Introduction

Damage to the left perisylvian cortex typically results in impaired phonological processing abilities. This impairment is readily detected on tasks that require phonological segmentation and manipulation, and on tasks that require grapheme-phoneme conversion, such as reading and spelling nonwords. The written language profile that typically results from such impairment, wherein nonword reading/spelling is impaired relative to real-word reading/spelling, is known as phonological alexia and agraphia. Although the impairment is most notable on nonword performance, decreased input from phonology to orthography commonly results in reduced reading and spelling accuracy for real words as well (Henry et al., 2007).

Several researchers have demonstrated that phonological processing abilities can be improved to some extent by re-training (Hillis Trupe, 1986; Kiran, 2005; Luzzatti et al., 2000). However, even with phonological abilities strengthened, most individuals with left perisylvian damage demonstrate residual spelling difficulties for real words. To further advance performance, two options might be considered: a) a lexical approach in which the spellings of specific words are retrained, or b) a strategic approach to enhance self-detection and correction of residual errors. There is ample evidence to show that lexical treatments result in improved spelling for targeted words in an item-specific manner. In contrast, a strategic approach has the potential to generalize to untrained words, yet there has been relatively little research examining the value of such treatments. Specifically, there is some evidence to show that spelling treatment to promote interactive use of residual lexical and sublexical abilities combined with self-correction strategies can be beneficial for individuals with surface agraphia (i.e., those with relatively preserved sublexical spelling abilities; Beeson et al., 2000), but its value for individuals with weak phonological skills has not been explored.

In this study, we implemented a two-stage treatment with two individuals with phonological alexia/agraphia with the goal of strengthening phonological processing abilities, and then promoting interactive use of sublexical and lexical knowledge to resolve spelling errors. We predicted that this approach would result in generalized improvement of spelling for untrained words.

Methods

Participants

Two individuals with aphasia due to left middle cerebral artery stroke participated in this study (Figures 1 and 2). Participant 1 was a 76 year-old, right-handed woman with 12 years of education who was 9 years post stroke. She had a spoken language profile consistent with conduction aphasia of moderate severity on the Western Aphasia Battery (Aphasia Quotient = 76), and a significant naming impairment on the Boston Naming Test (31/60; 52%). Participant 2 was a 43 year-old, right-handed woman with 14 years of education who was 5½ years post-stroke. She exhibited mild impairment of spoken language characterized by word retrieval difficulty, with a WAB AQ of 96.4 and a score of 46/60 (80%) on the Boston Naming Test.

Procedures

Pre-treatment assessment was conducted to examine semantic, phonological, and orthographic processing. Both participants had relatively preserved semantic processing abilities, but impaired phonological skills. Single word reading and spelling were assessed using controlled lists of stimuli that included 30 regular words, 30 irregular words, and 20 nonwords.

As shown in Figures 1 and 2, both participants demonstrated performance patterns consistent with phonological alexia and agraphia, with Participant 1 showing greater overall impairment. Single-word reading was mildly impaired for both participants, with spelling proving to be a more difficult task.

Each participant completed two stages of behavioral treatment. Stage 1 was directed toward improving phonological skills (sound-letter correspondences and blending), while Stage 2 involved an interactive treatment in which participants learned to detect and correct spelling errors using residual phonological and orthographic knowledge as well as an external spelling aid.

Stage 1: Phonological Treatment

Phonological treatment was implemented as follows:

1. Establish "key words" for 20 consonants (trained in 4 sets of 5) and 12 vowels (trained in 2 sets of 6).
2. Use a cueing hierarchy to train sound-letter/letter-sound correspondence for each targeted phoneme (e.g., "Write the key word for /d/. Now underline the /d/ sound in that word.").
3. Train "blending" in the context of nonword spelling (trained as 4 groups of 5 nonwords).

Stage 2: Interactive Treatment

Participants were trained to implement the following strategy for spelling real words:

1. Generate plausible spelling for irregularly spelled words using re-established phonological skills.
2. Evaluate spelling on the basis of residual orthographic knowledge (lexical check).
3. Use electronic device (Franklin Language Master) to check and correct spelling errors.

