Treating acquired writing impairment: strengthening graphemic representations

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Abstract
A writing treatment protocol was designed for a 75 year-old man with severe Wernicke’s aphasia. Four treatment phases were implemented: (1) a multiple baseline design that documented improvement in single-word writing for targeted words; (2) a clinician-directed home program that increased the corpus of correctly-spelled single words; (3) another multiple baseline series that documented acquisition of additional written words, as well as pragmatic training in the use of single-word writing to support conversational communication; and (4) a self-directed home treatment to further expand written vocabulary. The patient’s acquisition of targeted words suggested an item-specific treatment effect that strengthened weakened graphemic representations. The patient’s continued acquisition of correctly spelled words during the self-directed home treatment supported the use of this approach to supplement more traditional clinician-directed treatment.

Introduction
When people with severe aphasia do not regain the ability to produce meaningful spoken utterances, alternate modes of communication may be exploited. Gesture, drawing and written language may supplement or substitute for speech. Attempts at written communication are often similar to spoken utterances because common linguistic processes are impaired, however, spoken and written language may be differentially impaired (Black et al. 1989, Caramazza et al. 1983, Rapp and Caramazza 1997). Writing may be superior to spoken utterances when graphemic representations are better preserved than phonologic representations, or when peripheral processes necessary to implement graphomotor control are more intact than those processes that control speech. The individual described in this case report exhibited severe impairment of both spoken and written language, however, he was responsive to a treatment protocol to improve single-word writing at a time when his speech production processes appeared resistant to change.

The information processing model depicted in figure 1 shows the component processes necessary for writing single words (Goodman and Caramazza 1986a, Ellis 1987, Margolin 1984). Under normal circumstances, conceptual representations in the semantic system provide access to abstract graphemic representations in the graphemic output lexicon, a long-term memory store for learned spellings. These spatially ordered letter strings are held in a graphemic output buffer to be converted to the appropriate physical letter codes via the allographic conversion process (Goodman and Caramazza 1986b). Ultimately there is activation of the appropriate graphic motor programs for the execution of writing movements. This
processing sequence is referred to as the lexical-semantic route because whole words (i.e. lexical items) are activated by their meaning.

An alternate spelling route is available that bypasses the semantic representation. This route, depicted on the left side of figure 1, relies on sound-to-letter correspondences to convert phonology to orthography (Goodman and Caramazza 1986a). This nonlexical, phonologic spelling process typically is used to generate plausible spellings for unfamiliar words or nonwords; however, significant impairment of the lexical-semantic spelling route may result in overreliance on the nonlexical route (Behrmann 1987, Goodman and Caramazza 1986a). As shown in figure 1, spellings assembled using the sound-to-letter conversion are held in the graphemic output buffer in preparation for allographic conversion, as are semantically derived spellings.

Careful analysis of the writing performance of individual patients has shown that the various information processing components necessary for writing can be selectively impaired (Behrmann 1987, Hillis 1989, Margolin and Goodman-Schulman 1992). Additionally, there is a small, but growing, literature providing evidence that specific components of the writing process may be targeted for remediation with positive outcomes and that response to treatment can further clarify the nature of the impairment (Behrmann and Byng 1992, Carломagno

Figure 1. A cognitive model of single-word writing. The nonlexical spelling route indicated on the left bypasses the semantic system which is activated when writing is generated via the lexical-semantic route.
Iavarone Columbo 1994, Patterson 1994). For example, Hillis (1989) documented a successful treatment protocol to improve written naming in two individuals with severe aphasia that unveiled differences in their underlying deficits. Whereas one patient improved written naming for only the trained items, the other patient showed generalized improvement to spoken naming and untrained words. Hillis attributed the differential response to treatment to a unitary lexical-semantic deficit in the latter patient and an impairment of more peripheral writing processes in the former. Another detailed case report by Aliminosoa and colleagues (1993) demonstrated how a patient’s response to dysgraphia treatment helped confirm a deficit of the graphemic output lexicon and called into question a hypothesized impairment of the graphemic output buffer.

Carlomagno et al. (1994) reported a differential response to writing treatment in a group of six individuals with aphasia. A treatment hierarchy of visual and semantic cues was used to evoke correct spelling of target words. The treatment tasks included direct copy and delayed copy of target words, serial ordering of letters with visual cues provided (number of letters, word contour and pre-positioning of some letters) and semantic cues. Three of six patients benefited from the treatment, but three failed to respond until treatment shifted to focus on the re-establishment of sound-to-letter correspondences, suggesting a different focus of impairment.

