Problem-solving approach to agraphia treatment: Interactive use of lexical and sublexical spelling routes

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Abstract

Two patients with acquired spelling impairments due to left hemisphere brain damage participated in a treatment protocol to improve their written spelling. Prior to the initiation of writing treatment, both patients showed some ability to take advantage of sound-to-letter correspondences that resulted in phonologically plausible spelling errors. A homework-based treatment was implemented to improve their ability to resolve spelling errors by increased reliance on phoneme-to-grapheme conversion, self-correction, and use of an electronic speller. Both patients improved their spelling abilities and provided evidence of interactive use of partially spared lexical and sublexical spelling routes to resolve their spelling difficulties.

Introduction

Written communication requires the translation of thoughts and ideas into ordered sequences of words that are spelled in accordance with the conventions of the language. When we intend to write a word, our thoughts activate the appropriate lexical-semantic representation that in turn provides access to the corresponding item in our mental dictionary of spellings. This store of spellings is referred to as the graphemic (or orthographic) output lexicon (Shallice 1988, Ellis 1993, Roeltgen 1993, Rapcsak and Beeson in press). As depicted in figure 1, the semantic representation also activates the spoken word form in the phonological output lexicon, providing another means to activate the graphemic representation (shown as the arrow from phonological output lexicon to graphemic output lexicon). This abstract form of the written word is then held in the graphemic buffer as the graphomotor plan is selected and implemented to write the word. Under normal circumstances, spelling via this lexical-semantic route occurs with minimal effort. However, when spelling for a given word is not readily accessed (or is unknown), knowledge of phoneme-to-grapheme correspondences may be used to assemble plausible spellings as shown in figure 1. Because this sound-to-letter conversion process may occur without activation of the graphemic lexicon, it is referred to as a sublexical, or nonlexical spelling route (Ellis 1993, Rapcsak and Beeson in press).

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Figure 1. Schematic representation of cognitive processes necessary for writing via the lexical-semantic route (semantic system → graphemic output lexicon → graphemic buffer) and the sublexical route (phonological output lexicon → phonological buffer → phoneme-to-grapheme conversion → graphemic buffer).
The availability of the sublexical spelling route is revealed by phonologically plausible errors observed in 'slips of the pen' by normals (e.g. *surch* for search) (Wing and Baddeley 1980). In addition, interaction between the lexical and sublexical spelling routes has been demonstrated with normal subjects who showed nonword spellings to be influenced by the spelling of recently presented real words (Campbell 1983, Barry and Seymour 1988). For example, Campbell (1983) found that the spelling of the nonword /prein/ was more likely to be *prain* when it followed 'brain', and *prane* when it followed 'crane', indicating the influence of lexical spelling on the sublexical spelling route.

It is well documented that selective impairment of the cognitive processes necessary for spelling may result in dependence on residual, unimpaired processes. For example, damage to the graphemic output lexicon may result in reliance on the sublexical phoneme-to-grapheme conversion mechanism as a compensatory approach to spelling (Beauvois and Dérouesné 1981, Hatfield and Patterson 1983, Goodman-Schulman and Caramazza 1987). The resulting clinical profile is characterized by spelling errors for words having irregular or ambiguous spellings (e.g. *serin* for certain; *rain* for reign), a syndrome referred to as surface agraphia. Conversely, damage specific to the sublexical spelling route may cause spelling to be accomplished exclusively by the lexical-semantic route, so that the spelling of unfamiliar words and nonwords is markedly impaired, consistent with a profile of phonological agraphia (Baxter and Warrington 1985, Goodman-Schulman and Caramazza 1987).

Successful approaches to agraphia treatment have been reported that aim to strengthen the lexical-semantic route, as well as approaches that strengthen the sublexical route. For example, Hillis (1992) reported improved written spelling in a patient with impaired semantics in response to treatment that clarified distinctions among semantically related items. Several researchers have used cueing hierarchies to strengthen or regain access to representations in the graphemic output lexicon (Hillis and Caramazza 1987, Alimonsa *et al.* 1993, Beeson 1999). Other treatments directed towards phoneme-to-grapheme conversion abilities proved helpful to improve written spelling in individuals with lexical-semantic deficits (Carromagnino *et al.* 1994, Hillis and Caramazza 1994); and the homophone confusion that results from overreliance on the sublexical spelling route was addressed in a treatment reported by Behrman (1987).

