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Multiple Oral Re-reading treatment for alexia: the parts may be greater than the whole

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Abstract

This study examines the reasons for the success of Multiple Oral Re-reading (MOR; Moyer, 1979), a non-invasive, easily administered alexia treatment that has been reported in the literature and is currently in clinical use. The treatment consists of reading text passages aloud multiple times a day. Findings that MOR improves reading speed on practiced as well as novel text have been inconsistent, making MOR‘s role in the rehabilitation of alexia unclear. We hypothesized that MOR's treatment mechanism works through repetition of high frequency words (i.e., bottom-up processing). We designed and controlled our text passages to test the hypothesis that participants would not improve on all novel text but would improve on text that includes a critical mass of the words contained in the passages they were re-reading. We further hypothesized that the improvement would be at the level of their specific alexic deficit. We tested four participants with phonologic alexia and two with pure alexia during 8 weeks of MOR treatment. Contrary to the conclusions of previous studies, our results indicate that improvements in top-down processing cannot explain generalization in MOR and that much of the improvement in reading is through repetition of the practiced words. However, most patients also showed improvement when specific phrases were re-used in novel passages, indicating that practice of difficult words in context may be crucial to reading improvement.

Keywords

alexia; aphasia; reading; treatment

INTRODUCTION

The Multiple Oral Re-reading (MOR) technique is a treatment for acquired alexia that requires patients to read the same passages of text aloud several times a day. It has been shown to increase the reading speed of the practiced passage and, more importantly, to generalize to novel text (e.g., Moody, 1988; Beeson & Insalaco, 1998; Beeson, Magloire & Robey, 2005). In the original 1979 study using the MOR technique (Moyer, 1979) the patient read a passage aloud for 30 minutes a day for one week. A new selection was introduced each week and speed of reading the practiced and novel selections improved over the three months of treatment. In the 30 years since, the success of the MOR technique has

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been replicated several times for patients with different types of alexia. However, no clear explanation has yet been established for why MOR works.

In the first paper to describe MOR, Moyer suggested that the treatment may work because “all components of written language structure are simultaneously maintained over practice”. More specifically, the “structure provided by the whole facilitates processing of the parts”, and vice versa, in an interactive fashion (Moyer, 1979, p. 143). In other words, she proposed that an interaction occurs between bottom-up and top-down processing. In the context of the literature on MOR, bottom-up processing refers to recognition of single word forms and/or the visual, orthographic, and phonological processes that support single word reading. Top-down processing refers to the use of the context within which words are read: the syntax and semantics of the text passages. Though Moyer originally proposed an interaction of these two processes, subsequent studies have concluded that, since the treatment effect generalizes to novel text passages made up of different words, it follows that improvements in top-down reading processes drive the generalization (Tuomainen & Laine, 1991; Beeson & Insalaco, 1998). The first goal of the current study is to test the hypothesis that MOR’s generalization effects can be attributed to improved top-down processing.

The second goal is to determine the source of MOR’s generalization effects in two different types of alexia: pure alexia and phonological alexia. The demonstrated success of the MOR treatment is of great significance for people with alexia, and motivates further investigation of the mechanisms underlying its success. Understanding the specific causes of its success should lead to the construction of MOR training passages that are optimal for the particular alexic deficit that is targeted. It is to this aim that the second goal is directed. In pure alexia, the reading deficit occurs in the context of intact spelling, indicating that orthographic representations remain intact. Thus, pure alexia is theorized to be due to degradation of the *connections* between visual input and the orthographic lexicon. The result is a reading impairment that is more severe for long words compared with short words, but that does not differ according to the syntactic class of the words. In phonological alexia, length is not a factor in reading success. However, people with phonological alexia have poor pseudoword reading as compared to reading of real words, and they typically have difficulty reading functor words and affixed words in isolation (Friedman, 1995) and/or in text (Friedman, 1996). According to the model of reading presented in Figure 1, pure alexia arises from damage within the visual system, prior to accessing the orthographic lexicon (Friedman & Alexander, 1984). Phonological alexia could arise from damage to the connections between orthography and phonology or to the phonological lexicon itself (Friedman, 1995). Based on this or similar cognitive models of reading, it is possible to predict different ways in which MOR treatment might work for these two alexia types.

Previous studies have tested top-down vs. bottom-up hypotheses to explain the effect of MOR for both types of alexia by simultaneously measuring improvements in text reading and single word and/or pseudoword reading (Beeson & Insalaco, 1998; Tuomainen & Laine, 1991). However, no study has yet examined how individual words *within* the practiced passages are improving, nor has any study tested phonological and pure alexia patients as part of the same experiment. In a study of MOR in 3 pure alexia patients, Tuomainen & Laine (1991) sought to determine whether MOR has its effect by acting directly on the word form system (i.e., through bottom-up processing), which would be reflected by improvement on single words as well as text, or whether MOR works through “semantic and syntactic constraints” (top-down processing), which would be reflected by improvement to text alone. The authors favor a top-down processing account to explain their data, though one of their pure alexia patients improved on both text and single words, one improved only on text, and one did not show improvement.

Beeson and Insalaco (1998) evaluated the MOR technique with phonological alexia patients. Following treatment, both patients' text reading speed improved for novel text as well as for single words. One patient was only five months post-stroke, making interpretation of those data difficult. In their interpretation of the patient who began treatment one year after her stroke, the authors note that the patient improved on reading of functors in isolation more so than she improved on nouns, adjectives or verbs after MOR treatment. The authors theorize that this could be due to repetition of high frequency functor words during oral re-reading (through bottom-up processes) or to improved access to functor words in isolation through practicing of the "syntactic frames" provided by the text (through top-down processing). The current study is designed to examine these two possibilities further.

Individual words in the passages used for re-reading, in addition to those used to assess generalization to novel text, would need to be tightly controlled in order to tease apart the top-down vs. bottom-up explanations of the MOR treatment effect. By definition, high frequency words can be expected to appear in any text used in the practiced as well as the novel passages. Previous studies have not been able to determine to what degree repetition of high frequency words affected their results, because they did not control the individual words used in the training and novel text passages. We designed our study to address this methodological issue.