In the case presented here, we explored the effectiveness of writing treatment in a man who had significant Wernicke’s aphasia affecting both spoken and written productions. Our goal was to strengthen graphemic representations so that single-word writing would be available to supplement other communication modalities. The patient’s response to treatment was of interest from both clinical and theoretical perspectives. That is, treatment effectiveness and efficiency were examined, but we also sought to clarify the nature of the writing impairment and to gain insight as to what processes were amenable to treatment.

**Case description**

ST was a 75 year-old, right-handed man who experienced a large left tempor-occipito-parietal stroke subsequent to left carotid endarterectomy at age 71. The stroke resulted in mild right hemiparesis, right hemianopia, and severe Wernicke’s aphasia. The hemiparesis resolved to mild right-sided weakness and the hemianopia improved to a decrement in the peripheral right visual field, but significant language impairment persisted. ST was multilingual with Polish and Yiddish reported as his first languages and German and English learned later. His primary language had been English for more than four decades prior to his stroke and he was highly proficient for speaking, reading and writing in English. He had degrees from high school and technical college and was retired from a career as a professional toolmaker in the automotive industry.

ST received individual therapy during the first year post stroke and intermittently after that time with documented improvements in auditory comprehension and the use of gesture for communication. He participated in an aphasia group for three years that emphasized alternate modes of communication including gesture and drawing and he was enrolled in a weekly aphasia group at the time of this study. By four years post stroke, ST’s neologistic jargon had evolved to fluent stereotyped utterances that were well articulated with meaningful prosodic variation, but
lacking semantic content. Utterances were similar to the following: ‘no, no, this one here, the other one, same thing, all the time, same thing.’ This linguistically-weak communication was useful to communicate some ideas when supplemented by gesture and occasional drawings, given an active listener who assumed the major burden of conversation. Many instances of communication breakdown went unrepaired when the listener could not infer meaning from ST’s utterances and gestures. ST owned a communication book that he occasionally used to convey autobiographical information, but he rarely selected other written words to convey meaning. ST rarely accomplished meaningful written communication other than writing his name and occasional instances when numbers were written to indicate the age of a person. Prior to the initiation of the treatment reported here, ST was evaluated with standardized measures of aphasia, single-word writing and nonverbal cognitive abilities. The establishment of single-word writing was considered a potential approach for improved functional communication.

### Pre-treatment assessment

The oral language subtests of the Western Aphasia Battery (WAB; Kertesz 1982) were administered to examine ST’s auditory comprehension and verbal expression. He received an aphasia quotient of 31.7 with a profile consistent with Wernicke’s aphasia (table 1). Spoken language consisted of fluent but empty spoken utterances with no ability to repeat words or sentences, name objects, or complete high probability phrases. ST had relatively good auditory comprehension of concrete, high frequency nouns and simple commands, but showed moderate-to-severe impairment of auditory comprehension for phrases, sentences and spoken commands with complex syntax or relational terms. ST was unable to read aloud but reading comprehension was relatively good for high frequency, concrete nouns as tested by the WAB reading subtests (table 1). Reading errors were noted for written commands at the sentence level (e.g. draw a cross with your foot) and auditory-to-written word matching resulted two semantic errors (purse → wallet, window → glass).

Portions of the Johns Hopkins University (JHU) Dysgraphia Battery (Goodman and Caramazza 1985) were administered to assess ST’s single-word writing. Written naming of pictures was severely impaired with no correct written responses for 29 items. ST typically wrote only a single letter when attempting to write the name of a pictured item; the initial letter was correct on six of 29 words. Single-word writing-to-dictation was also severely impaired with no correct responses for 35 words from a grammatical class list (10 nouns, 10 verbs, 10 adjectives, 5 functors). ST’s writing-to-dictation differed from his attempts at written picture naming in that he wrote phonemically implausible nonwords (e.g. happy → begal) for 26 of 35 words and he wrote eight unrelated words (e.g. annoy → down). On the writing-to-dictation task, ST wrote seven of 35 initial letters correctly, but there was no indication of an ability to use sound-to-letter correspondences to write words because there were no phonemically plausible misspellings (e.g. serkel for circle) and ST did not attempt the spelling of any nonwords (e.g. merber). The paucity of correct responses made it senseless to gather a large writing corpus and disallowed meaningful contrasts of lexical features such as imagery, frequency, or grammatical class.