Many individuals with aphasia and agraphia show damage to multiple components of the cognitive architecture for writing, so that both the lexical and sublexical spelling routes are impaired (Hillis Trupe 1986, Alimonsa *et al.* 1993, Beeson 1999). When it is the case that partial information is available from lexical and sublexical spelling routes, it makes sense that rehabilitation attempts should promote summation of the information gained from each route. For example, Hillis (1986) showed that even when the sublexical mechanism is only partially functional, it may provide enough graphemic information to cue the correct written response from the graphemic output lexicon, or block semantic errors that arise in the damaged lexical-semantic route.

Rapp (1997) recently described an individual (LAT) with acquired agraphia related to probable Alzheimer's disease whose phonologically plausible spelling errors reflected contribution of both the lexical and sublexical processes. The patient produced many phonologically plausible misspellings of real words, and showed excellent nonword spelling, a profile that was suggestive of impaired access to the graphemic output lexicon. Rapp noted that many of the plausible spellings for real words contained low probability phoneme-to-grapheme correspondences, for example, 'bouquet' was spelled *bouket*, suggesting the influence of partial lexical knowledge (*ou* and *et*) as well as application of phoneme-to-grapheme conversion (*k* rather than *qu*). In contrast, LAT
spelled the nonword /lokei/ as *loki* when compared to non-word spellings (e.g. *napi* for /nɔpi/). Thus, it appeared that LAT’s use of low probability elements in his spelling attempts was derived from partial lexical knowledge of the word, combined with sublexical knowledge derived by phoneme-to-grapheme conversion.

The interaction of lexical and sublexical processes has also been suggested in the context of acquired alexia by Hillis and Caramazza (1995), and more recently by Southwood and Chatterjee (1999). Hillis and Caramazza (1995) reported on three patients with damage to both semantic and sublexical reading routes whose oral reading showed that at least partial information was computed by the lexical-semantic system and partial information was derived from the grapheme-to-phoneme conversion mechanism. In each patient, oral reading was better than expected based on either lexical-semantic abilities or sublexical grapheme-to-phoneme conversion abilities, suggesting that partial information from both mechanisms interacted to access the lexical-phonological representations in oral reading. Southwood and Chatterjee (1999) presented similar findings in an individual with deep dyslexia.

We present here two patients whose error patterns included attempts at semantic retrieval of spelling that reflected partial knowledge of the word form (e.g. *bo_t* for bought), as well as errors that showed some reliance on phoneme-to-grapheme conversion (e.g. *boil* for loyal). The patients are of interest because they appeared to take advantage of partial lexical and sublexical information for spelling in an interactive manner in order to resolve spelling errors. The first patient (SV) was followed over 10 months as she developed strategies to improve her spelling. Her success and insight into her problem-solving approach to spelling provided a treatment plan that subsequently was facilitated in a second patient (SW) over a 10-week period. These problem-solving strategies were intended to promote interaction between lexical and sublexical spelling routes.

**Case report: SV**

SV was a 44-year-old, right-handed woman who experienced a left hemisphere stroke at age 39. An MRI head scan taken two days after the stroke revealed a moderately large, left hemisphere infarct involving the temporal lobe, insula, and frontal operculum. SV’s medical history was also significant for ovarian cancer diagnosed 6 weeks after her stroke. During the first year post onset of stroke, SV’s language profile evolved from Broca’s aphasia of moderate severity to anomic aphasia of mild severity. She received ongoing aphasia therapy, with greatest attention initially given to expressive language formulation. During the second year after her stroke, reading of text-level material was the focus of treatment; her positive response to a reading treatment protocol was reported elsewhere (Beeson and Insalaco 1998).

SV was highly educated with two Bachelor’s degrees (physics and anthropology) and a Master’s degree in philosophy. She was a computer programmer prior to her stroke, and had been an avid reader and amateur writer of fiction. At four years post onset, SV requested assistance in her effort to return to writing fiction. At that time, her written language formulation was slow and effortful, with spelling errors and occasional errors of lexical selection.
Language assessment

Administration of the Western Aphasia Battery (WAB, Kertesz 1982) yielded an Aphasia Quotient of 94.5 reflecting a very mild anomic aphasia. SV showed good auditory comprehension for single words and yes–no questions, but had some persistent difficulty with commands that required processing of syntactic constructions such as, ‘Point to the pen with the book’. Her naming abilities were good for common objects, and she scored 57 out of 60 on the Boston Naming Test (BNT, Kaplan et al. 1983). At that time, SV’s single-word reading accuracy was essentially without error. Her verbal digit span was limited to 4 as examined on the Wechsler Memory Scale—Revised (Wechsler 1987) Digits Forward Subtest, placing her performance below the third percentile relative to her age group.

