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Lexical access *via* letter naming in a profoundly alexic and anomic patient: A treatment study

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Abstract

We report the results of a letter naming treatment designed to facilitate letter-by-letter reading in an aphasic patient with no reading ability. Patient M.R.'s anomia for written letters reflected two loci of impairment within visual naming: impaired letter activation from print (a deficit commonly seen in pure alexic patients who read letter by letter) and impaired access to phonology *via* semantics (documented in a severe multimodality anomia). Remarkably, M.R. retained an excellent ability to pronounce orally spelled words, demonstrating that abstract letter identities could be activated normally *via* spoken letter names, and also that lexical phonological representations were intact when accessed *via* spoken letter names. M.R.'s training in oral naming of written letters resulted in significant improvement in her oral naming of trained letters. Importantly, as M.R.'s letter naming improved, she became able to employ letter-by-letter reading as a compensatory strategy for oral word reading. M.R.'s success in letter naming and letter-by-letter reading suggests that other patients with a similar pattern of spared and impaired cognitive abilities may benefit from a similar treatment. Moreover, this study highlights the value of testing the pronunciation of orally spelled words in localizing the source of prelexical reading impairment and in predicting the functional outcome of treatment for impaired letter activation in reading. (*JINS*, 1998, *4*, 595–607.)

Keywords: Alexia, Anomia, Aphasia, Treatment

INTRODUCTION

Brain damage often disrupts recognition of written letters and words in previously literate adults. Acquired dyslexia can result from impairment to peripheral visual systems or to central orthographic, semantic, and phonological subcomponents of reading. *Pure alexia* describes the relatively selective disruption of reading in the context of spared spelling and general language function (i.e., alexia without agraphia; Dejerine, 1892). Patients with pure alexia often employ a letter-by-letter reading strategy characterized by slow yet generally accurate reading, and response latencies that increase predictably with increasing word length (e.g., Patterson & Kay, 1982; Warrington & Shallice, 1980). These patients typically rely on this compensatory strategy even when they retain some residual ability to comprehend written words normally (e.g., Arguin & Bub 1993; Bub & Arguin, 1995; Coslett & Saffran, 1989; Coslett et al., 1993; Howard, 1991). Letter activation (i.e., the encoding of abstract letter identities from print) appears to be abnormally slowed or inaccurate in most (possibly all) pure alexic patients, though the degree of this prelexical deficit varies from patient to patient (e.g., Behrmann et al., in press; Behrmann & Shallice, 1995). Letter naming ability also varies across pure alexic patients, with poor letter naming making letter-by-letter reading impossible for some patients (Patterson & Kay, 1982).

Letter-by-letter reading circumvents the source of impairment to normal reading, allowing individual letter identities access to central reading procedures (e.g., Friedman et al., 1993). As such, letter-by-letter reading may engage the same mechanisms that underlie the normal ability to pronounce orally spelled words, though the ability of pure alexic patients to pronounce orally spelled words is seldom reported. Pronouncing orally spelled words has most often been explained as involving letter name conversion systems separate from central orthographic and phonological procedures for oral reading or spelling (e.g., Cipolotti & War-

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rington, 1996), and the performance of alexic patients in pronouncing orally spelled words has been omitted from the vast majority of detailed discussions about acquired reading disorders.

Recently, Greenwald and Berndt (1998) have proposed an integrated account of orthographic processing in which the pronunciation of orally spelled words is supported by the same mechanisms involved in reading, spelling and naming. Based in part upon evidence from Patient D.E.S. (Greenwald & Berndt, 1997), they argue that pure alexia can arise not only from impaired letter activation but also from impaired encoding of abstract letter order from print. On this account, abstract letter order is normally encoded at the level of the Ordinal Graphemic Code, a transient code common to reading, spelling, pronouncing orally spelled words, and letter-by-letter reading. This account predicts that letter-by-letter readers abnormally encode letter identities and/or letter order from print, but encode these same letter identities and their abstract order relatively normally from auditory letter names (spoken aloud or subvocally). In contrast, D.E.S. had a specific deficit at the level of the Ordinal Graphemic Code that resulted in severely impaired reading, spelling, pronunciation of orally spelled words, and (despite good memory and good letter naming) a complete inability to read letter by letter. Thus, these authors note that while abstract letter activation (Behrmann et al., in press), good immediate memory, and good letter naming (Patterson & Kay, 1982) are necessary for letter-by-letter reading, they are not sufficient.