Some copying tasks were administered to examine the more peripheral writing
Table 1. Summary of ST’s pre-treatment assessment on the western aphasia battery and selected cognitive measures

<table>
<thead>
<tr>
<th>Western Aphasia Battery</th>
<th>ST’s Score</th>
<th>Possible</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. Spontaneous Speech</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Fluency</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td><strong>II. Auditory Comprehension</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes/No Questions</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>Auditory Word Recognition</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>Sequential Commands</td>
<td>27</td>
<td>80</td>
</tr>
<tr>
<td><strong>III. Repetition</strong></td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td><strong>IV. Naming</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Object Naming</td>
<td>0</td>
<td>60</td>
</tr>
<tr>
<td>Word Fluency/Animals</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Sentence Completion</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Responsive Speech</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td><strong>V. Reading</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading Comprehension of Sentences</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>Reading Commands</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Written Word—Object Matching</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Written Word—Picture Matching</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Picture—Written Word Matching</td>
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<td>6</td>
</tr>
<tr>
<td>Spoken Word—Written Word Matching</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Letter Discrimination</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

Aphasia Quotient = 31.7
Aphasia Type = Wernicke’s

<table>
<thead>
<tr>
<th>Wechsler Memory Scale—Revised</th>
<th>ST’s Score</th>
<th>Mean</th>
<th>SD</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digits Forward (verbal)</td>
<td>0</td>
<td>7.8</td>
<td>2.0</td>
<td>Severely impaired</td>
</tr>
<tr>
<td>Tapping Forward (visual)</td>
<td>6/14</td>
<td>7.6</td>
<td>1.5</td>
<td>20th %ile</td>
</tr>
<tr>
<td>Visual Paired Associates</td>
<td>8/18</td>
<td>8.4</td>
<td>4.3</td>
<td>Within normal limits</td>
</tr>
<tr>
<td>Figural Memory</td>
<td>6/10</td>
<td>5.8</td>
<td>1.8</td>
<td>Within normal limits</td>
</tr>
<tr>
<td><strong>Progressive Coloured Matrices</strong></td>
<td>16/36</td>
<td>—</td>
<td>—</td>
<td>25th %ile</td>
</tr>
<tr>
<td><strong>Clock Drawing</strong></td>
<td>33/37</td>
<td>34.0</td>
<td>3.0</td>
<td>Within normal limits</td>
</tr>
</tbody>
</table>

processes. ST was able to directly copy words (20/20) with no evidence of apraxia or other impairment of graphomotor control. His performance was poor for delayed copy of single words (3/38); ST typically copied only the first few letters of a word correctly, resulting in 49 out of 127 letters correct (39%). In order to examine ST’s allographic conversion abilities, he was asked to transcode words from uppercase to lowercase and vice versa, while the words remained in view. Despite several demonstrations, ST failed to shift letter case; he persisted in copying words directly. When presented single letters of the alphabet for transcoding from upper to lowercase, ST correctly transoded the first five letters and then reverted to direct copy. His performance was similar when asked to transcode from lower to uppercase; he changed the case for only six letters, and then began copying letters directly.

The severity of ST’s writing impairment made it difficult to isolate the breakdown to specific processes or representations, but some assumptions seemed
justified. ST’s performance on the standardized language assessment suggested that visual and auditory processing for high imagery, concrete nouns was adequate to access corresponding semantic representations in many instances. His comprehension of spoken words was evident during the writing-to-dictation tasks, in that ST often provided an appropriate gesture for an item that he could not write. In contrast, there was little evidence that semantic representations activated the appropriate abstract representations in the graphemic output lexicon because most of ST’s written responses were completely unrelated to the target word. On the occasions when ST wrote the correct initial letter, there was no apparent knowledge of other component letters or word length, suggesting significant degradation of graphemic representations. It was not surprising that ST showed no ability to take advantage of the nonlexical spelling route because he had limited control over phonology.

The integrity of ST’s peripheral writing processes was not clear. His inability to copy words after a delay suggested that the graphemic buffer might be impaired, however, ST’s performance was too degraded to reveal a word-length effect often taken as a confirmatory sign of a graphemic buffer impairment (Caramazza et al. 1987). His impaired ability to transcode letters from upper to lowercase and vice versa implicated the allographic conversion process as a possible additional source of impairment. It was reasonable to assume that ST’s graphomotor skills were relatively well preserved in that letters were well formed, and he was able to directly copy words without difficulty.

Selected neuropsychological tests were administered to assess ST’s nonlinguistic cognitive abilities. On the Wechsler Memory Scale—Revised (1987), ST was unable to repeat any numbers for the digit span task, but he had a visual memory span of about 5 on the Tapping Forward Subtest indicating a mild impairment of visual span (table 1). He also showed a mild impairment of visual problem-solving as measured by the Coloured Progressive Matrices (Raven 1976). However, ST’s visual learning appeared relatively intact when assessed using the visual paired associates and figural memory subtests of the Wechsler Memory Scale—Revised (Wechsler 1987). ST also performed well on a clock drawing task demonstrating preservation of those visuospatial construction skills.