Assessment of SV’s single-word writing was performed using the Johns Hopkins University (JHU) Dysgraphia Battery (Goodman and Caramazza 1986, Beeson and Hillis in press). Of 232 words presented for writing to dictation, she made 30 uncorrected errors (12%) and 17 additional self-corrected errors (see table 1). Significantly more errors were made on words that do not follow regular sound-to-letter correspondences (e.g. debt → deat) compared to regularly spelled words (10 vs. 4 errors out of 55, $\chi^2 = 4.01, p < .05$). There was no effect of concreteness, part of speech, or word length on spelling accuracy. Uncorrected spelling errors included phonologically implausible spellings that showed partial word form knowledge or visually similar words (60%, e.g. sketch → skitch; budge → bunch), phonologically plausible spelling errors (20%, e.g. phase → fase), and some partial responses (e.g. wept → w_ped). SV showed

Table 1. SV’s errors on written spelling of dictated words from the Johns Hopkins Dysgraphia Battery before (Pre TX) and after (Post TX) treatment

<table>
<thead>
<tr>
<th>Real Words</th>
<th>Possible</th>
<th>Pre TX</th>
<th>Post TX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spelling Regularity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regular</td>
<td>55</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Irregular</td>
<td>55</td>
<td>10$^a$</td>
<td>4</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>110</strong></td>
<td><strong>13</strong></td>
<td><strong>4</strong></td>
</tr>
<tr>
<td>Concreteness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete</td>
<td>21</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Abstract</td>
<td>21</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>42</strong></td>
<td><strong>8</strong></td>
<td><strong>2</strong></td>
</tr>
<tr>
<td>Part of Speech</td>
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</tr>
<tr>
<td>Noun</td>
<td>20</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Adjective</td>
<td>20</td>
<td>3</td>
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</tr>
<tr>
<td>Verb</td>
<td>20</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Functor</td>
<td>20</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>80</strong></td>
<td><strong>9</strong></td>
<td><strong>8</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>232</strong></td>
<td><strong>30</strong></td>
<td><strong>14^b</strong></td>
</tr>
<tr>
<td>Nonwords</td>
<td>34</td>
<td>11</td>
<td>7</td>
</tr>
</tbody>
</table>

$^a$ = significantly more errors on irregularly spelled words (PreTx), $p<.05$

$^b$ = significantly fewer errors after treatment, $p<.05$

1 The word lists for the Johns Hopkins Dysgraphia Battery are available in Beeson and Hillis (in press).
some ability to use the sublexical spelling route in that she correctly spelled 23 out of 34 nonwords. Her errors on nonword spelling were most often incorrect choice of vowels. There was no evidence of impairment to the peripheral writing processes in that SV showed no difficulty in letter formation or graphomotor control for writing.

In summary, SV showed relatively well recovered comprehension for single words presented in spoken and written modalities, and relatively normal oral naming and oral reading abilities. There was no evidence of semantic impairment in any modality. Her spelling errors typically reflected partial knowledge of the written word form, and there was no evidence of impairment of graphomotor skills. SV’s nonword spelling indicated that she had access to the sublexical spelling route, but her phoneme-to-grapheme conversion mechanism was not perfect. SV’s pattern of performance can be best explained as partial impairment of the graphemic output lexicon and the sublexical spelling route.

Treatment and outcome

SV was seen biweekly to develop strategies for improved writing and spelling. SV’s efforts to improve her writing were largely self-directed in that she completed written assignments at home. Clinical sessions were directed towards establishing procedures to resolve her spelling difficulties and providing feedback regarding her compositions. When SV could not retrieve the spelling of a word, or when she thought that her spelling was incorrect, she was encouraged to try to assemble the spelling using her knowledge of sound-to-letter correspondences. SV was able to sound out words and tried to retrieve the corresponding letters for each phoneme. She had previously established a corpus of key words that helped her retrieve the appropriate grapheme for most phonemes, using an approach similar to that described by de Partz (1986), Hillis Trupe (1986), and Hillis (1992). SV’s key words were ones that she reliably spelled correctly. For example, if she could not easily retrieve the grapheme k for the sound /k/, she would recall that Kim starts with the sound /k/, and then correctly recalled the grapheme k. After sounding out a word and assembling an attempt at spelling, SV examined the spelling to determine if it was correct. Self-correction was common. When SV was unsure of her spelling, she entered spelling attempts into the electronic speller, which provided possible alternatives for misspelled words. SV’s word recognition was good, so that she typically selected the correct alternative offered by the electronic speller.