Assuming that knowledge of abstract letter order is required for oral reading, it would seem that success in using the letter-by-letter reading strategy is evidence that this ordinal knowledge is intact. In patients with severely impaired letter naming, however, this ordinal knowledge can be assessed by asking them to pronounce orally spelled words. Good performance in this task is evidence for both intact letter identities and intact ordinal knowledge; poor performance would reflect impairment to one or more subcomponents of the task which then could be examined further across specific language tasks. The task of pronouncing orally spelled words can provide critical information in attempts to specify the locus of functional breakdown within the normal reading system. This information may also determine the prognosis for some types of reading treatment.

Attempts to remediate acquired reading disorders are typically motivated by a primary interest in returning functional reading to the patient, and only an incidental interest in how specific subcomponents of the reading system will respond to intervention. Even in the relatively few cases in which reading treatment is based upon detailed cognitive neuropsychological assessment, improvement in a targeted subcomponent of reading may not result in functional reading, if an "upstream" impairment within the reading system is treated while a "downstream" impairment is untreated or apparently untreatable. For example, Berndt and Mitchum (1994) demonstrated successful training of grapheme-to-phoneme conversion in the severely dyslexic Patient L.R., but the functional effect of this treatment was limited by L.R.'s downstream deficit in blending phonemes. When we consider approaches to treating reading deficits that arise from impairment within prelexical visual processing, such as pure alexia, we must assess the extent to which downstream impairments may affect treatment outcome. For example, within the theoretical framework proposed by Greenwald and Berndt, described above, treatment targeting impaired letter activation or impaired letter naming from print would have limited functional outcome if the patient had additional impairment at the level of the Ordinal Graphemic Code itself. In this case, the patient may learn to name letters aloud, but would be unable to encode the relative order of the letters for reading.

In this paper, we describe a letter naming treatment designed to facilitate letter-by-letter reading in an aphasic patient with no reading ability. Our goal was to give Patient M.R. some level of reading function through this compensatory letter naming strategy, albeit not a normal method of reading. Detailed cognitive neuropsychological assessment of M.R.'s reading and naming revealed a severe anomia for printed letters reflecting two loci of impairment to visual naming: impaired letter activation from print (a deficit also seen in letter-by-letter readers) and impaired access to phonology *via* semantics (documented in severe multimodality anomia). However, M.R.'s pattern of reading and naming deficits is of particular interest in that she demonstrated a remarkably preserved ability to pronounce orally spelled words. In studying M.R.'s deficits and her response to the reading treatment, we were able to address issues relevant to letter-by-letter reading: (1) Can a severe case of impaired letter activation respond to intervention?, and (2) How may letter-by-letter reading relate to the ability to pronounce orally spelled words? This study also demonstrates the value of assessing a patient's pronunciation of orally spelled words as part of an attempt to distinguish deficits of phonological access from phonological loss. The results of this reading treatment can be used to predict the extent to which other patients with similar cognitive deficits may benefit from a similar treatment program.

Assessment

Patient

Patient M.R. is a 72-year-old right-handed woman with an eighth grade education. She is a retired clerical worker who denied developmental reading or spelling difficulties. In 1991, 13 months prior to the current treatment study, M.R. suffered a left hemisphere hemorrhagic lesion involving the occipital lobe and extending from the inferior temporal region to the temporal–parietal–occipital junction, as revealed by magnetic resonance imaging (MRI) at 2 weeks postonset. Neurological examination at that time indicated right homonymous hemianopsia, anomia, severe alexia with agraphia, buccofacial and limb apraxia, and Gerstmann's syndrome, with no accompanying sensory deficits. In addition, M.R.'s acute condition was thought to be consistent with a possible multimodality agnosia that largely resolved in the weeks following the event. Ophthalmologic examination confirmed the hemianopsia and indicated visual acuity with corrective lenses at 20/30 bilaterally. Prior medical history was unremarkable except for hypertension and a remote history of depression.

At 8 months postonset, we initiated extensive assessment of M.R.'s language and visual–semantic processing. M.R.'s performance in a screening with the Western Aphasia Battery (Kertesz, 1982) was consistent with an anomic aphasia, in that spontaneous speech was fluent with marked word-finding difficulty, confrontation naming was severely impaired, auditory comprehension was largely spared except for complex sequential commands, and repetition was excellent for sentences, single words, and nonwords. M.R. correctly named aloud only 3 of 60 pictures (5%) from the Boston Naming Test (Kaplan et al., 1983).