Both participants completed daily homework during each phase of treatment. Homework for phonological treatment was presented on DVD, providing repeated practice saying and writing individual sound-letter correspondences. Upon mastery of this skill, homework included nonword blending tasks. During interactive treatment, participants were provided with audio recordings of irregular words for which they were to generate, evaluate, and correct spellings (using the external spelling device as needed). Homework was reviewed during treatment sessions.

Results

Participant 1 received one-hour treatment sessions three times a week, achieving mastery of sound-letter correspondences and nonword blending after approximately 9 weeks, and completing interactive treatment in 5 weeks for a total of 42 treatment sessions. Participant 2 attended therapy twice a week, meeting criterion for phonological treatment in 14 sessions and completing interactive treatment in an additional 9 sessions (for a total of 23 treatment sessions).

The phonological test battery was re-administered following the first phase of treatment (Post 1) and again following interactive treatment (Post 2), along with the re-assessment of spelling of untrained words (with and without the use of the external spelling device) and nonwords. Both participants made significant overall gains on phonological processing tasks that did not involve orthography as shown in Figures 1b and 2b, as well as on sound-letter and letter-sound transcoding tasks (Figures 1c and 2c). In addition, on the nonword tasks Participant

1 improved by 15% on reading and 40% on spelling; Participant 2 improved by 40% on reading and 20% on spelling (Figures 1d and 2d).

With regard to untrained real words, reading scores remained high, with slight improvements for each participant, and spelling performance also increased. Participant 1 improved spelling of regular words by 20%, and both participants' spelling of irregular words increased by 10%. When using the electronic speller to detect and self-correct errors, overall spelling accuracy was 90% or better for both individuals (Figures 1d. and 2d.). In contrast to these improvements in phonological processing and written language performance, spoken language skills remained relatively stable.

Discussion

The two participants in this study who demonstrated chronic impairment of spelling were responsive to phonological and interactive treatment, showing improved spelling for untrained items following behavioral treatment. These cases add to the small cohort of treatment studies that show a therapeutic effect of phonological treatment for individuals with phonological alexia/agraphia. Furthermore, the participants' responsiveness to interactive treatment and their ability to detect and correct errors with the use of an electronic speller supports the value of this second phase of treatment to provide strategic compensation for residual weakness in written language processing. Thus, the treatment sequence proved to be both restorative and compensatory in nature. In sum, the response to treatment by these two participants provides favorable evidence for the therapeutic value of the phonological-to-interactive treatment sequence, however, questions remain regarding the limits of recovery in such individuals.

References

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Henry, M. L., Beeson, P. M., Stark, A. J., & Rapcsak, S. Z. (2007). The role of left perisylvian cortical regions in spelling. *Brain and language, 100*(1), 44-52.

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Kiran, S. (2005). Training phoneme to grapheme conversion for patients with written and oral production deficits: A model-based approach. *Aphasiology, 19*(1), 53-76.

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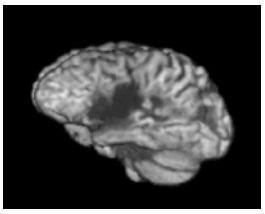
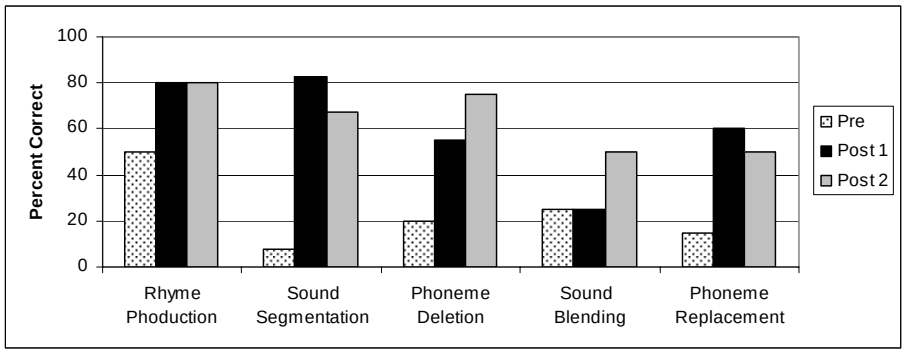
Figure 1. Participant 1.