For homework, SV wrote short vignettes. During the first several months, she complained of difficulty with the creative aspects of writing, so she requested assistance in selecting a topic for her written stories. For example, she might be asked to write a descriptive narrative about the ocean, or about a dog. Over time, SV shifted from needing assistance in topic selection to complete independence regarding the creative aspects of her writing. Her stories were composed in longhand and then copied into a word processor. She typically wrote about 200 words every two weeks.

Examination of SV’s hand-written drafts provided evidence of her problem-solving for spelling. There appeared to be increasing reliance on sound-to-letter correspondences to derive plausible spellings, for example, for ‘expans’ SV wrote eggspanse and then corrected it to expanse. Many of SV’s spelling attempts appeared to reflect a combination of partial word form knowledge as well as some reliance on the sublexical spelling route. For example, for ‘search’ she wrote the following sequence: srck → sirech → search; for ‘commotion’, she wrote, comosh_n → commosh_n → commotion; for ‘maneuver’ she wrote...
monufd → maneful → mani_fal → maneuver. When her problem-solving attempts failed, SV made use of the electronic speller that typically allowed her to find the correct spelling. As is apparent from the example errors, SV had greater difficulty retrieving vowels in comparison to consonants.

SV used this problem-solving approach in the context of her creative writing homework for 10 months. Her bimonthly treatment sessions served to hold her accountable for weekly writing and to monitor her progress. Clinical observation and SV’s self-report indicated that the creative aspects of her writing were easier and spelling was improving. After 10 months, the JHU Dysgraphia Battery was re-administered to examine single-word spelling (see table 1). Of 232 words presented for writing to dictation, SV made only 14 spelling errors (5%), a significant reduction from 30 errors at pretreatment, \( \chi^2 = 6.43, p < .05 \), with 9 additional self-corrected errors. There were no significant lexical effects, which was not surprising given the small number of errors, but there was a significant increase in the number of phonologically plausible errors when compared to pretreatment from 20% to 86%, \( \chi^2 = 17.05, p < .05 \).

Because verbal digit span was the only standardized measure that showed a significant impairment prior to treatment, SV was re-administered the Digits Forward Subtest of the WMS-R. Her digit span remained stable at 4, reflecting a persistent deficit for verbal working memory.

Following the 10-month period devoted to writing, SV was asked to compose an essay to describe her problem-solving approach to spelling. She wrote the following essay to describe her spelling strategies:

How Do I Spell Relief? Written by SV

I spell relief easily, each letter flows into the next. Most words are like that—mother, door, bed. I just know how to spell them. Some words take a little effort, like effort, board, different. I know some letters immediately. Sometimes I sound it out in my head, like board—I know it starts with b and ends with d, I know it’s an o and that it’s not alone, and then the rest just pops out. Sometimes I write down what I have and that jogs the rest. For example, d_v_d > different. I sometimes write phonetically—experience > experience. With phonetic spellings, often I have to resort to the electronic speller. Some words are tough. When I say the word, I have no idea where to start. Then I have to begin with the first letter. Is it b—like bed, d—like dog, f—like food, g—like girl, k—like Kim, m—like mother, n—like needle, p—like purple, t—like turkey, etc? These sample words are usually nouns and usually concrete. When I find the first letter (like is it v or f?), often the rest is easier. Sometimes it backfires. I have the word agst (with g—like giraffe). It takes a while to discover it should be adjust—so it’s not g—like giraffe, but J—like Jupiter. Sometimes words that should be easy are difficult; sometimes words that should be difficult are easy.