As previously reported (Greenwald et al., 1995), we traced M.R.'s inordinate difficulty in oral naming of viewed objects and pictures to multiple sources within the oral picture naming system: First, a multimodality anomia implicating impaired activation of lexical phonology from semantics; second, impaired activation of semantics from viewed objects; and third, mild disruption to semantic processing. That prior report details our experimental treatment for M.R.'s severe picture anomia, which resulted in significant improvement in her oral picture naming for trained stimuli, but no generalization of the treatment to oral reading.

The treatment of M.R.'s nonfunctional oral reading, which we will describe here, began 1 month after the picture naming treatment was completed. At that time, her overall pattern of language deficits continued to be consistent with an anomic aphasia. Her immediate memory as measured by digit span was within normal limits at seven digits forward.

Oral reading

In baseline testing for the current reading treatment study, we presented M.R. with lists of single content words to read aloud. First, we asked her to read words and nonwords matched in length (four to eight letters) from the Battery of Adult Reading Function (Rothi et al., 1984), including 30 regularly spelled words, 30 exceptionally spelled words (matched across group for word frequency), and 30 pronounceable nonwords. We also asked her to read a list of 120 highly imageable (i.e., high image) nouns representing 12 semantic categories of high, middle, or low frequency in the English language (Francis & Kucera, 1982). M.R. was unable to respond to any written stimuli presented to her for oral reading, although it was clear that she put forth great effort across all tasks.

We addressed the possibility that M.R.'s reading would improve if she were presented with each letter of the target word individually rather than the whole written word. We allowed her to view each constituent letter of each target word one at a time in sequence (at a rate of approximately 1 letter/s), but she remained unable to respond to any of the 10 regular words, 10 exception words, and 10 nonwords presented to her in this way.

M.R. was unable to employ a letter-by-letter reading strategy, though we encouraged her to do so. Her oral naming of visually presented letters was severely impaired, and she was able to name aloud only 3 of 26 upper case letters (12%) presented individually. M.R. was also severely impaired in producing sounds corresponding to individual printed letters, providing a correct phoneme for only 4 of 26 letters (15%). The few correct responses M.R. produced in these tasks may reflect chance outcome in that she responded to nearly all the test items with perseverative responses.

Oral naming across input modalities

M.R.'s severe anomia for written letters and words was consistent with her overall pattern of severe multimodality anomia. As reported in detail in our prior report, M.R. exhibited severe word-finding difficulty in spontaneous speech as well as severely impaired oral naming of pictures (7/120; 6%), auditory definitions (41/120, 34%), palpated objects (6/42; 14%), and viewed gestures (18/48; 38%). With the exception of the gesture (i.e., verb) naming task, these scores are based on her naming of the same set of 120 high image nouns that had been administered for oral reading, or a subset of this set. The auditory definitions corresponding to each of the 120 high image nouns incorporated semantic category, function, and semantic associate information, but not visual structural information. In additional testing, M.R. was also severely impaired in oral naming of one- and two-digit arabic numerals (3/20; 15%), common written symbols (1/10; 10%), and letters traced in her palm (1/26; 4%). Errors across naming tasks were predominately semantically related to the target or *no response*, with a tendency for perseverative errors. M.R. produced virtually no visual errors across naming tasks.[1]

As shown in Figure 1, M.R.'s severe impairment across many naming tasks contrasts sharply with her remarkably preserved oral naming of orally spelled words. When words were spelled aloud to her, M.R. correctly pronounced 60 of 60 (100%) high, middle or low frequency nouns from the set of 120 nouns that had been administered for oral reading.

Further assessment revealed a second auditory–verbal task for which M.R.'s oral naming was relatively preserved: She was able to correctly name 30 of 40 environmental sounds (75%) presented to her individually on audiotape. However, she demonstrated severe impairment in naming to auditory definition, most likely due to the heavy demands this task placed on her semantic memory. In contrast, the task of pronouncing orally spelled words does not appear to require semantic mediation (Greenwald & Berndt, 1998).

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[1] Proportions of M.R.'s primary error types are detailed in the previous paper.