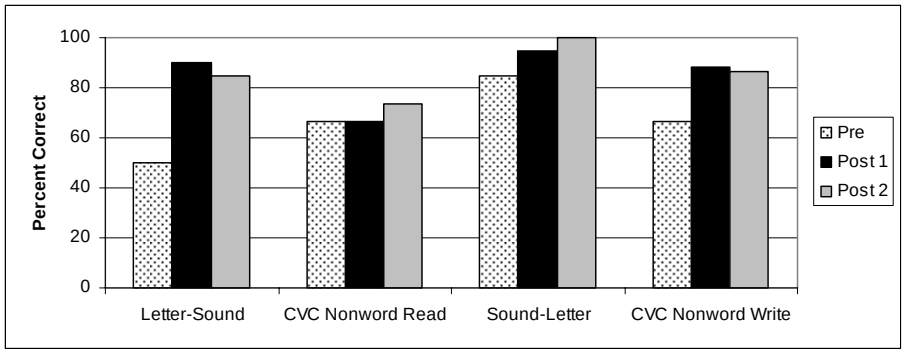
1a. Surface rendering of Participant 1's left hemisphere lesion.



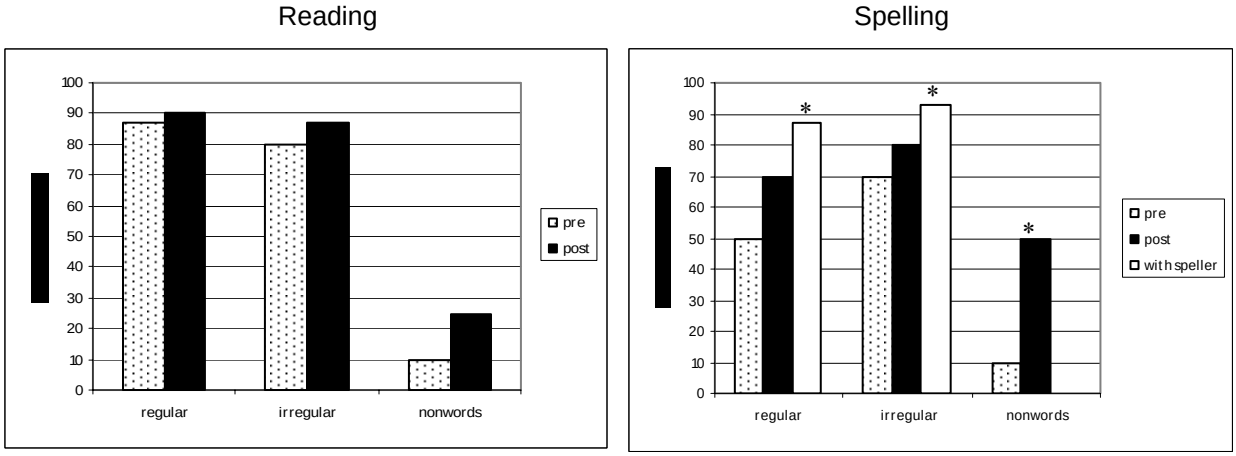
1b. Performance on phonological tasks that do not involve orthography. Significant improvement on Pre-Post 1 and Post 2 phonological composite scores ($p < .05$ using χ^2 test).



1c. Performance on letter-sound and sound-letter conversion tasks. Significant improvement on Pre-Post 1 and Post 2 composite scores ($p < .05$ using χ^2 test).



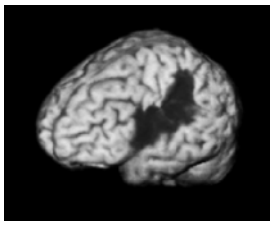
1d. Reading and spelling accuracy for regular and irregular words and nonwords.