Discussion of SV’s performance

Over the course of 10 months of self-directed writing homework using a problem-solving approach to resolve spelling errors, SV improved her spelling accuracy. Her remaining errors suggested increased use of the sublexical spelling route given the high proportion of phonologically plausible misspellings. SV’s description of her problem-solving approach to spelling described use of both lexical and sublexical spelling routes. In her essay, SV first described how some words are retrieved from the graphemic output lexicon without difficulty (‘I just know how to spell them’). She next indicated that partial graphemic representations are available for some words—and when she writes down part of the word, it often helps her retrieve the spelling. By writing part of the word, SV provided a visual representation of the partial
word form that served to trigger successful access to the graphemic representation. Next, SV detailed how she uses phonology to derive graphemes (‘Sometimes I have to sound it out in my head’). She indicated that she may only have to retrieve a letter or two via phoneme-to-grapheme conversion to prompt retrieval of spelling from the graphemic output lexicon. SV provided examples whereby her attempts at phonetic spelling prompted her to retrieve the correct spelling. It was evident that her phonetic attempts often failed to fully conform to phoneme-to-grapheme correspondences, and that she was able to self-correct her spellings even for words that are irregularly spelled (so they must be retrieved from the graphemic output lexicon). SV’s self-corrections appeared to reflect interaction of partially correct information from the sublexical route and information available in the graphemic output lexicon. SV also detailed that in some instances she needed to use her key words (‘sample words’) to derive the grapheme associated with a given phoneme. She went on to note that sometimes the sublexical approach to spelling yielded spelling errors, particularly for sounds that translated to more than one grapheme (e.g. j and g), and that these ambiguous spellings caused her difficulty. The electronic speller was useful for deriving correct spellings from phonologically plausible errors, and also helped SV when she failed to retrieve the appropriate vowels.

In summary, SV described her use of partial information obtained from both lexical-semantic and sublexical spelling routes to resolve her spelling difficulties. Her improved spelling suggested that the problem-solving procedure strengthened the processes or representations necessary for spelling. We wanted to know if the procedures used by SV would be useful for similar patients to improve written spelling abilities, and whether improvement might be achieved in a time frame that is more consistent with typical service delivery constraints. We had the opportunity to address these questions with patient SW.

Case report: SW

SW was a right-handed, 42-year-old high-school graduate, who managed an equipment rental company prior to a traumatic head injury. Fourteen months prior to the initiation of this treatment protocol, SW had a motor vehicle accident causing a head injury with severe contusional oedema and a left temporal subdural hematoma. The hematoma was evacuated and a small portion of the anterior temporal lobe was removed due to confusion. An MRI head scan performed after surgery revealed damage to the left anterior temporal lobe, and a separate lesion in the region of the left basal ganglia, extending into the frontal white matter.

At six months post-injury, administration of the Western Aphasia Battery revealed mild anomic aphasia with an Aphasia Quotient of 86.1. SW’s auditory comprehension was good for single words, sentences, and commands. His primary deficit was word retrieval for common nouns as well as low frequency words, as noted on the Boston Naming Test (12 correct out of 60). SW often provided appropriate verbal descriptions for words that he could not retrieve, suggesting preserved semantic knowledge. Initial language treatment was directed towards improving lexical retrieval of content words. At one year post-injury, SW’s naming performance on the BNT showed improvement to 24 correct out of 60, and he showed effective use of semantic circumlocution to compensate for persistent word retrieval difficulties. SW also experienced mild episodic memory impairment, so that the use of external memory aids, such as a daily planner and journal was indicated.
At the time of the initiation of writing treatment, SW had a mild persistent anomic aphasia (WAB aphasia quotient = 90.9). His single-word comprehension was essentially flawless, but word retrieval remained impaired as noted on the Boston Naming Test (27 correct out of 60; 17 additional correct in response to phonemic cues). Single-word reading and writing were assessed using subtests from the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA; Kay et al. 1992). SW made no errors on a task requiring reading of concrete nouns and selection of the corresponding picture from a field of five (40/40, PALPA Subtest 48). Oral reading of single words was assessed using the PALPA Subtests 31 and 32. As shown in table 2, SW made 13 errors out of 160 words. His errors were either visually similar words (e.g. pact → pack, purpose → propose) or mispronunciations of target words.

SW performed well on a test of written naming for pictured objects (PALPA Subtest 53). He correctly wrote the names of 39 out of 40 with his one error being a phonologically plausible misspelling (scissors → sissors). Writing to dictation was assessed with PALPA Subtests controlled for imagery, frequency, and grammatical class. As shown in table 2, SW correctly spelled fewer than half of the dictated words (69 uncorrected errors out of 160, with 17 additional self-corrected errors). His spelling errors were predominantly phonologically plausible misspellings (43/160 = 64%; e.g. system → sistum, purpose → purpose). Other error types were single- or multiple-letter deletions or substitutions that were phonologically implausible, but showed considerable partial knowledge of the word form (e.g. audience → aiudiet; bonus → boons), and a few visually similar words (ancient → accent). No semantic errors were made. SW made significantly more errors on low imagery versus high imagery words, $\chi^2 = 8.9$, $p < .05$, and there were no effects for word frequency or part of speech. SW showed some ability

Table 2. SW’s errors on written spelling of dictated words and reading of single words from the Psycholinguistic Assessment of Language Processing in Aphasia before (Pre TX) and after (Post TX) treatment.