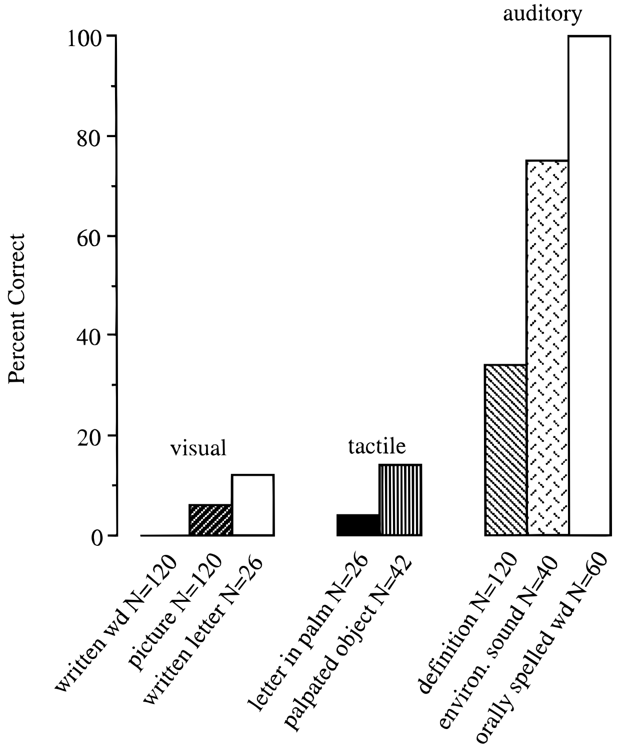

Fig. 1. Oral naming across input modalities, including nonfunctional oral reading.

In additional testing of pronouncing orally spelled words, we compared M.R.'s ability to pronounce regularly spelled words (i.e., made up of high probability grapheme-to-phoneme correspondences in English) *versus* exceptionally spelled words (i.e., having unique or low probability translations from grapheme to phoneme). Given the same single word lists balanced for word frequency, word length (4–8 letters), and approximate imageability from the Battery of Adult Reading Function (Rothi et al., 1984) that were used in the oral reading task, M.R. correctly pronounced 30 of 30 regular words (100%) and 26 of 30 (87%) exception words [$\chi^2(1, N = 60) = 2.41, p = .12$]. Her four errors were regularizations of exceptional spellings, and her performance in this task was not influenced by imageability, word frequency, or length. Given another subset of this test, M.R. performed perfectly (100%) in pronouncing a list of 30 orally spelled nonwords (e.g., *jisp*).

In summary, despite severe anomia across many naming tasks, M.R. retained excellent ability to pronounce orally spelled words, even exceptionally spelled, low image, and low frequency words. Her excellent performance given words and nonwords in this task reflects her ability to hold strings of letters in memory, to encode both abstract letter identity and abstract letter order from auditory information, and to access lexical and sublexical phonological codes from these abstract graphemic codes. Her poor oral naming of written letters, and her resulting inability to read letter by letter, seem to involve impairment to a different component of the reading system: activation of these abstract graphemic codes from print. We therefore examined her visual analysis and recognition of written letters and words.

Visual analysis

M.R.'s visual processing of viewed objects was severely impaired, as we have previously described in detail (Greenwald et al., 1995). M.R. demonstrated intact early visual analysis and intact "object recognition units" (e.g., Ellis & Young, 1988), but severe impairment in accessing semantic information from viewed objects. This general deficit pattern is sometimes labeled a visual associative agnosia (Lissauer, 1890), although M.R.'s lack of visual errors in picture naming (less than 1%) is not consistent with a visual agnosia, in which large numbers of visually related errors would be expected (Farah, 1990). One example of M.R.'s visual–semantic processing impairment, described in our prior report, was that her performance in semantic associate picture matching declined predictably as visual load increased.

We hypothesized that M.R.'s visual processing of written letters was impaired similarly to her visual processing of viewed objects. We administered a letter cancellation task in which we asked her to circle occurrences of the letter *A* that were intermixed with other letters in all four quadrants of a page. A model of the target letter was provided at the top of the page. M.R.'s perfect performance in this task reflects adequate visual attention to the page presented, as well as intact ability to distinguish the target letter shape from others in the array.

M.R. also demonstrated perfect performance in a letter decision task. We presented her with each of 20 written stimuli individually (i.e., 10 real letters and 10 nonsense letter-like shapes), and asked her to say aloud whether each item was or was not a real letter in English. M.R. quickly and accurately judged all stimuli correctly, suggesting that she had intact *letter recognition units* or *abstract letter identifiers* (ALIs; Evett & Humphreys, 1981).