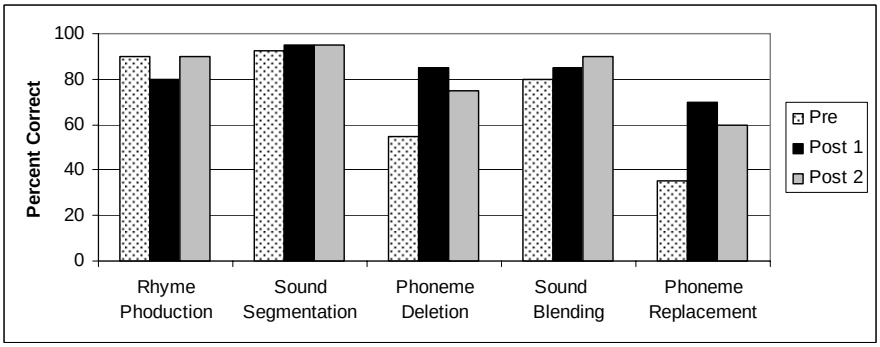
* significant pre-post tx improvement; $p < .05$, McNemar test

Figure 2. Participant 2.

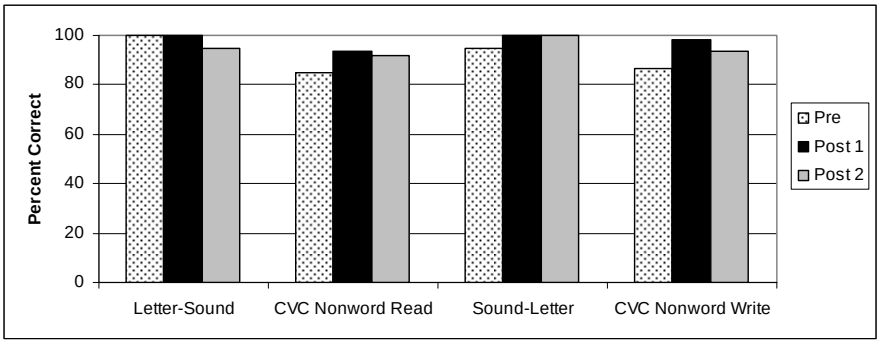
2a. Surface rendering of Participant 2's left hemisphere lesion.



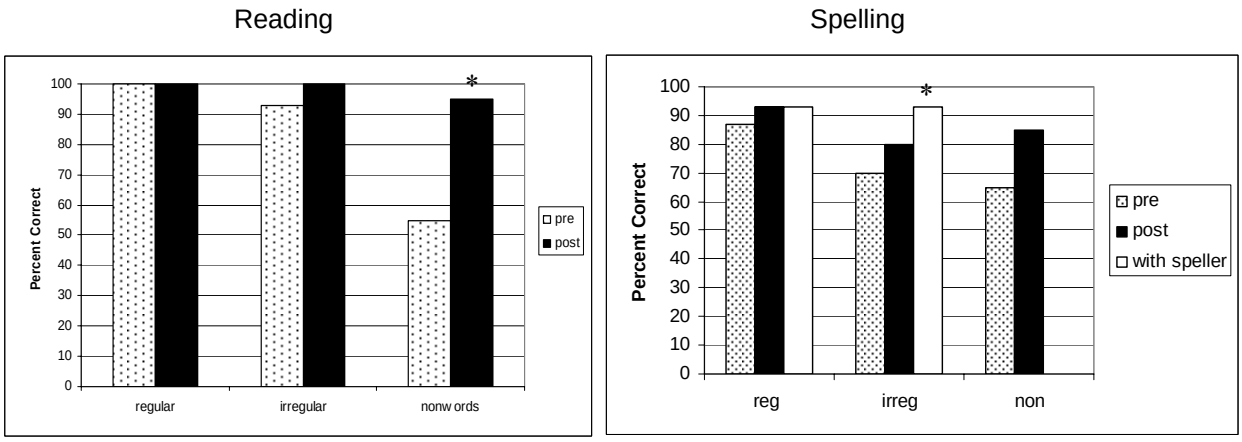
2b. Performance on phonological tasks that do not involve orthography. Significant improvement on Pre-Post 1 phonological composite scores ($p < .05$ using χ^2 test).



2c. Performance on letter-sound and sound-letter conversion tasks. Significant improvement on Pre-Post1 composite score ($p < .05$ using χ^2 test).



2d. Reading and spelling accuracy for regular and irregular words and nonwords.



* significant pre-post tx improvement; $p < .05$, McNemar test