In summary, ST’s chronic Wernicke’s aphasia was characterized by utterances that carried limited content but offered some prosodic information to supplement his gestural communication. Several sources of impairment may have contributed to ST’s inability to write meaningful words. His memory for spelling appeared degraded or lost for most words and he appeared to have poor ability to hold graphemic information in short-term memory. Despite ST’s poor writing ability, he showed some strength in visual memory for nonlinguistic information. Single-word writing was targeted for a trial treatment period to determine if the impaired writing processes were amenable to rehabilitation.

**Treatment plan**

The initial treatment phase employed a multiple baseline design to examine the effectiveness of a cueing hierarchy to re-establish single-word writing in order to facilitate communication. This treatment was implemented twice weekly for a total of 10 sessions. Subsequent treatment phases evolved with several goals in mind: (1) to expand ST’s single-word writing vocabulary; (2) to maximize his use of single-
word writing for daily communication and conversational exchange; and (3) to shift responsibility for rehabilitation from the therapist to ST. ST’s writing performance was followed for roughly 16 months, but he received only 27 hours of individual treatment during that time (plus ten sessions for testing only), as will be described.

*Treatment phase 1*

**Procedure**

A cueing hierarchy depicted in figure 2 was implemented to elicit and re-establish correct spelling of common nouns and verbs considered to have functional value for ST (see list in appendix). The treatment protocol was modeled after other lexical approaches to dysgraphia treatment (Aliminosa *et al.* 1993, Carlomagno *et al.* 1994, Hillis 1989) and was modified during several pilot sessions with ST. The protocol included arrangement of anagram letters (i.e. scrambled component letters) followed by repeated copy of the target words, so it was referred to as the Anagram and Copy Treatment (ACT). The treatment sequence employed a bracketing approach in that failed trials were followed by easier tasks which were then made progressively more difficult. For example, when ST could not write a target word, he was provided the component letters (typed in 72-point font on heavy paper) to arrange in the correct order (see figure 2). Correct letter arrangement was followed by copy of the target word with pencil and paper. Incorrect arrangement of the anagram letters was corrected by the clinician and followed by repeated copy. Once the anagram arrangement was mastered, the task was made more difficult by the inclusion of two foil letters (one vowel and one consonant) and the same anagram and copy procedure was followed. After ST successfully arranged the anagram letters (and rejected the foil letters) and performed the required direct copy of the words, he was asked to write the target word from memory. This recall task was repeated so that three correct spellings of the target word were accomplished independently.

The rationale for the ACT task hierarchy was as follows: The initial probe challenged ST to spell the word independently and allowed the clinician to determine if partial graphemic knowledge was available. When he could not spell the word correctly, the provision of the anagram letters decreased task difficulty by removing the need for letter selection and allowed ST to compare possible letter arrangements against his own graphemic representation (degraded though it might be). The anagram spelling encouraged ST to encode the identity and position of each letter in a target word. Repeated copying was used to help stabilize the orthographic representation for ST. Finally, delayed recall was intended to encourage reestablishment of orthographic representations in long-term memory and their maintenance in the graphemic buffer during writing attempts.

ACT was supplemented by daily writing homework that required ST to repeatedly copy the target words presented as labelled pictures. He was also provided a written naming task to test his recall for those words he had copied. This procedure was referred to as Copy and Recall Treatment (CART). ST was instructed to work on his writing for at least 30 minutes daily. Although no strict record was kept of his work at home, ST consistently completed the daily homework which showed that he typically copied each target word a minimum of 20 times.
Figure 2. Schematic depiction of Anagram and Copy Treatment (ACT).

Over the course of this treatment phase, writing was probed for two sets of nouns (n = 6 each) and two sets of verbs (n = 5 each). As shown in Figure 3, baseline probes were taken prior to the initiation of ACT and CART to document stable performance. After treatment began, probe measures were taken during each treatment session to test ST’s ability to write words before the cueing hierarchy was implemented. ST was presented the pictured items and asked to write the name, for
example, ‘write bagel.’ There was no time limit imposed for writing and ST was allowed to correct self-detected spelling errors. After the establishment of a stable baseline, noun sets 1 and 2 and verb set 1 were treated in sequence with the ACT and CART approach. Criterion for mastery was set at ≥ 80% correct for a given set over two sessions.

1 The spoken name of the pictured item was provided to maximize semantic activation during the writing task. Over time it was apparent that ST did not need to hear the spoken name in order to write the word, so the auditory input was faded out.
Results

As shown in figure 3, ST failed to correctly spell any of the target words during the baseline probes for four sets of words. Following treatment initiation, spelling performance improved for trained items and criterion was met sequentially for the three treated sets. ST’s writing was accomplished with relatively normal speed (about 3 to 5 seconds per word, unless he took more time for self-correction) and normal graphic motor control. There was no improvement in the spelling of verb set 2, which was not entered into treatment until treatment phase 2.