However, M.R. was impaired in a second task commonly used to assess activation of ALIs from print: cross-case letter matching. We asked M.R. to match one upper case letter to one of three lower case letters (e.g., *G*: *c*, *g*, *e*), and she correctly matched only 20 of 26 target letters (77%) across case overall. When we excluded those letters that can be matched correctly across case based only upon physical similarity (e.g., *Cc*, *Oo*, *Ww*), M.R.'s score was only 9 of 15 (60%). This latter score more accurately represents her impaired ability to access abstract letter identities from print rather than her ability to simply match physical letter shapes.[2]

In summary, though M.R. is able to distinguish real letters from nonsense letters, she is clearly impaired in cross-case letter matching. Of these two tasks designed to assess abstract letter identification, the letter decision task could be inherently easier than the cross-case matching task in that

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[2] In a separate task, when we asked M.R. to match an auditory letter name to one of three written letters, she correctly matched only 20 of 26 (77%).

letter decision requires only that a letter shape be recognized as familiar or not, whereas the matching task requires that the most closely related letter shape be selected from a group of familiar letter shapes (all of which are related as alphabetic characters in English). Also, visual load is greater in the cross-case matching task as compared to the letter decision task. Given M.R.'s difficulty in visual processing with increasing visual load, it is possible that performance in cross-case matching may have worsened further had we presented a still larger visual array. M.R.'s impaired cross-case matching is evidence that her activation of ALIs from print is disrupted, in contrast to her excellent ability to access ALIs given auditory letter names in pronouncing orally spelled words. We next assessed the extent to which M.R. was able to use prelexical graphemic codes to access lexical orthographic representations from print.

Word recognition

We assessed M.R.'s word recognition for three types of stimuli: auditory words, orally spelled words, and written words. In each condition, M.R. was presented with single words or nonwords and was asked to decide if each presented item was or was not a real word. Accuracy but not response time was recorded. In the auditory word condition, M.R. performed nearly perfectly (98%) in distinguishing 30 real words (97%) from 30 nonwords (100%) taken from the Battery of Adult Reading Function (Rothi et al., 1984). Real words were 15 regular and 15 exception high and low image words balanced for length and frequency, and matched in length to orthographically legal nonwords. In another condition of this task in which the word and nonword stimuli were spelled aloud to her, M.R. responded correctly for 56 of 60 orally spelled items presented (93%), including 30 words (90%) and 30 nonwords (97%) [$\chi^2(1, N = 60) = .26, p = .60$]. She recognized regular words (100%) better than exception words (80%), although this was not a significant difference in this small sample [Fisher Exact Test $(1, N = 30) = 2.9, p = .22$].[3] Her performance was not influenced by word frequency, imageability, or word length.

In contrast, M.R.'s performance in visual lexical decision was extremely poor. Given a mixed written list of 40 high image words (taken from the set of 120 nouns administered in oral reading) and 40 nonwords (20 legal nonwords and 20 pseudohomophones) matched in length (3–7 letters), M.R.'s overall accuracy was only 22 out of 80 (28%). She performed even worse for real words (18%) than nonwords (38%), although this was not a significant difference [$\chi^2(1, N = 80) = 3.07, p = .08$]. There was no influence of word frequency on her performance in this small sample of high, middle and low frequency words [Fisher Exact Test $(2, N = 40) = 3.39, p = .18$], nor was there any influence of word length. She performed just as poorly given legal nonwords (40%) as pseudohomophones (35%) [Fisher Exact Test $(1, N = 40) = .14, p > .90$].

In summary, M.R. demonstrated extremely impaired word recognition from print. Her poor performance in visual lexical decision could not be attributed to an inability to understand the task, because she performed very well in the two auditory conditions. We next assessed the degree to which M.R. obtained any comprehension of written words.

Written comprehension

M.R.'s comprehension of single written words was profoundly impaired. In a semantic category sorting task, we asked M.R. to sort high image written words into distant semantic categories (e.g., *body parts vs. fruits*), close semantic categories (e.g., *fruits vs. vegetables*), or subgroups within semantic category (e.g., *summer clothing vs. winter clothing*). We gave M.R. four sets of 10 written words from two distant semantic categories ($N = 40$), and she sorted only 24 of 40 (60%) accurately ($z = 1.42, p = .156$, two-tailed). Thus, even in determining the broad semantic category of written words, M.R. performed no better than chance. She correctly sorted only 22 of 40 (55%) written words into close semantic categories ($z = .79, p = .430$, two-tailed), and only 24 of 40 (60%) written words into subgroups within semantic category.[4]

M.R. was also severely impaired in written word–picture matching. Using the same set of 120 high image words she had been unable to read aloud, we presented her with one written word and a choice of four semantically related pictures. She was able to select the correct picture match for only 30 of 120 written words (25%), and word frequency did not influence her performance.[5] Again, her performance in written word comprehension was no better than chance.