<table>
<thead>
<tr>
<th>Real Words</th>
<th>Writing</th>
<th></th>
<th></th>
<th>Reading</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Possible</td>
<td>Pre TX</td>
<td>Post TX</td>
<td>Possible</td>
<td>Pre TX</td>
<td>Post TX</td>
</tr>
<tr>
<td>Frequency/Imagery</td>
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<td>Low/High</td>
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<td>20</td>
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<td>1</td>
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<td>Low/Low</td>
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<td>12</td>
<td>8</td>
<td>20</td>
<td>4</td>
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<td>Part of Speech</td>
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<td>69</td>
<td>29*</td>
<td>160</td>
<td>13</td>
<td>13</td>
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<tr>
<td>Nonwords</td>
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<td>10</td>
<td>8</td>
<td>24</td>
<td>9</td>
<td>14</td>
</tr>
</tbody>
</table>

* = significantly fewer total errors at PostTX compared to PreTX, $p<.05$
to spell nonwords, but did not do this without error (10 errors out of 24). Most of the nonword spelling errors reflected errors in selection of vowels.

In summary, SW had good auditory comprehension for single words with mild impairment of single word reading. He showed impairment of both spoken and written output modalities, particularly for low frequency, low imagery words. The impairments did not implicate the semantic system in that SW provided good semantic descriptions for most words that he failed to retrieve for spoken naming, and he made no semantic errors. Although SW’s written naming of selected common objects was good, a more comprehensive spelling assessment revealed a significant impairment. More than half of SW’s spelling errors were phonologically plausible misspellings, with the rest of his errors reflecting partial lexical knowledge for most words. Like SV, SW’s spelling performance can best be explained by assuming partial impairment of the graphemic output lexicon and the sublexical spelling route. His reliance on the sublexical spelling route was consistent with a profile of surface agraphia.

Treatment and outcome

A home programme for writing was implemented with SW over a 10-week period. He agreed to write daily entries into a personal, narrative journal. He was instructed to spend as much time as needed to solve his spelling difficulties using the problem-solving strategies that included writing partially correct responses, attempting self-correction, using sound-to-letter correspondences, and finally, using an electronic speller to obtain alternatives for his plausible misspellings (table 3).

SW was seen for weekly therapy sessions to monitor his journal writing and his use of problem-solving strategies for spelling. Given SW’s mild memory impairment, it was necessary to repeatedly reinforce the instructions for his daily writing in the journal and problem-solving approach for spelling, particularly at the outset. During the clinical session, SW’s journal was reviewed, and any remaining spelling errors were identified. He was prompted to use the problem-solving approach to self-correct identified errors. SW’s homework included numerous examples of his multiple attempts to solve spelling errors (e.g. relaxed: relacs → relask → relaxed; sales: seals → sail → salles → sales; hospital: hosipat → hosipital → hosipatol → hospital). Similar multiple attempts to resolve spelling errors were observed during therapy sessions, often culminating with the use of the electronic speller* (e.g., whole: bowl → bowe → boll → bolle → whole*; impossible: imposible → impassable → impussable → impossible*; supposed: sepost → supossed*).

After 10 weeks, SW’s spelling was re-assessed using word lists from the PALPA. SW made 29 uncorrected errors (and 50 self-corrected errors) out of 160 words, a significant decrease from 69 errors prior to treatment ($\chi^2 = 23.53$, $p < .05$). SW continued to

<table>
<thead>
<tr>
<th>Table 3. Homework instructions for SW to guide him to use problem-solving strategies to resolve spelling errors</th>
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<tbody>
<tr>
<td>Write about your day. Use sentences.</td>
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<tr>
<td>When you have trouble spelling a word:</td>
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<tr>
<td>• Try to write it like it sounds.</td>
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<tr>
<td>• Decide if the spelling is correct.</td>
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<tr>
<td>• If incorrect, try to correct it.</td>
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<tr>
<td>• Use the electronic speller to check it, or to find the correct spelling.</td>
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<td>• Make a list of words that were hard.</td>
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</table>
produce more errors on low versus high imagery words ($\chi^2 = 4.02, p < .05$). His uncorrected errors were predominantly phonologically plausible misspellings of target words (69%), with the remaining errors being single or multiple letter errors yielding phonologically implausible misspellings that were close to the target.