Following treatment phase 1, the written naming task from the JHU Dysgraphia Battery was re-administered to determine if there was any generalization of improved spelling to untrained words. ST did not correctly spell any of the 29 items and his responses were similar to those at pre-treatment in that most were single letters, with only 7 out of 29 correct initial letters.

Discussion

ST was able to re-learn spellings for targeted words over the course of ten treatment sessions. His response to treatment was item-specific in that there was no evidence of improved spelling for untrained words, thus suggesting that ST would be required to slowly rebuild his written vocabulary. Given that ST’s treatment included both ACT with the therapist and CART as homework, the question arose as to whether or not he would benefit from CART alone. In other words, was the anagram and copy procedure a necessary component for ST’s continued improvement in written spelling? The next treatment phase provided an opportunity to answer that question.

Treatment phase 2

Procedure

During the summer, ST was not scheduled to attend individual therapy, but he was willing to continue daily writing homework. Therefore, over the course of summer, ST was provided homework for CART for 20 new words (verb sets 2 and 3 and noun sets 3 and 4), in addition to continued practice for words mastered during treatment phase 1. Homework packets identical in format to those used during treatment phase 1 were exchanged by mail on a weekly or biweekly schedule. The packets included pages with labelled line drawings of the target words, along with blank lines where ST was to repeatedly copy the word. Additional ‘self-test’ pages were also provided so that ST could practice written naming without the model (i.e. the recall task).

Results

ST returned completed homework sheets by mail every 5 to 7 days. He occasionally prompted his wife to call for more homework when he had completed all that he had received. The returned homework documented that ST was consistently working on writing using the CART approach but data were not available to evaluate his learning, so after 3 months, he was brought to the clinic for a writing evaluation. As shown in figure 3, on session 16, ST maintained his ability to correctly write the words from noun sets 1 and 2 and verb set 1 and he had learned.
to write verb set 2. In addition, he correctly wrote all words in verb set 3 and noun set 3 (see words in appendix). ST also performed without error when those words were presented on a writing-to-dictation task (i.e. without pictures). Noun set 4 was added for CART after Session 16.

After another month of CART homework, ST returned for evaluation. In session 17 (figure 3), he correctly wrote 20 out of 22 words in noun sets 1 and 2 and verb sets 1 and 2. In addition, ST correctly wrote the words in noun sets 3 and 4 (n = 5 each). A re-administration of the written naming task from the JHU Dysgraphia Battery at the end of phase 2 yielded only two correct spellings out of 29 (‘cake’ and ‘glasses’), which were words that had been targeted for treatment because of their functional value for ST. No other words were spelled correctly, nor was there a qualitative improvement in ST’s spelling of untrained words.

Discussion

ST continued to show an item-specific treatment effect with a clinician-directed home program of CART so that his corpus of functional written words was increasing. At that time, however, there was little evidence that ST was using writing to assist conversational interaction, which prompted the inclusion of procedures to promote generalization of writing to everyday communication attempts in the next treatment phase.

Treatment phase 3

Procedure

Individual therapy was reinstated on a weekly basis for eight sessions followed by a two-month vacation break and another eight treatment sessions. This treatment period spanned from September to May. Twenty nouns were targeted for treatment by ST’s wife as functionally useful items (e.g. movie, haircut, tuna); these items were sequentially trained as noun sets 5, 6, 7, and 8 (see appendix). ACT was employed to introduce the new target items and CART was continued for homework for all new and previously learned words. An additional focus of the treatment sessions was a conversational exchange in which ST was coached to use writing to supplement his communication. During this activity the clinician initiated discussions and asked questions that were likely to prompt use of target words that ST had mastered. For example, the clinician might ask, ‘What did you have for breakfast today?’ to which ST might write ‘coffee’ ‘bagel’. Meaningful written responses resulted in successful communication and continued conversation. When ST failed to respond or gave an inappropriate response, he was coached regarding possible written responses within his repertoire. The interaction was truly conversational in the sense that the topic was allowed to shift naturally, so that only a subset of items was probed in most sessions.

Results

As shown in figure 4, ST failed to write noun sets 5 and 6 on multiple probes prior to treatment, but improved written spelling following the implementation of ACT and CART. Due to time constraints and ST’s previously stable performance on untrained words, noun sets 7 and 8 were only probed on one session prior to
Figure 4. Patient ST's writing performance on probes taken during baseline and treatment for four set of nouns. Vertical lines (with connecting dashed lines) indicate the initiation of treatment for a given set of words. (See text for discussion of treatment phases.)

treatment. Again, ST rapidly met criterion for those sets after treatment initiation (figure 4).