Our study focuses on people with two types of alexia: mild pure alexia and "phonological text alexia", a term for a mild phonological alexia first described by Friedman (1996). Our participants with pure alexia read faster than the mildest patient reported by Behrmann (1998) and about twice as fast as the two successful patients reported by Tuomainen and Laine (1991; patients HT and TT). Our participants with "phonological text alexia" are comparable to Beeson and Insalaco's (1998) patients and other mild phonological alexia patients reported in the literature (Crisp & Lambon Ralph, 2006; patients DB and TH) in terms of reading error patterns, but our participants had to begin treatment reading at a higher rate of speed than those previously reported in order to be included in our study. Friedman theorized that phonological text alexia exists on a continuum with phonological alexia (Friedman, 1996). Patients with phonological text alexia have impaired pseudoword reading, but relatively intact single word oral reading, including function word (functor) reading. However, oral text reading, particularly of functors and affixes in text, is impaired (Friedman & Lott, 1995; Friedman, 1996). In terms of behavioral presentation, then, the restriction of functor reading errors to text is what distinguishes patients who are at the level of phonological text alexia on the continuum from those at the level of phonological alexia. Since text reading is where these patients' deficits are most apparent, MOR is a particularly suitable treatment for them. The treatment is also suitable for high-level pure alexics who are able to access wordforms but can benefit from improved reading speed.

The current study is unique in that we controlled the functors, content words, and phrases used in the untrained passages and assessed generalization by timing participants' reading of these passages before and after each week of MOR therapy. Our untrained passages contain the same number of words as the trained passages, but differ in terms of which words from the trained passages are re-used (functors, content words, phrases, or a minimal overlap of words). If, as others have hypothesized, generalization effects can be attributed to improved top-down processing, we would expect equal improvement across all untrained passages after treatment, including those containing minimal trained words. An alternative hypothesis is that MOR's generalization effects could be due to bottom-up improvements in specific words or groups of words. Our tightly controlled test passages allow us to track what types of words are improving as text reading improves in order to differentiate the two hypotheses.

We administered MOR therapy to two participants with mild pure alexia and four participants with phonological text alexia. Our design required that, in a single two-hour session, the participants read 8 text passages 300 words in length as well as practicing that week's training passage with the Speech Pathologist. Most of the patients reported in MOR studies previously would likely be unable to complete all of this reading without fatigue, but it was required in the current study in order to test our hypotheses. Therefore, we included only mildly impaired patients in this study.

It should be noted that even within diagnostic category (pure or phonological text alexia) the participants were dissimilar in their lesion sites and cognitive profiles prior to therapy. In order to take into account the similarities and differences when evaluating our hypotheses, we use a "case-series methodology" here (Lambon Ralph, Moriarty & Sage, 2002). This method allows detailed discussion of each participant (as in a single-case study) as well as comparison across participants (as in group studies).

Our predictions for the two alexia types studied here are as follows: we predicted that the phonological text alexics would improve on the phrase passages, the functor passages or both, but not on the content passages (performance on these words should be at ceiling pre-treatment). Repetition of the functors within the training passages should improve access to them, and this should transfer to untrained passages containing those same functors. As originally suggested by Moyer, difficult words may need to be practiced in context in order for access to them to improve. Our untrained Phrase passages reflect the benefit of practicing not just single, difficult words in context, but the specific phrases that contain some of these words.

Unlike patients with phonological alexia, patients with pure alexia were not expected to be affected by the part-of-speech of the trained words re-used in the untrained passages. If the reinforcement of visual-orthographic connections to the specific words in the practiced paragraphs is responsible for the reduction in reading times for pure alexia patients after MOR, then the pure alexia patients would improve on all three types of untrained passages (Functor, Phrase and Content) because all three contain trained words. However, they would not improve on passages with minimal overlap of words from the trained passages. Each time a word is seen and read aloud during training, visual-orthographic links are reinforced. Therefore, if that word is seen again in a novel context, time to access the word would be expected to decrease. Improved access would be the same whether the repeated items are content words, functor words or phrases.

Finally, it is possible that, as others have suggested, MOR improves the use of top-down processing (Tuomainen and Laine, 1991) rather than affecting the underlying deficit and improving reading from the bottom up. If this is the case, then the benefits of MOR therapy should be the same for pure alexia and phonological text alexia. Participants should improve on any untrained passage, including those with no practiced words, as all passages should benefit equally from improved top-down processing.

METHOD

Participants *(See* Tables 1 and 2)

Phonological Text Alexia Participant 1 (PhTA1)—PhTA1 was diagnosed with cerebral amyloid angiopathy, which was the likely cause of the three successive intracranial hemorrhages she suffered in left temporo-parietal and occipital areas. Although she had a left visual field cut, she did not have a length effect. Rather, her text reading was slow and characterized by errors on functors and affixes.

Phonological Text Alexia Participant 2—PhTA2 suffered an infarct in the left middle cerebral artery, resulting in damage to the left posterior frontal region, extending caudally to post-central anterior parietal cortex, and ventrally to the posterior frontal opercular aspects of the Sylvian fissure. His text reading was slow and he made errors primarily on functors and affixes.

Phonological Text Alexia Participant with Low Reading Accuracy 1 (PhTA3)— This participant suffered an infarct in the left middle cerebral artery, affecting nearly all of the left frontal lobe, as well as posterior temporo-parietal regions, including part of Wernicke's area, and part of the left thalamus. In the acute stage, she presented with non-fluent aphasia. When she entered our study 9 years later, her speech was fluent but included frequent phonemic paraphasias and some word-finding difficulties. Prior to entering the current study, PhTA3 completed a separate experimental treatment protocol in our lab, as described elsewhere (Lott et al., 2009). Her reading was slow and included many functor and affix errors and substitutions. This participant was unable to achieve our cut-off reading accuracy score of 90% on the experimental passages.

Phonological Text Alexia Participant with Low Reading Accuracy 2 (PhTA4)— This participant suffered a left hemisphere stroke resulting in a lesion encompassing most of the left insula and affecting the temporal lobe from the temporal pole to Wernicke's area. The parietal and frontal opercula were also damaged. Her reading was slow with errors primarily on functors and affixes. Her oral single word reading included errors on multi-syllabic words. This participant was also unable to achieve our cut-off reading accuracy score of 90% on the experimental passages.