In order to determine if SW’s spelling improvements reflected a general pattern of language recovery that was not specific to writing, oral naming and oral reading were reassessed. SW’s confrontation naming on the BNT remained unchanged with 27 out of 60 correct (21 additional correct in response to phonemic cues) reflecting a stable, persistent oral naming impairment. His single-word reading accuracy showed no change, indicating a persistent, mild oral reading impairment (table 2).

Following treatment, SW was also asked to write a short explanation of how he dealt with spelling difficulties. SW completed his written response as homework, but was not asked to create a polished essay as SV chose to do; his thoughts are included below with strikethroughs and spelling errors included.

**How To Spell—Written by SW**

When I spell a word I try to say the word. If I can say the word I have to picture it in my head. If I can’t see it then I keep thinking it over and over. I can say it over and over also. Finally it will be in my head and then I can see it then I can spell it. If I can’t ever see it I have to find it in my Franklin speech speller.

When ever I’m spelling a word I can’t just write I think about the word and how it sounds. Each letter makes a different sound so I try to pick the right letter. I keep saying it over and over and right (sic) the letter down that makes the sound for the word.

**Discussion of SW’s performance**

Over the course of 10 weeks, SW established a daily routine of writing in a personal journal. His journal provided evidence of problem-solving attempts to correct spelling errors, often including phonologically plausible misspellings that were ultimately corrected. At the end of the 10 weeks, his spelling skills were significantly improved on a writing-to-dictation task. This improvement was observed in the face of a significant persistent impairment of oral naming, and a mild impairment in oral reading. SW’s residual errors were predominantly phonologically plausible, suggesting his persistent use of the sublexical spelling route when retrieval from the graphemic output lexicon was unsuccessful. It was apparent that SW’s improvement also reflected a notable increase in his successful self-correction attempts.

SW’s comments about his approach to spelling emphasized his attempts to visualize the spelling of words that posed a problem, suggesting that he focused initially on accessing the representation in the graphemic output lexicon. He simply tried to ‘see’ the word. When direct access failed, SW described trying to sound out the word, and he again emphasized the need to say the word over and over as he attempted to retrieve each letter. It was apparent from SW’s sequence of corrected spellings that he often used the information gained from phoneme-to-grapheme conversion to cue retrieval of spellings from the lexical-semantic route (e.g. relaxed: *relacs* $\rightarrow$ *relask* $\rightarrow$ *relaxed*).

**General discussion**

Patients SV and SW provided evidence of interactive use of partially damaged lexical and sublexical spelling routes to resolve spelling errors. Their multiple written spelling attempts showed use of phoneme-to-grapheme conversion rules to generate plausible spellings for problem words; however, they often corrected overapplication of sublexical
rules by allowing phonologically plausible misspellings to assist in the retrieval of correct orthographic representations. Both patients significantly improved their spelling abilities following repeated practice with this problem-solving approach. The procedures emerged in the context of our work with SV over a long period of time (10 months), whereas SW showed improvement over a 10-week period.

A number of questions arise as we consider SV and SW’s spelling improvement. By what mechanism did spelling improve? Was it item-specific improvement of spellings reflecting a strengthening of specific graphemic representations, or was it a more general, strategic effect allowing them to resolve spelling difficulties? We cannot answer these questions with certainty, but can make comment. In the case of SW, the large number of self-corrected spelling errors on the post-test (50 out of 160 words) argue in favour of improved problem-solving, more so than strengthened graphemic representations. SV, on the other hand, made very few spelling errors by the end of treatment, and her total number of self-corrections declined, so that it appeared that graphemic representations were strengthened or more easily accessed. Because SV showed considerable insight regarding her rehabilitation, she was asked, ‘Do you think your spelling is better now (for specific words)? Or do you think that you are correcting your errors better?’ To that SV replied, ‘I think it is both.’ She went on to say, ‘more words just flow now . . . I know how to spell them. But when I get stuck, I use the phonetic spelling.’ So, SV perceived that she improved her access to graphemic representations and also improved her ability to resolve her spelling errors using sublexical knowledge. Given that SV had greater experience using the problem-solving approach than SW, she may have strengthened graphemic representations via repeated stimulation that SW had not yet amassed.