ST was responsive to the pragmatic treatment that prompted the incorporation of written responses into conversational exchanges; however, this loosely structured treatment component did not lend itself to precise data collection during each session. Extensive interactive conversational probes to elicit written spelling were obtained during two sessions to examine ST’s performance. During session 22 (October), ST provided appropriate written responses conversational probes on 15 out of 23 opportunities (65%); and during session 35 (April) he responded appropriately on 20 out of 25 opportunities (80%). ST’s increased use of written communication was noted in ST’s aphasia group and at home. ST’s wife provided anecdotes of successful written communication at home, such as his writing ‘egg’
to indicate his breakfast choice. In one notable instance, ST wrote ‘rain’ to indicate to his therapist that there had been bad weather during their vacation cruise. ST’s wife confirmed that he had solicited the spelling of ‘rain’ and practiced writing it many times before coming to therapy. ST also began to provide several written words (as opposed to a single word) to convey messages. For example, ST wrote ‘women’ ‘haircut’ ‘40 years’, to describe a middle aged woman who was getting her hair cut. On another occasion, he wrote ‘wife’ ‘poker’ ‘$1500’ to tell of his wife’s good fortune.

Periodic re-assessment of all previously mastered words showed relatively good maintenance of written spelling as ST’s corpus of written words grew: September (32/32 = 100%), January (35/37 = 95%), February (39/46 = 80%) and May (53/66 = 80%). ST was re-administered portions of the JHU Dysgraphia Battery at the end of treatment phase 3. He correctly spelled 2 out of 29 pictured items and was unable to spell any words given by dictation (0/15). There were no notable qualitative improvements in ST’s attempts to write words on the JHU Dysgraphia Battery relative to his initial assessment. In other words, there was no indication of improved partial word-form knowledge for untrained words.

Discussion

Fourteen months after the initiation of treatment, ST clearly had demonstrated the ability to increasingly build his single-word vocabulary for writing. He also showed appropriate use of those words to support his communication during conversational exchange structured by the clinician and increased use of written communication at home. There was no evidence of generalized improvement in written spelling in that ST failed to spell untrained words, and his spelling errors did not reflect any qualitative improvement. However, there was some evidence that ST could seek to learn new words on his own, so that he might shape his vocabulary development for writing. The final treatment phase was thus designed to shift responsibility to ST for the identification of new target words and self-implementation of home practice for spelling of those words.

Treatment phase 4

Procedure

In order to shift responsibility for selecting target words from the clinician to ST, he was provided an illustrated picture dictionary (Parnwell 1993) and was instructed to select items that he wanted to learn to spell. ST selected 5 words (noun set 9 in appendix) and he was instructed to copy the spelling from the picture dictionary into a personal notebook specifically dedicated to spelling practice. Following a week of homework that consisted of repeated copy of the target words, ST correctly spelled 4 out of 5 of the targeted words when probed by the clinician. He was then instructed to select 5 more words to learn at home (word set 10 in appendix) and returned the following week able to spell 4 out of the 5. Confident that the self-directed approach to learning new spellings was established, ST was directed to proceed with his self-directed spelling practice at home.

Results

After six weeks of self-directed practice (including a 2-week hiatus for a family vacation), ST returned to the clinic for an assessment of his progress using the self-
directed procedure. At that time, ST’s spelling notebook was inspected to note the words he had targeted to learn. There were 40 new words that ST had practiced writing in his notebook. When those items were presented orally (along with a quick sketch to confirm comprehension), ST correctly wrote 14 out of 40 words. Correct responses ranged in word length from 4 to 9 letters (e.g. love, bingo, bananas, hamburger), with a mean of 5 letters, which did not differ significantly from the mean for words misspelled by ST (5.8 letters). ST’s responses to the 40 self-selected words offered a rich sample of spelling errors that was previously unavailable because his spelling errors were rarely related to the target (other than some correct initial letters). Error responses included 5 words with single- or multiple-letter errors that were recognizable renditions of the respective target words (e.g. mailbox → moilbox, strawberry → stowbeern), 2 were correctly spelled semantic errors (trip → carry, bear → polar), 7 appeared to be misspelled semantic errors (e.g. roll → bagle [bagel], gorilla → g-zzly [grizzly], plum → pera [pear]), 2 were visually similar words (robe → lobe, tired → lied), 7 were unclassifiable errors (e.g. syrup → shenb, burn → pank) and 3 were no responses. In all cases of semantically related errors, ST wrote words that were from his corpus of trained words.