Pure Alexia Participant 1 (PA1)—This participant suffered a left hemisphere stroke affecting the occipital and medial temporal lobe. He has a small area of blurred vision in the upper right visual field. He had returned to work at the time of the study and presented as highly functional on all language tests, though oral text reading was somewhat halting with occasional errors on word-endings. He showed no measurable length effect, but was considered pure alexic because his reading was impaired in comparison to his pre-morbid abilities and to his writing skills, which were intact (perfect scores on all writing sections of the Boston Diagnostic Aphasia Examination (BDAE; Goodglass, Kaplan & Barresi, 2001).

Pure Alexia Participant 2 (PA2)—This participant suffered a closed head injury when he was hit by a car. Primary impact caused a fracture of the right frontal bone/orbital roof/ medial orbit causing a lesion in the right frontal lobe. He sustained left occipital and temporal hemorrhagic contusions as a result of contrecoup injury. He has a field cut in the upper right quadrant of the visual field. He performed well on most language tests. He showed a slight length effect (average speed for reading 3 letter words was 870 msec, 5–6 letter words was 1253 msec and 7 letter words 1525 msec) and made occasional, self-corrected errors, usually on word-endings in text reading (for example, he read "provide" as "project"), but his writing was intact (perfect scores on all writing sections of BDAE (Goodglass, Kaplan & Barresi, 2001), except for writing "tomatoe" for "tomato").

Participant Testing

Table 2 shows participants' scores on sections of the BDAE (Goodglass, Kaplan & Barresi, 2001), the RCPM (Raven's Colored Progressive Matrices; Raven, 1976) and TONI (Test Of Nonverbal Intelligence; Brown, Sherbenou & Johnson, 1997); the latter two tests are standardized tests of intelligence that use visuospatial rather than linguistic stimuli. Table 3 shows participants' scores for a pseudoword reading list developed in our lab. The pseudowords are 3–4 letters in length and were created by changing one letter in each of a list of matched real words. Participants read these two lists on separate testing days.

Oral and silent reading speed and accuracy were assessed using standardized reading passages 1, 3, and 5, and 2, 4, and 6, respectively, from the Gray Oral Reading Test (GORT III, Wiederholt & Bryant, 1992). Passages from Form A were used for pre-testing, while passages from Form B were used for post-testing (see Table 3). As in Moyer (1979), reading speed, not comprehension, was the focus of the treatment. Therefore, comprehension of our experimental training and generalization passages was not assessed, but general reading comprehension was evaluated pre- and post-treatment with the GORT. Silent reading comprehension was also assessed using passages from the Gates-MacGinitie reading test (1965).

The four participants with phonological text alexia show deficits on pseudoword reading and make functor and affix errors in text. The two participants with pure alexia show no pseudoword reading deficits and their errors on word endings are not exclusive to affixed words. Based on these patterns of deficit, the alexia diagnosis categories in which we placed these participants are appropriate (see Tables 2 and 3).

Stimuli

Stimuli consisted of trained and untrained text passages. There were five types of text passages: the training (practiced) passages; three types of untrained passages used to assess the source of generalization to novel text; and neutral control passages, which contained minimal overlap of words with the trained passages, as described below.

Training passages came from an educational workbook at grades 6–8 reading levels (Instructional Fair, Inc., 1990). These passages had minimal dialogue, few words or names with challenging pronunciations, and came from the earliest parts of the workbook, which progressed gradually in difficulty. A total of eight passages were edited and abridged to 300 words in length, and each was printed on a single page in *Times New Roman* 15-point font. The words in each training passage were coded as functors or content words according to their syntactic role in the training passage. Some words were coded as ‘other’ and were not included in analyses or word counts when creating the passages used to assess generalization. ‘Other’ words included adverbs and inflectionally affixed words (in which the affix does not change the part of speech of the root word). Including these words would make interpretation of the results of the content passages difficult, as we would be unable to determine if errors were due to the affix or to the content word itself. The articles ‘*a*’, ‘*an*’, and ‘*the*’ were also coded as ‘other’. Phrases of 3–5 words in length were also coded and marked in the training passages.

Using the coded phrases, functors and content words from each training passage, we created the following three types of new passages to be used as untrained passages:

1. A Phrase passage sharing 60–80% of the phrases contained in the training passage, while differing in overall narrative structure and content.
2. A Functor passage sharing 60–80% of the derivationally affixed words and functors contained in the training passage, with minimal overlap of phrases or content words and differing in overall narrative structure and content.
3. A Content passage sharing 60–80% of the content words contained in the training passage, with minimal overlap of phrases, a minimal number of shared affixed words, and, to the extent possible, a minimal number of overlapping functors as

well. These passages also differed in overall narrative structure and content from the training passage.

The untrained Phrase, Functor and Content passages were never trained. They were used as testing material only, before and after their respective Training passage was trained. Each passage contained 295–300 total words, no dialogue, no words with challenging pronunciations, no repetition of proper nouns or of words coded as '*other*' (with the obvious exception of the articles '*a*', '*an*' and '*the*'). The passages differed completely in subject matter from each other and from the Training passages. Words re-used to create the untrained Phrase, Functor and Content passages had the same meaning and/or part of speech when used in the Training passage. All untrained passages contained an equivalent number of practiced words. All 32 passages were matched in terms of the total number of content, functor, and "*other*" words per passage.

In addition, four Control passages were created to control for the possible effects (on reading speed and accuracy) of simply re-reading the same passage after a week's delay, regardless of any specific training or practice. Control passages were constructed in a similar fashion to the other untrained passages, but contained no trained content words and minimal trained functors from that week's, or any previous weeks' Training passages.

Total time to read each passage aloud was assessed. We analyzed the reading time results of participants who read at or above 90% accuracy and used accuracy as the measure of improvement for those participants who read below 90% accuracy. The inaccurate reading of a significant number of words would distort measures of speed and lead to uninterpretable reading time data for the passages.

Procedure

Overall—Treatment consisted of one two-hour session per week for 8 weeks. Each week a different Training passage was trained. The untrained Control, Phrase, Functor and Content passages were never trained, but were tested before and after their respective training passage was trained. Since there were only four Control passages, each session included pre- or post-testing of a Control passage, but never both, as with the other passages.

