p < .03$) and concurrent articulation ($t(16) = 3.13$, $p = .006$) conditions than the concurrent tapping condition, while no effect was observed in the contrast between the covert reading and concurrent articulation conditions. For the effect of syllable length, no difference was observed between monosyllabic and multisyllabic items, $F(1,16)= .21$, $p = .65$. Further, the syllable length x reading condition effect was significant, $F(2, 32) = 3.34$, $p = .047$, $\eta_p^2 = .17$.

3.2.2.4 Relationship Between Decoding and Orthographic Learning

For overt reading, we assessed the relationship between target decoding accuracy and level of orthographic learning, as measured with the choice and spelling task. A linear regression was performed with target decoding accuracy as the independent variable and the target choice accuracy as the dependent variable. We found no significant correlation between the two, r(21) = 0.02, p = .587. Similarly, we did not observe a significant correlation between decoding accuracy and spelling accuracy (r(21) = .001, p = .89).

3.3 Discussion

One of the aims of Experiment 2 was to test whether the findings of Experiment 1 could be replicated. Our results confirm the most important findings. We replicated the reading comprehension findings: participants showed no difference in comprehension of stories read overtly or covertly. In assessing orthographic learning, we found evidence of independent learning as measured with the choice task and spelling task: participants recognized and spelled target items more accurately than their homophone alternatives. Further, we replicated the learning difference seen between the two modes of reading. That is, participants showed better learning for items encountered during overt than covert reading as measured by the choice task. The findings concerning the syllable length were also replicated: Participants showed similar learning for monosyllabic and multisyllabic items in the choice and spelling task.

Furthermore, we found evidence of learning in the naming task, a third measure of learning introduced in this experiment. Participants showed faster naming speed for target pseudowords compared to homophones, though their naming accuracy was virtually the same. This is not surprising, but also not fully predicted, because 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). We also found that the learning difference observed between overt and covert reading in the choice task of the first experiment extended to the spelling task in this experiment. It should be acknowledged that the stimulus set was modified in the second experiment and so item level differences could have contributed to the spelling task yielding positive results this time. As noted, this finding is a departure from what has been observed in children (de Jong and Share, 2007; de Jong et al, 2009) where no difference is seen in the amount of learning achieved with overt and covert reading.

For overt reading, the negative correlation observed between the target decoding accuracy and choice task was not replicated in this experiment. No apparent relationship was found between the target decoding accuracy and performance in the choice and spelling tasks. As noted, this behavioral profile is another departure from what is observed in children where target decoding accuracy has been found to be positively correlated to the choice task accuracy (e.g., Cunningham et al., 2002; Nation et al., 2007).

Another objective of this experiment was to assess the effects of articulatory suppression on orthographic learning during covert reading. In the decoding session assessments, participants showed an effect of reading condition on comprehension. Articulatory suppression significantly lowered comprehension compared to the two other reading conditions. There was no difference between covert reading and concurrent tapping, ruling out dual task effects as a possible explanation for the poor comprehension seen in concurrent articulation. This is an interesting finding as no orthographic learning difference was observed between the conditions, indicating a dissociation between reading comprehension and orthographic learning.

In our orthographic learning measures, reading with concurrent articulation yielded similar amounts of learning as covert reading without articulatory suppression. The outcomes for covert reading and concurrent tapping were similar in the choice and spelling tasks. In the naming task, learning was higher for covert reading and concurrent articulation than for concurrent tapping. Overall, these findings suggest that articulatory suppression does not affect the learning of visual form of words during covert reading. This is another departure from the behavioral pattern of orthographic learning seen in beginning readers where articulatory suppression does limit learning. We consider the explanation for this in the General Discussion.

Finally, though there was no effect of syllable length on the choice and naming tasks, we found that participants were more accurate spelling the monosyllabic than multisyllabic pseudowords in the spelling task. Since this pattern was only apparent in one of the four analyses conducted on the spelling task, it might require further work for robust conclusions.

4.0 General Discussion

Share (1995) posited that phonological recoding is a critical mechanism of self-teaching and that this mechanism is beneficial for novice and skilled readers alike. However, he also argued that this process may change as reading skill develops. Given this, it is interesting to ask how the behavioral pattern of orthographic learning of the skilled reader compares to that of the child. The overarching purpose of our study was to map out the behavioral profile of orthographic learning in adults with an experimental paradigm that would allow for easy comparison to studies involving children. Specifically, we aimed to establish whether orthographic learning occurred following independent reading, compare the amount of learning in overt and covert reading, and investigate if articulatory suppression affects the acquisition of the visual form of new words in covert reading. To this end, we conducted two experiments using a protocol first provided by Share (1999), and which has since been widely employed in studies involving children. Overall, in both experiments, we found evidence of orthographic learning following independent reading, but with important differences between the two modes of reading.

Specifically, the comparative evaluation of the two modes of reading revealed that orthographic learning was higher following overt reading: participants showed higher recognition and spelling accuracy for items read overtly than for those read covertly. This is a clear departure from the behavioral profile of children where overt and covert reading yield equivalent amounts of learning (de Jong and Share, 2007; de Jong et al, 2009). Evidently, the two modes of reading must support different types of decoding in adults as they have different physiological realizations: overt reading requires vocalization, but covert reading does not. In children, this overt-covert decoding distinction could be a non-issue because lexicalized decoding has yet to be developed, and as a result, children rely upon a more effortful speech-based phonological recoding process that functions similarly in overt and covert reading.

In our second experiment, we assessed the role of phonology and speech in orthographic learning in adults. We found that learning during covert reading is not hampered by articulatory suppression. Participants showed similar amount of learning in all the reading conditions: covert reading, concurrent articulation, and concurrent tapping. This is yet another difference in the behavioral profile between novice and skilled readers. In children, articulatory suppression has been shown to lower orthographic learning during covert reading. However, the null effects of articulatory suppression in adults are not surprising given the overt-covert distinction drawn above and the possibility that covert reading, in adults, supports lexicalized decoding which may rely upon speech-based processes to a lesser degree than the phonological recoding processes that support decoding in early readers.

The findings from this research offer sound contributions towards understanding an individual's continued development as a reader. They provide clear evidence of orthographic learning via self-teaching in adult readers of English. They show that the behavioral profile of orthographic learning in adults differs from that of children. Particularly salient is the finding that, in skilled readers, overt reading yields better learning of novel words than covert reading. This has practical significance as it directly brings into question the manner in which adult readers should decode and learn the visual form of new words.

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