A final administration of a portion of the grammatical class word list from the JHU Dysgraphia Battery was presented by dictation. Of 35 words presented, ST correctly wrote only one word (music) which was a word he had targeted for treatment. Rather than attempting to spell most words on the list, ST repeatedly indicated that he did not know how to write most of the words, so there were few error responses to examine. ST made one semantic error, hungry → eat and ‘eat’ had been a treated word.

Discussion

ST demonstrated that he was capable of executing a self-directed program to master written spelling of targeted words. Although ST targeted more words than he was able to master in the six-week period, nearly half of the 40 words he selected were spelled correctly or were recognizable misspellings of the target word. This rate of acquisition was considered reasonable for the time invested by ST. One concern about the self-directed treatment was ST’s selection of some target words that appeared to have limited functional value (e.g. wolf, skunk, polar bear, grizzly bear). ST’s wife reported that she expressed her concern to ST about his apparent lack of discernment regarding selection of target words. Following the cluster of wild animals, ST selected a list of food items which he used to express preferences (e.g. hamburger, milk), and some other useful words, such as ‘windy’ (selected at a time when the weather had, in fact, been windy). ST’s wife was counselled to continue to allow ST the freedom to select his own target words, but was encouraged to call his attention to useful words as they occurred in everyday interactions.

Post-treatment assessment

After treatment, some additional testing was performed in an effort to further clarify the nature of ST’s writing impairment. A lexical decision task from the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA; Kay Lesser and
Coltheart (1992) was administered that required ST to indicate real English words presented in written form among a field of nonwords with plausible spellings. The real words were controlled for imageability and frequency of occurrence and the nonwords were derived from real English words (PALPA subtest 25). ST correctly rejected 54 of 60 nonwords, but selected only 30 out of 60 real words. There was an effect of imagery in that 26 of 30 high imagery words were correctly identified, but only 4 of 30 low imagery words were correctly selected. There was no effect of frequency in that high frequency and low frequency words were identified with relatively similar accuracy (14/30 and 16/30, respectively).

Two additional PALPA subtests were administered to examine single word processing in auditory and visual modalities. Spoken words were presented for a picture matching task in which target pictures were presented with 4 foil items (2 semantic distractors, 1 visual distractor, 1 unrelated distractor; PALPA Subtest 47). ST correctly selected 39 of 40 pictures in response to the spoken word, making one semantic error (paintbrush → palette). The same 40 items were presented on another day for a written word to picture matching task (PALPA subtest 48). ST correctly matched 36 of 40 written words to the appropriate picture, making four semantic errors (belt → suspenders, thumb → finger, stirrup → saddle, paintbrush → palette).

The delayed copy task for single words was re-administered to ST at the end of treatment. He remained unable to copy single words after exposure for 5 seconds. His responses were similar to that observed prior to treatment, in that he typically recalled only the first few letters of a word. ST correctly recalled 59 out of 127 words (46%), compared to 49 out of 127 (39%) prior to treatment, a difference that was not significant, t(44) = −1.13, p = 0.13.

ST was also re-administered a transcoding task in which he was asked to copy words from uppercase script to lowercase script. Initially ST copied the words directly without changing case, as he had done on previous testing; however, with re-instruction, ST was able to perform the task. He correctly transcoded 110 words from uppercase to lowercase.

The oral language subtests of the Western Aphasia Battery were re-administered at the end of treatment to determine if there were any significant changes in ST’s spoken language or auditory comprehension over the course of the 14 months of writing treatment. ST’s aphasia quotient was 31.82 following treatment, which was essentially unchanged relative to his pre-treatment AQ of 31.7.

**General discussion**

ST responded to a writing treatment protocol with item-specific improvement in single-word writing. This improvement occurred in the context of relatively unchanged performance on standardized measures of auditory comprehension and speech production. ST showed no improvement for spoken production of words that he mastered in writing, nor did he improve his writing for untrained words. Thus, it appeared that treatment served to strengthen specific graphemic representations for only those words that ST repeatedly practiced. His growing lexicon provided new insight into the status of his cognitive processes necessary for writing.
As ST developed a corpus of words that he could write, it was apparent that the peripheral processes necessary for writing were better preserved than expected. Prior to treatment, the integrity of the graphemic output buffer was called into question because ST’s writing attempts were often restricted to one or two letters, and he was unable to perform delayed copy of single words. After the initiation of treatment, however, it was apparent that ST was capable of re-learning the spelling for 8, 9 and 10-letter words with no greater difficulty than 3, 4 and 5 letter words. As these graphemic representations were strengthened, the adequate functioning of the graphemic output buffer was evident. In addition, the allographic conversion process that guides the selection and formation of individual letters was clearly functional for those words that ST mastered during treatment. Initially, this process had appeared damaged because ST had difficulty transcribing letters from upper to lowercase and vice versa. In retrospect, ST’s difficulty with letter transcribing may better be explained as a failure to appreciate the nature of the task, rather than an impairment of allographic conversion.