Experimental Testing—Each session began with post-tests of the prior week's Control passage (if applicable), training passage, and modified Phrase, Functor and Content passages, followed by pre-tests of the next week's passages. The participant was instructed to read each passage out loud from beginning to end without stopping, as quickly and accurately as possible. Reading speed and accuracy were recorded. No feedback regarding accuracy or response time was provided during pre- or post-testing.

Post-tests were interleaved with pre-tests such that post-testing of the previous week's stimuli always preceded pre-testing of the upcoming week's test passages. For example, the order of testing for Week 2 was as follows:

1. Week 1 passage POST-tests – Reading aloud: Control passage 1, Training passage 1, untrained Phrase passage 1, untrained Functor passage 1 and untrained Content passage 1.
2. 10 minute break.
3. Week 2 passage PRE-tests – Reading aloud: Training passage 2, untrained Phrase passage 2, untrained Functor passage 2, untrained Content passage 2.
4. Training with feedback for Training passage 2.

While most sessions included both pre- and post-testing, the first session obviously contained no post-testing since no passages had yet been trained, and the last session contained no pre-testing since no passages remained.

Training—After the week's pre- and post-testing were completed, treatment for the week's Training passage began. Though training with feedback was not always the method used in previous studies, we felt that correcting errors during training was better for the participants. Also, higher accuracy results in more precise measurements of reading times. During training, the participant was told that should s/he make a mistake, the experimenter would stop him/her and point to the incorrect word for him/her to re-read. The participant was instructed to re-read only the specific word, not to go back to the beginning of the sentence. If the participant could not read the word correctly after this cueing, the experimenter said it for him/her. The participant was only instructed to repeat whole sentences if s/he made enough errors to completely lose the flow of the sentence. The participant read the training passage three times in this manner with cueing from the experimenter. This concluded the training session for the passage, and the participant was then given a copy of the passage for home practice. In order to increase the likelihood that the participant was reading the passage correctly at home, the participant was instructed to call the experimenter's office once every day for the next week and read the passage over the phone with feedback provided. The participant also practiced the passage 5 more times each day, unassisted. To encourage participants to carry out home practice as instructed, they were provided with written log sheets on which to record each home practice session, which they then reviewed with the experimenter at each treatment session.

Post-Testing—After the final week of MOR therapy, reading (including Form B of the GORT) and language tests were re-administered to assess any changes in profile. Those tests in which a participant had achieved a score within normal range prior to therapy were not re-administered (See Tables 2 and 3).

RESULTS

(Figure 2 shows reading speed for participants PhTA1, PhTA2, PA1 and PA2. Figure 3 shows reading accuracy scores for PhTA3 and PhTA4.)

Participants with Phonological text alexia (PhTA1, PhTA2)

Figure 2 displays the mean number of syllables read per second for each of the five passage types (Control, Training, Phrase, Functor, Content) pre- and post-training, averaged across the 8 weeks of treatment (except for Control passages ($n = 4$)), for PhTA1 and PhTA2. The interaction of testing time by passage type was significant for both participants, ($F(4, 31) = 16.02$, $p < .0001$ and $F(4, 31) = 9.10$, $p < .0001$, respectively). Planned pair-wise comparisons between pre and post-training for the five passage types also revealed significant increases in syllables/second for reading the Training passages for both PhTA1 (mean change in syllables/s = 0.43, $t = 8.27$, $p < .0001$) and PhTA2 (mean change = 0.65, $t = 4.02$, $p < .01$). For the untrained, generalization passages, the Phrase passages differed significantly in speed between pre and post treatment for PhTA1 (mean change = 0.10, $t = 3.74$, $p < .01$), and the Functor passages differed significantly for PhTA2 (mean change = 0.19, $t = 5.05$, $p < .01$). The Content passages did not improve significantly for PhTA1 ($t = 1.13$, p>.05) or PhTA2 ($t = 1.30$, p>.05), nor did the Control passages (PhTA1: ($t = 1.52$, p>.05) or PhTA2: ($t = .20$, p>.05)). ANOVAs of speed of reading revealed no difference for passage type pre-treatment for either PhTA1 or PhTA2 ($F(4, 31) = 1.08$, $p > .05$ and $F(4, 31) = 2.11$, $p > .05$, respectively), but highly significant differences post-treatment (PhTA1:

$F(4, 31) = 22.21$, $p < .0001$; PhTA2: $F(4, 31) = 20.37$, $p < .0001$). Overall pre- and post-treatment accuracy was high for PhTA1 (97.7% and 98.1%) and PhTA2 (95.5% and 96.4%).

For both participants, average syllables read per second on the GORT form B, both orally and silently, increased after treatment, while comprehension remained relatively high (see Table 3). In addition, PhTA2 showed a significant improvement in pseudo-word reading from 5/20 pre-treatment to 12/20 post-treatment (McNemar p=0.019, one-tailed).

Participants PhTA3 and PhTA4 (Phonological text alexia, low reading accuracy)

PhTA3 and PhTA4 were unable to read the passages at 90% accuracy pre-treatment, making measurements of their speed of reading invalid. Instead, we report their accuracy results here and in Figure 3. PhTA3's accuracy on the Training passages improved significantly from pre- to post-treatment (74.1% to 90.1%; mean change in percent correct = 16.5 $t = 9.89$, $p<.0001$) as did PhTA4's (89% to 94%; mean change in percent correct = .054, $t = 5.29$, $p< .01$). PhTA3's accuracy in reading the generalization passages improved after treatment, but was still quite low (range= 66% – 76%). Figure 3 shows the changes in her accuracy from pre- to post-treatment for the different generalization conditions. Planned pairwise comparisons revealed significant increases in accuracy for the Functor and Phrase passages for PhTA3. The mean change in percent correct for the Phrase passages was 8.6%, $t = 6.81$, $p<.0001$ and for the Functor passages 16.5%, $t = 9.89$, $p<.0001$. PhTA4 showed significant improvement only on the Phrase passages (from 87% to 90% correct; mean change = .027, $t = 2.69$, $p<.05$). Neither PhTA3 nor PhTA4 showed significant changes in accuracy on the Control passages (PhTA3: $t = .64$, $p>.05$ PhTA4: $t = .25$, $p>.05$)

After MOR therapy was completed, PhTA3 and PhTA4 were re-tested with GORT Form B and showed an increase in syllables per second on oral and silent reading. Comprehension remained stable or improved for PhTA4 and decreased for oral reading for PhTA4 (see Table 3). PhTA3 and PhTA4 also showed an increase in pseudoword reading accuracy, though this improvement did not reach statistical significance. PhTA3 improved from 1/20 to 5/20 (McNemar p=0.063, one-tailed) and PhTA4 improved from 1/20 to 6/20 (McNemar p=0.109, one-tailed) after MOR therapy.