Oral spelling to dictation

Given the superiority of M.R.'s oral naming for auditory stimuli *versus* visual or tactile stimuli, particularly for the orthographic task of pronouncing orally spelled words, we hypothesized that she would also perform well in another auditory orthographic task: oral spelling to dictation. We therefore dictated lists of single words and nonwords to M.R.: Word lists were balanced for spelling regularity, word frequency, and approximate imageability, and matched in length to legal nonwords (four to eight letters). M.R. was required

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[3] Her performance in this condition may have been influenced by her ability to identify each spelled word prior to making the lexical decision; although she was not allowed to pronounce the orally spelled word aloud in this task, she may have named each item subvocally prior to deciding its lexical status.

[4] As described in our previous report, M.R. sorted the corresponding pictures into distant semantic categories with 93% accuracy, but only 65% pictures from close semantic categories, and 68% of pictures from subgroups within semantic category. In an auditory variant of the task, she performed nearly without error in making semantic category decisions for words from distant categories (98%), close categories (98%), or subgroups within category (95%).

[5] In the auditory condition of this task, M.R. matched 75 of 120 (63%) spoken words to one of four pictured semantically related objects, as described in our prior report.

to listen to the spoken word, repeat the word aloud, and then to spell the word aloud. She correctly spelled aloud 28 of 30 legal nonwords (93%). Her performance in spelling words was influenced by spelling regularity in that she spelled aloud 27 of 30 regular words (90%), but only 14 of 30 (47%) exceptionally spelled words [$\chi^2(1, N = 60) = 11.09, p < .001$]. Her errors in oral spelling of exception words often reflected partial lexical knowledge (e.g., BOUQUET: *b-o-c-u-e-t*; AISLE: *e-i-s-l-e*; SUBTLE: *s-u-b-t-o-l*) and the sublexical application of high probability grapheme to phoneme translation (e.g., ANSWER: *a-n-s-e-r*). Her performance was not influenced by word frequency, imageability, or word length.

Summary

M.R.'s overall performance in oral spelling to dictation is far superior to her oral naming given visual or tactile stimuli. Her difficulty in oral spelling of exception words to dictation cannot be attributed to a general deficit in retrieving letter names, because she had no such difficulty in spelling regular words or nonwords. Her excellent letter naming in oral spelling contrasts sharply with her severely impaired letter naming from print.

Despite her largely preserved ability to pronounce exception words when they were spelled aloud to her, M.R. produced many errors in spelling exception words. These spelling errors often reflected partial lexical knowledge of exception words. Thus, overall, she appeared able to access lexical representations for spelling, but was often unable to maintain these lexical representations during oral spelling. The nature of her errors in oral spelling did not suggest a simple loss of memory for letters in final letter positions, but rather competition from sublexical processing, resulting in responses in which partial lexical knowledge combined with high probability sublexical translations from phoneme to grapheme.

The disparity in M.R.'s performance given exception words across the tasks of oral spelling *versus* pronouncing orally spelled words may reflect one or both of the following mechanisms: (1) slower response speed in the oral spelling task may permit greater interference from sublexical processing, as compared to the faster whole-word response in pronouncing orally spelled words; (2) even incomplete graphemic information may support lexical access when words are spelled aloud (i.e., if the ALIs activated are sufficient to distinguish the target word from its lexical competitors).

Written spelling to dictation

M.R.'s ability to write to dictation was briefly assessed to determine the extent to which she could activate abstract letter identities needed for writing. The same lists of 30 regular words, 30 exception words, and 30 nonwords administered in oral spelling to dictation were administered, and M.R. was asked to listen to each word, to repeat the word aloud, and then to write the word. M.R. produced cursive writing when dictated regular words, and she produced printed words when dictated the nonwords and exception words. In printing, M.R. complained that sometimes even when she knew the correct letter, she had difficulty remembering how to form the letter (e.g., for some productions of *p* or *d* she complained that she meant to write the letter *b*; she spelled YACHT as *v-a-c-h-t* but traced over the *v* several times saying that she knew it was not quite right). This mild to moderate letter formation difficulty likely accounts for her worse performance in written spelling for nonwords (77%) and for exception words (30%) as compared to her oral spelling of the same stimuli, reported above. In contrast, there was no evidence of impaired letter formation during her cursive writing, and she accurately wrote 93% of regular words in cursive. Though we cannot directly compare M.R.'s performance in cursive writing of regular words to her printing of exception words, spelling regularity did appear to affect her writing to dictation just as it influenced her oral spelling to dictation. In many of M.R.'s errors in printing exception words to dictation, partial lexical knowledge was evident (e.g., TOMB: *t-o-o-m-b*), just as it was in oral spelling to dictation. M.R.'s writing of exception words was not influenced by word frequency, imageability, or word length.