In retrospect, we recognize that it would have been valuable to repeatedly probe SW’s spelling on a standard measure over the course of treatment, rather than simply before and after treatment. Repeated probes for single-word spelling compared to oral naming abilities may have provided a more clear understanding of the treatment effect relative to untreated behaviours. Additionally, it may have provided insight regarding his improved spelling strategies versus item-specific learning.

It is worth considering whether a strategic approach to agraphia treatment is preferable to treatments that are more item-specific in nature. The problem-solving strategy appeared to promote summation of partial information from several processes. In contrast, it is assumed that item-specific treatment effects are due to the increased frequency of access, thus lowering the threshold for activation for particular graphemic representations (Hillis 1992). For example, the approach used by Behrmann (1987) targeted a corpus of homophones for training in order to resolve the inherent ambiguity resulting from use of phoneme-to-grapheme conversion. Her patient mastered the homophones that were trained, but failed to generalize to untrained homophone pairs. Thus, item-specific treatment may lead to relatively predictable results, but is likely to show limited generalization. For patients like SV and SW, it may be beneficial to complement strategic treatment with item-specific stimulation for targeted items. This was done on an informal basis with SV and SW in that they were ‘tested’ during their treatment sessions on words that had given them difficulty. The corpus of words that emerged as troublesome would be likely candidates for item-specific treatment.

In cases of relatively severe language impairment, patients may not have information from multiple processing mechanisms available for interactive use. For example, patient ST, reported by Beeson (1999), showed virtually no residual ability to perform phoneme-to-grapheme conversions, so that item-specific treatment intended to
strengthened selected graphemic representations appeared to be the only plausible treatment option. Patient JS reported by Hillis Trupe (1986) did not have adequate sublexical information to write phonologically plausible spellings, but (with treatment) JS was able to retrieve partial graphemic information that served to cue correct written responses, and to block semantic errors that arose via the damaged lexical-semantic route. We conclude that the decision to use strategic or item-specific treatment will depend on the available cognitive mechanisms for a given patient at a given time in their rehabilitation process. If the patient is capable of taking advantage of information from both the lexical-semantic and sublexical routes, it certainly makes sense to promote an interactive strategy to resolve spelling difficulties.

Finally, we want to draw attention to the fact that the treatment approach reported here was largely dependent on homework accomplished by the patients with relative independence. Both SV and SW showed that they actively brought to bear lexical and sublexical processes as they tried to resolve spelling errors. Corrective feedback for spelling attempts was available at home by means of the electronic speller. Thus, the homework-based treatment had precisely the components important for effecting change: stimulation of weakened processes and representations with corrective feedback to stabilize the correct responses. Another critical feature, particularly for SW, was the fact that stimulation was provided on virtually a daily basis as he accomplished his homework. This level of intensity may be critical to adequately stimulate and strengthen the cognitive processes necessary to effectively rehabilitate spelling. SV continues to work on writing in an effort to more closely approximate her premorbid writing abilities. She reported that as single-word spelling and word retrieval became less effortful, she was able to direct more attention to the creative aspects of her writing. A recent example of her writing is included in the appendix that demonstrates her inherent talent and the fruits of her persistent efforts.

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References


Appendix

Begging the Same Question

...I am still begging the same question
By the same light,
Eating the same stone...

W. S. Merwin, Another Year Come

Life. Every day, when I wake up, I ask the same question—sometimes explicitly, most often in other ways. Is this it? Is this life?

Before Stroke (BS), I had more going on. I worked forty hours plus a week, with heavy emphasis on plus. After Stroke, particularly at the beginning, the tasks were different, but the hours were almost the same. So, the lesson? Obviously not to become the greatest software engineer around. I was barely coherent. To read again was certainly a laudable goal, and in some ways the most challenging thing I have ever had to do. And certainly I was focused on doing it. But, after all, to climb out of a hole is not a lifetime commitment, is it? Surely not.

Life. Maybe I should use a Zen approach. I am not well versed on Zen, but I know very well the sound of one hand clapping. Every aphasia person does. But I want more. I want a purpose. I have begun to construct a new life; I need a new purpose. Forget Zen. It works for a while, but it is not my bag. Work is not my bag (I wish it were). I don’t like music or art—not with the passion of life some do. What I do like—and with a passion, newly awakened—is writing. Great! We are back to the sound of one hand clapping. Maybe it will tap out a Morse code of writing great things to come.

Sheila Vail
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