PhTA4 also showed significant improvements on the Boston Naming Test (BNT) (McNemar, p=.019, two-tailed) and the oral word reading section of the BDAE (Goodglass, Kaplan & Barresi, 2001) (Wilcoxon, p=.039, 2-tailed; see Table 2).

PA1 and PA2 (Pure alexia)

Figure 2 displays the mean number of syllables read per second for each of the five passage types pre- and post-training, averaged across the 8 weeks of treatment (except for Control passages ($n = 4$)), for participants PA1 and PA2. The interaction of testing time by passage type was significant (PA1: $F(4,31) = 26.08$, $p < .0001$; PA2: $F(4, 31) = 25.72$, $p < .0001$). Planned pair-wise comparisons of the five passage types revealed significant increases in syllables/second for reading the Training passages for PA1 (mean change in syllables/s = 0.88, $t = 8.87$, $p <.001$) and for PA2 (mean change in syllables/s = 1.00, $t = 10.23$, $p < .0001$). As predicted, all generalization passages that overlapped with Training passages improved significantly for PA1 (Phrase: $t = 4.79$, p<.01; Functor: $t = 5.22$, $p <.01$ Content: $t = 3.84$, $p <.01$). For PA2 all generalization passages improved (Phrase: $t = 3.48$, p<.05; Content: $t = 4.27$, p<.01) except the Functor passages ($t = 1.00$, p>.05). Also as predicted, the Control passages did not improve significantly for PA1 ($t = 3.058$, p>.05) or PA2 ($t = 2.55$, p>.05). ANOVAs of speed of reading (syllables/s) revealed no difference for passage type pre-treatment (PA1: $F(4, 31) = .85$, $p > .05$; PA2: $F(4, 31) = 2.57$, $p > .05$), but highly significant differences post-treatment (PA1: $F(4, 31) = 28.32$, $p < .0001$; PA2: $F(4, 31) =$

39.53, $p < .0001$). Pre- and post-treatment accuracies for all passages for both participants were close to 100%.

Average syllables read per second both orally and silently on the GORT form B increased after treatment while comprehension remained high in both participants (see Table 3).

DISCUSSION

Our main hypothesis regarding the effects of MOR was borne out by both the phonological text alexia patients and the pure alexia patients. That is, the MOR technique improves the reading of untrained passages that overlap with trained passages at the level of the specific alexic deficit. The treatment is simple to administer and, though it is repetitive, the participants reported here enjoyed it. They liked having homework outside of therapy, and they found the feedback during training helped them to understand which words were making reading difficult for them.

Reading rate for novel passages containing practiced functors and/or phrases increased after MOR treatment for participants with phonological text alexia (difficulty reading functors in text). Reading rate for novel passages containing a significant number of practiced words of any kind increased after MOR treatment for participants with pure alexia (slowed identification of all types of words). Reading rate for novel passages containing a minimal number of words from the training passages did not increase after MOR treatment for any of the participants. The lack of a generalization effect for *truly* novel text stands in contrast to previous studies hypothesizing that generalization to novel text is due to top-down processing and indicates a bottom-up mechanism for MOR's treatment effect.

Our results for the Training passages are consistent with previous literature (e.g., Moyer, 1979; Beeson & Insalaco, 1998) in that all patients improved on these passages through practice. Although we did not measure comprehension for the experimental passages, the results of the GORT indicate that comprehension did not suffer when reading speed increased (see Table 3). In the four patients for whom we could reliably measure speed, we also replicated previous studies that found generalization of the treatment effect to novel reading material differing in content and narrative structure. None of our patients showed a significant difference in speed or accuracy between pre and post-treatment time-points on the Control passages designed to test generalization to a *truly* novel passage. These results are inconsistent with a top-down processing explanation for MOR's effect, which predicts improvement on all passages, regardless of how they overlap with the training passages. To reliably test the top-down processing hypothesis, it was necessary to work with patients who could read at a certain speed. Though this exclusionary criteria made our treatment effect sizes smaller than what has previously been reported, it also gave us the controls we needed in the design to test the top-down processing hypothesis properly.

Our results suggest that bottom-up improvements specific to the deficits of each patient play an important role in MOR's treatment and generalization effects. The results from the untrained Content passages are the first line of evidence to support our bottom-up hypothesis. The Content passages were designed to reflect the outcome of practicing content words during re-reading of the Training passages. The results for the phonological text alexia patients tell us that practicing these content words does not significantly contribute to generalization to novel text. Also supporting the bottom-up hypothesis is the finding that these patients did improve on the Functor and/or Phrase passages indicating that a critical mass of functors or phrases containing functors from the practiced passage must be included in an untrained passage in order for generalization effects to be measurable for patients with phonological text alexia. Previous studies have investigated this idea. Beeson and Insalaco

(1998), whose patients were also mild phonological alexics, found a decrease in reading time for functors presented in isolation after MOR treatment. Though their ultimate conclusion is that “context effects” are responsible for their patients’ improvement on novel text, they also discuss the possibility that the reason their patients improved on single functor reading was that the high frequency of functors in the training passages allowed more repetition of functors than of words of any other part-of-speech. Our study controlled for the number of functors and *which* functors were re-used in our untrained passages. Therefore, we were able to determine that our phonological alexia patients benefited from repetition of the specific functors and/or phrases that they practiced. Without sufficient overlap of functors and/or phrases, as in the Content passages, no improvement was seen. Lack of improvement on the Content passages in the phonological alexia patients argues against the top-down processing hypothesis to explain generalization in MOR. Again, top-down processing would be expected to affect all passage types equally.

Further supportive evidence comes from the four Control passages, which represent a negative control condition, in that they were written using as few words that overlap with words in the Training passages as was feasible. Neither the phonological nor the pure alexia patients improved on the Control passages. If top-down processing were the driving factor behind MOR, we should have seen improvement on these passages. This condition is particularly important in the case of the pure alexia patients. They were expected to improve on all untrained passages that overlapped with the Training passages; therefore, only the Control condition can show their level of generalization to a passage that is truly novel text (i.e. with minimal overlap of any practiced words, including functors). Neither pure alexia patient showed generalization effects on these passages.