Overall summary of assessment

Patient M.R. presents with nonfunctional reading and profound anomia in the context of strikingly preserved ability to pronounce orally spelled words. Her pattern of oral naming performance highlights the value of multimodality naming assessment: Despite M.R.'s profound anomia across many tasks, it is clear that her lexical phonological representations are largely intact when accessed *via* orally spelled words.

M.R.'s profound reading impairment appears to arise from abnormal encoding of prelexical abstract graphemic codes from print, though she is able to encode these graphemic codes via the auditory modality when letters are spelled aloud to her. She is unable to obtain lexical or sublexical activation from print, and her naming of written letters is severely impaired. Unlike many pure alexic patients with impaired letter activation from print (e.g., Behrmann & Shallice, 1995), M.R. is unable to read letter by letter.

Rationale for Treatment

We designed a reading treatment program for M.R. in which we attempted to teach her to read letter by letter. Given M.R.'s success in learning to name trained pictures in the prior picture naming treatment, we hypothesized that she could also learn to name individual written letters. We predicted that if she were able to name written letters consistently, she would be able to read letter by letter by virtue of her excellent ability to pronounce orally spelled words.

Thus, despite the severity of M.R.'s reading and naming impairments, she was a good candidate for reading treatment due to the following attributes: (1) prior success in the picture naming treatment; (2) largely intact memory; (3) an excellent ability to pronounce orally spelled words; (4) a strong desire to read; (5) availability for a consistent schedule of treatment. An obvious limitation of the intended letter naming treatment was that M.R. would learn to name letters presented in a particular font and would likely remain unable to read words printed in an alternate case or font. However, we predicted that even this degree of functional reading had the potential to contribute positively to M.R.'s quality of life. For example, M.R. complained that her alexia caused her frequent social embarrassment, leading her to avoid a number of social situations that she had previously enjoyed. For example, she reported that at social gatherings she was unable to distinguish between two serving canisters, one marked "coffee" and the other "water" (for tea). She remarked that this was a source of great embarrassment to her in that she was always dependent upon others to serve her, rather than being able to serve her friends. M.R. was also unable to read basic safety or warning signs.

Our goal for M.R.'s reading treatment, therefore, was to provide her with sufficient letter naming ability to allow her to read even short written words. We noted that correct naming of even the first letter of a word would be useful to M.R. in some contexts, in that this would be sufficient to allow her to distinguish one written word from an alternative. Training in letter-by-letter reading had the potential to contribute significantly to M.R.'s safety and social adjustment.

With this in mind, we designed a letter naming treatment that simultaneously targeted presumed functional impairment in letter activation from print and in phonological activation of letter names *via* semantics. In contrast to M.R.'s prior picture naming treatment, we did not attempt to target these two loci of impairment separately because we wanted to provide M.R. the best chance of reading improvement during a short time available to us for the treatment. Moreover, we predicted that simply combining visual, phonological and tactile–kinesthetic cues in this treatment would lead to both improved letter activation and improved phonological retrieval of letter names. It was expected that this intervention would address the following experimental questions: (1) Will significant improvement in oral naming be observed for trained letters? (2) Will oral naming improvement generalize to untrained stimuli and tasks, including word reading? (3) What are the theoretical implications of the treatment results?

Treatment

Our goal in M.R.'s reading treatment was not to reconstruct the complex visual word recognition system. Not only was M.R. beyond what some would consider the period of maximal spontaneous recovery or physiologic restitution (e.g., Rothi, 1992), but the disruption of written word recognition was so complete in her case that there was no foothold where treatment at the word level could begin. Instead, we targeted one component of visual word recognition, abstract letter activation; within this, we attempted to restore her ability to access ALIs for letters of one particular font and case so that she could employ the compensatory strategy of letter-by-letter reading.