It was noteworthy that some of the words that ST re-learned to write emerged as semantically related errors for untrained words. Semantic errors often are interpreted as evidence of impairment to the lexical-semantic system (Bub and Kertesz 1982, Rapcsak et al. 1991); however, semantic errors can also arise from the output lexicon (see Caramazza and Hillis 1990, Hillis and Caramazza 1995 for details of this argument). ST’s pre-treatment writing assessment showed no semantic errors, but after treatment he occasionally wrote a semantically related word (from his trained corpus of words) for an untrained word. For example, ST wrote the nonword, ‘fand’, for hungry on a pre-treatment writing-to-dictation task; but after treatment he wrote ‘eat’ for hungry. Eat was a word that ST had mastered during treatment, but he had not worked on hungry. Given that eat is logically included in the distributed semantic representation evoked by hungry, it follows that the concepts would be simultaneously activated in response to the stimulus hungry. Under normal circumstances, hungry should be written because its graphemic representation receives the highest activation. However, if the graphemic representation for hungry was unavailable, but eat was readily available, then the semantic substitution is relatively predictable. The fact that ST only made semantic errors using words that he had re-learned during treatment suggested that his restricted graphemic output lexicon was the probable locus of his emergent semantic errors.

ST’s apparent failure to detect his semantic dysgraphias may have been attributable to concomitant damage to the graphemic input lexicon (for recognizing written words), documented by his poor lexical decision performance. (Recall that he failed to recognize 30 out of 60 real English words on a lexical decision task.) ST also made several semantic errors (4/40) on the written word/picture matching task, whereas he made only semantic error when the same items were presented in the auditory, rather than written, modality.

The interpretation of ST’s writing improvement as a strengthening of the graphemic output lexicon does not necessarily suggest that he had fully intact lexical-semantic representations. Indeed, it was likely that he had some lexical-semantic impairment; however, there was little evidence of significant change to ST’s lexical-semantic representations over the treatment period. In some patients, strengthening of the central lexical-semantic system can result in concomitant improvement in spoken and written naming (Hillis 1989); which was clearly not the
case for ST. Nor was there evidence of significantly improved processing of auditory input to the lexical-semantic system. In hindsight, a more extensive analysis of ST’s information processing deficits prior to treatment may have allowed more precise isolation of the treatment effect.

Returning to the clinical aspects of this study, a few comments are warranted about the evolution of the multiphase treatment sequence used with ST. The clinician-directed home program that was initially designed to complement the anagram and copy treatment (treatment phase 1) ultimately gave rise to a self-directed home program with the potential for extensive vocabulary expansion (treatment phase 4). It became clear that the ACT protocol was not necessary for continued spelling improvement, but it was not clear whether ACT was a necessary component of the overall treatment sequence. Clinical impression suggested that the hierarchical structure of ACT provided the necessary support for ST to shift from complete agraphia to the mastery of his first set of words, but it is possible that repeated copy alone may have been adequate (see Aliminosa et al. 1993 for example). We are currently treating other patients with CART alone in order to clarify when (if ever) the anagram treatment is necessary.

The pragmatic training that encouraged ST to use written words to supplement his conversational interactions (treatment phase 3) appeared to be a necessary treatment component to facilitate the functional use of writing for ST. The subsequent family and clinical reports of successful written communication (using trained words) was strong validation of the functional impact of the writing treatment. Another factor influencing the use of written words in conversation may have been the need to build an adequately large corpus of words so that the available vocabulary was sufficient for communication. This factor may have contributed to ST’s slow implementation of written communication.

It is worth reiterating that ST’s acquisition of a functional written vocabulary resulted in significant changes in his ability to communicate. ST ultimately began to write several words in combination (with no formal syntax) to convey a thought or event. This chaining of ideas paired with gesture, drawing and prosodic information conveyed by his stereotyped utterances moved ST to a new level of communicative competence. His success prompted the treatment of other individuals with severe aphasia who also showed the capacity to re-establish written communication while their spoken language was severely limited. The fact that written words can be constructed one letter at a time, with ample time to examine, reject, and revise, provides a flexibility that is unavailable for speech production. This difference may be a critical element allowing individuals with multiple processing deficits to re-establish written communication when spoken communication fails.

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References


### Appendix

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<td>Noun 1</td>
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*baseline only in Phase 1, trained during Phase 2

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