We argue against a top-down processing or “context effects” account for MOR because our results indicate that a significant part of the mechanism behind MOR is bottom-up. However, both theories, due to their grounding in single word reading models, are probably too simplistic to explain the phenomenon of generalization after MOR training. That five of the six participants presented here showed improvement on the untrained passages containing trained phrases indicates that some combination of top-down and bottom-up processing may explain the treatment effect. The Phrase passages measure the benefit of practicing specific sequences of words as well as the benefit of practicing difficult words in context (i.e., within the phrases). Moyer’s original hypothesis, that bottom-up and top-down processes interact during practice in MOR and that words (parts) benefit from practice within the structure of text (whole), is supported by our data on Phrase generalization. Treatments like MOR that include the practicing in context of specific words appropriate to a patient’s deficit may be more likely to generalize.

In order to gain more information about the source of the improvements on the Phrase passages, we analyzed the errors for a subset of the untrained Phrase passages. Using accuracy as the measurement of improvement for PhTA3 and PhTA4 allowed us to analyze what was driving generalization in the Phrase passages in a way that would not be possible with speed data. Comparing accuracy changes on the re-used phrases, PhTA3 showed the greatest improvement on functor words within phrases (25%) as opposed to only 14% on content and unaffixed “other” words. Affixed words coded as “other” showed a slight (5%) decrease in accuracy. Analysis of PhTA4’s errors showed a different pattern. She showed a slight (2–4%) improvement on content, functor and unaffixed “other” words within the phrases, but an 18% increase in accuracy for the affixed words coded as “other”. This analysis suggests that, even within the syntactic context of a phrase, treatment effects are based on improvements to specific word types that are unique to the patient’s particular deficit.

PhTA4 and PhTA1 improved, albeit by different measures, only on the phrase passages. PhTA3 improved on the Phrase as well as the Functor passages and further analysis revealed that improvement on the Phrase passages was due to increased accuracy for the functors within the phrases. For PhTA4, it was the affixed words, a group of words our design did not measure, which appeared to be responsible for the improvement on the Phrase passages. Though we were unable to determine the specific word types that were the source of improvements in speed, it is possible that PhTA1's improvement on the Phrase passages was due to improved speed of reading affixed words. In future studies, we will be able to include an untrained generalization passage made up of practiced, affixed words to look into this issue further.

Three of the four phonological text alexia patients showed improvement on pseudoword reading after treatment, though only PhTA2's improvement reached significance. These data indicate that MOR may actually improve bottom-up connections between orthography and phonology, and that this improvement can be detected in a task that measures these connections. This is consistent with Tuomainen and Laine's (1991) hypothesis that if MOR targets the deficit underlying a reading problem and works from the bottom up, improvement in single word reading can be predicted. Pseudoword reading is a reasonable measure of changes to orthography-to-phonology connections in our patients, as most were at or near ceiling on reading of single, real words (see Table 3). PhTA2's improved orthography-to-phonology connections did not translate to measurable improvements in speed in the more complex task of text reading, though it may have been part of the reason he improved on the functor passages.

Obviously, there were no pseudowords in the Training passages, so PhTA2's improvement on pseudoword reading cannot be explained by repeated practice of specific words. It seems to be an example of MOR treatment improving the connections themselves. While the other patients seemed to benefit from practicing difficult words in context (Phrase passages), PhTA2 seemed to benefit from practicing the specific words he had difficulty with (reflected by his improvement only on the Functor passages), perhaps improving on functor word reading as his orthography-to-phonology connections improved. Though PhTA2 did not show any other evidence of improved integrity of these connections, it is possible that he would have with further weeks of MOR treatment. It may be that MOR can act directly on the deficit itself in some people and work on specific words that are difficult *because* of the deficit in others.

The patients in the current study began treatment reading more quickly than most other patients reported in previous MOR studies. Enrolling these types of participants was the most effective way for us to examine the two hypotheses to explain MOR's treatment effects. The information our data have provided can be applied to future studies investigating how to optimize MOR treatment for patients of all levels. Our phonological alexia participants did not demonstrate a part-of-speech effect in single word reading and one of our pure alexia participants did not demonstrate a length effect. Previous studies have shown that after MOR treatment, participants beginning at a lower reading rate than ours can demonstrate abolition of length effects (Beeson et al., 2005) and part-of-speech effects (Beeson & Insalaco, 1998). Our data may reflect what would have happened if these patients continued to be treated with MOR: reading speed and/or accuracy gains would get smaller, but reading would continue to improve.

Taken together, the data reported here indicate that the treatment mechanism of MOR for people with alexia is at least partially due to bottom-up processes. In phonological alexia, repetition priming of functors and phrasal units containing difficult words led to improved speed and/or accuracy in untrained text. The exact pattern of improvement varied across patients, but no phonological alexia patient improved on the Content passages. Pure alexia patients, who do not have phonological problems leading to difficulty with functors, *did* show improvement on the Content passages. However, they did not improve on passages containing few practiced words (Control passages), indicating that, for pure alexia, strengthening of visual-orthographic connections improves speed of reading practiced, but not unpracticed, words. Therefore, the generalization effects associated with MOR appear to be largely driven by improved bottom-up processes that are specific to the type of deficit of the patient.

By evaluating these patients as a group as well as individually, we were able to elucidate patterns of breakdown that cause alexic reading deficits. Moyer reported success with MOR 30 years ago and Speech Pathologists continue to rely on it clinically. There is certainly some evidence that MOR works, and, as a result of the current study, we now have a better understanding of *why* it works. Our design required all participants to be mildly impaired. However, our participants whose accuracy was too low to measure speed showed improvements in accuracy that were consistent with our hypotheses, suggesting that MOR can benefit more impaired patients. Future case series studies should investigate the use of MOR with other and more severe alexia patients, as the treatment is simple, tends to generalize, and can be useful in informing cognitive models of alexia.

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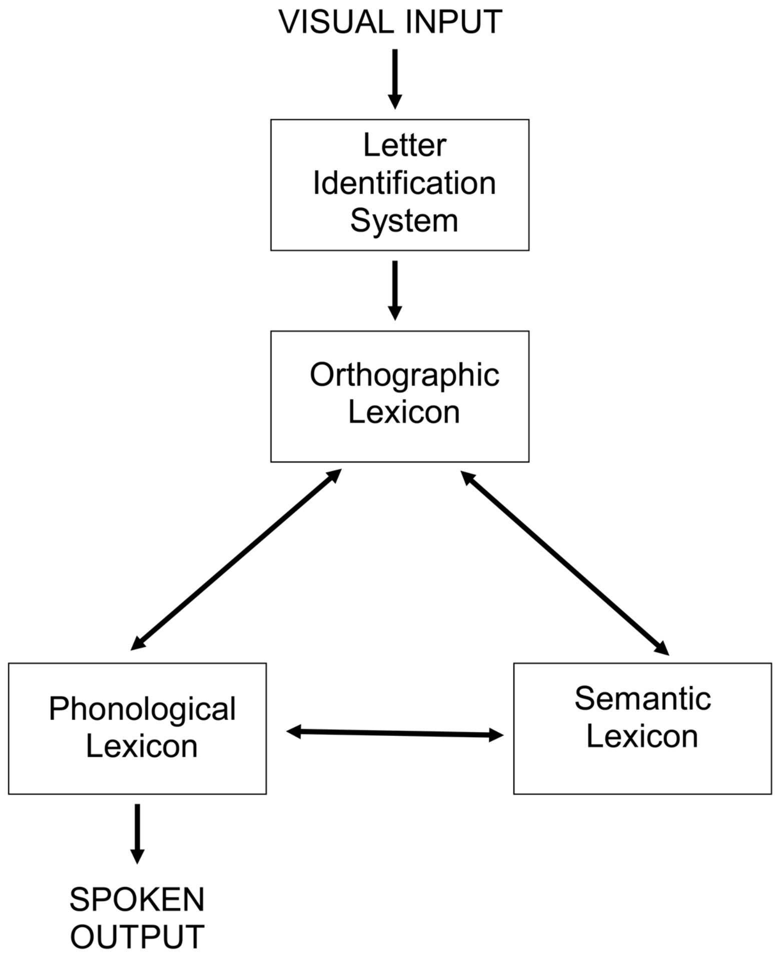
VISUAL INPUT
Letter Identification System
Orthographic Lexicon
Phonological Lexicon
Semantic Lexicon
SPOKEN OUTPUT

Figure 1.

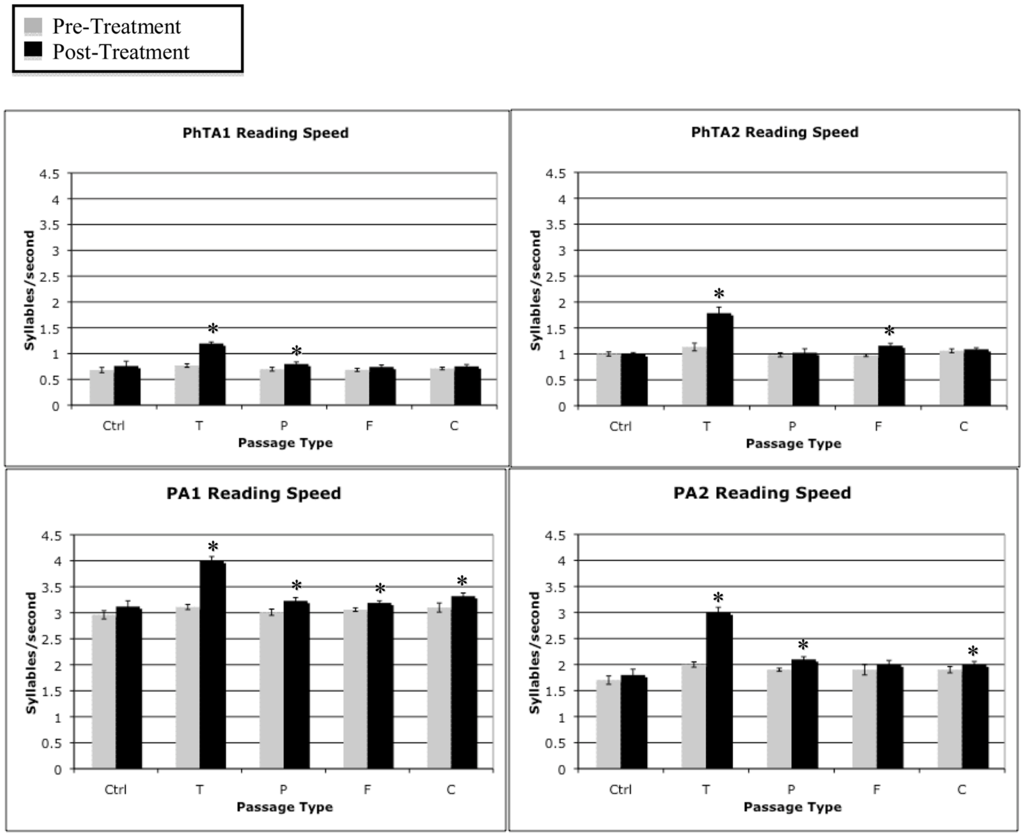

Figure 2.

Reading speed in syllables per second for phonologic text alexia patients PhTA1 and PhTA2 and pure alexia patients PA1 and PA2. Significant improvements in reading speed were found for the training passages (T) for all patients. Various patterns of improvement were found on the novel generalization passages containing specific words from the T passages (P=Phrase; F=Functor; C=Content words). No significant improvements were found for the control (Ctrl) passages.

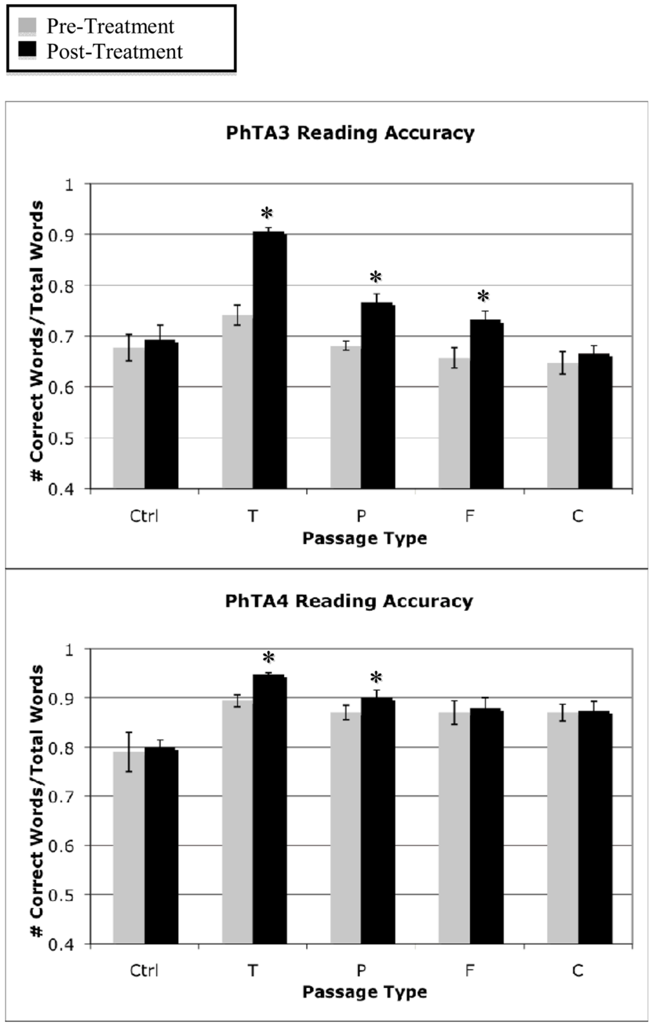

Figure 3.

Reading accuracy for phonologic text alexia patients PhTA3 and PhTA4. Significant improvements in reading accuracy were found for the training passages (T) as well as the generalization passages that contained trained functors (F) and/or phrases (P). Neither patient showed generalization in the content (C) passages or the Control (Ctrl) passages.

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Table 1

Study Participants

Patient	**Age**	**Education (Years)**	**Lesion location**	**Time post-onset**	**Aphasia diagnosis**	**Alexia diagnosis**	**Etiology**
PhTA1	60	18	left temporo-parietal and occipital, right frontal	13 mo.	Anomic	Phonologic Text	Multiple hemorrhages
PhTA2	61	18	left posterior frontal, anterior parietal	12 mo.	Resolved Non-fluent	Phonologic Text	Stroke
PhTA3	69	18	left frontal, posterior temporo-parietal	9.5 yrs.	Anomic	Phonologic Text	Stroke
PhTA4	39	12	left insula, temporo-parietal	3 yrs.	Anomic	Phonologic Text	Stroke
PA1	53	18	occipital, medial temporal	2 yrs.	None	Pure	Stroke
PA2	62	16	right frontal, left temporo-occipital	2 yrs.	None	Pure	Head injury

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Table 2

Standardized Language and Cognition Tests

TESTS	*Max*	PhTA1 *pre*	PhTA1 *post*	PhTA2 *pre*	PhTA2 *post*	PhTA3 *pre*	PhTA3 *post*	PhTA4 *pre*	PhTA4 *post*	PA1 *pre*	PA1 *post*	PA2 *pre*	PA2 *post*
RCPM	36	34		36		21		36		36		35	
TONI *(score/percentile)*	45	38/94%		36/79%		26/66%		33/61%		40/90%		35/74%	
BDAE													
Basic word discrimination	37	34	34	**37**		**35**		**35**		**37**		**37**	
Commands	15	13	14	14	15	15	15	14	14	**15**		**15**	
Complex Ideational Material	12	10	10	10	12	10	9	9	9	**12**		**12**	
Repetition: Words	10	**10**		**10**		6	6	**10**		**10**		**10**	
Repetition: Sentences	10	**10**		**10**		3	3	9	*	**10**		**10**	
Responsive naming	20	14	14	**20**		15	20	18	20	**20**		**20**	
Boston Naming Test	60	26	32	**56**		34	38	*19*	*31*	**58**		**	
Special categories	12	**12**		**12**		**12**		12	12	**12**		**12**	
Oral word reading	30	**30**		**29**		26	25	*21*	*29*	**30**		**30**	
Oral sentence reading	10	**9**		2	7	4	5	3	4	**10**		**10**	
Oral Sentence comp.	5	**5**		4	5	**5**		**5**		**5**		**5**	
Sentence/paragraph	10	**10**		**10**		4	8	10	8	**10**		**10**	

RCPM: Raven's Coloured Progressive Matrices; TONI: Test of Nonverbal Intelligence; (Cognitive tests were used as exclusionary criteria and were not tested post-treatment)

Italics indicate a significant difference between pre and post-testing

Tests on which patients scored within normal range pre-treatment (indicated in **bold**) were not tested post-treatment.

* Patient became frustrated and refused to complete more than the first two sentences (which she repeated correctly).

** Due to experimenter error, the BNT results were not valid. However, PA2's responsive naming, special categories and spontaneous speech showed no indication of anomia.

Table 3

Reading test scores, pre- and post-MOR treatment

TESTS	*Max*	PARTICIPANTS											
		PhTA1		**PhTA2**		**PhTA3**		**PhTA4**			**PA1**		**PA2**
		pre	***post***	***pre***	***post***	***pre***	***post***	***pre***	***post***	***pre***	***post***	***pre***	***post***
GORT (*Pre:* Form A; *Post:* Form B)													
Oral (passages 1,3,5)													
Comprehension	**15**	12	11	14	14	12	7	13	13	14	12	13	11
Average syllables/s		0.62	0.8	0.94	1.1	0.89	1.01	.66	1.11	2.87	4.25	1.81	1.97
Silent (passages 2,4,6)													
Comprehension	**15**	10	12	11	13	6	10	8	10	14	15	10	14
Average syllables/s		0.6	0.95	0.98	1.2	1.38	1.50	2.35	4.01	1.90	4.48	1.83	2.24
Gates-MacGinitie													
Silent Reading Comprehension	**36**	28	27	34	32	18	21	21	18	36	35	36	35
Pseudoword reading													
Pseudowords	**20**	13	13	*5*	*12*	1	5	1	6	20	20	20	20
Matched real words	**20**	20	20	20	20	17	18	18	19	20	20	20	20

Italics indicate a significant difference between pre and post-testing