Experimental stimuli

The experimental stimuli consisted of 24 letters of the alphabet, printed in size 24 bold upper case Geneva font and separated into three sets of eight letters each. Stimuli were matched across set for approximate letter frequency in the written English language (Francis & Kucera, 1982). Two of these sets were designated as the training sets (*Set 1–trained* and *Set 2–trained*), while the third set was to remain untrained. In addition, one set of eight single arabic numerals and one set of eight common symbols (e.g., $, &, #) were included as untrained stimulus sets. Stimuli also included larger strings of letters or numbers (i.e., for each item in the letter sets, a three letter word and a four letter word comprised of letters from that set were selected; for each item in the arabic numeral set, a three digit number and a four digit number comprised of numerals from that set were selected). These words or larger numbers were not trained but were incorporated into probe tasks which were presented as the pretreatment baseline, daily treatment probes, and posttreatment measures: (1) oral naming of written letters, (2) oral naming of written numerals and symbols, (3) oral word reading, and (4) letter sounding (i.e., providing the corresponding sound for a single written letter).

Experimental design

The experimental design was a single subject multiple baseline design across behaviors (McReynolds & Kearns, 1983).

Pretreatment baseline. To verify stable baseline performance in all probe tasks (i.e., oral naming of letters; oral naming of numerals and symbols; oral word reading; letter sounding), four consecutive baseline scores were obtained for M.R. during the 3 to 4 days prior to the initiation of treatment. During each of the three baseline sessions, all 24 letter stimuli, 8 numeral stimuli and 8 symbol stimuli, as well as all three- to four-letter words or numbers were tested across all probe tasks. Baseline accuracy scores were documented for each subset of stimuli (e.g., Set 1–trained) so that any change in performance could be compared across the stimulus subsets.

Daily treatment probe measures. During the treatment phase, each subset of the experimental stimuli was repeatedly presented in the probe tasks. The probe measures were completed at the beginning of each treatment session before training commenced, and the examiner provided no feedback during these probes. The order of item presentation in probe measures was randomized. After the probe was completed, the treatment portion of the session commenced and no further probes were administered until the beginning of the next treatment session.

The items probed at the beginning of each treatment session included the 10 current treatment items. In this way, we were able to measure M.R.'s learning of the trained items from session to session.

Because we also wished to evaluate possible generalization of training to untrained stimuli and tasks, we also included a portion of the untrained items and tasks in the probe at the beginning of each treatment session. Across every four sessions of the treatment phase, we obtained an accuracy score for the eight items of each of the stimulus subsets, and thus we collected ongoing data for each task across stimulus subsets throughout the course of the study.

Treatment schedule. M.R.'s treatment can be described as two experimental phases of letter naming training; the same training procedures were used in both phases. In Phase I of the treatment, one set of eight letters was trained while all other items remained in baseline. Subsequently, a second set of eight letters was trained. The order of item presentation during training was randomized. The treatment portion of each session was approximately 15 min in length, and each treatment item was trained four times per session (including experimental probes in addition to treatment, total session time was 20–30 min). Training continued until reaching an 88% criterion over two consecutive sessions or until 24 training sessions were completed. All sessions were videotaped. M.R.'s treatment schedule included 1 morning and 1 afternoon treatment session each day during the work week, although occasional interruptions to this schedule were required. Thus, each trained set of letter stimuli was trained for approximately $2\frac{1}{2}$ weeks.

In Phase II of the treatment, M.R. received further training on the previously trained Sets 1 and 2 simultaneously, which required her to distinguish target letters from a larger set of 16 letters. During Phase II training, the third set of letter stimuli remained in baseline. All procedures for Phase I were followed in Phase II (i.e., each letter was trained four times per session). However, in Phase II, M.R. was given additional practice trials for some target letters that proved to be particularly difficult for her to name.

It should be noted that at the time of this study, M.R. was a resident in our hospital's nursing home unit, and thus was available for frequent research sessions. Her treatment program could be modified for clinical settings in that daily practice could be provided by a family member or other caregiver, and clinical sessions could be limited to once a week evaluation of progress. In this case, the treatment plan would require only six clinical sessions over the course of approximately 6 weeks.

Scoring and reliability

Throughout the experiment, verbal responses were scored as correct or incorrect. Only the target response was accepted as correct, and all incorrect responses were recorded. Interobserver scoring reliability for correct–incorrect responses was sampled for 30% of sessions. Point-to-point scoring agreement was 100%.

Procedure

The examiner presented M.R. with each letter individually printed on an unlined 7.6 × 12.7 cm index card, asking "What is this called?" M.R. then attempted to respond. If her response was correct, the examiner gave her immediate positive feedback, saying, "Yes, it's a ____." M.R. was then required to trace the letter with her finger while repeating its name three times.[6]

If M.R.'s initial response was incorrect, the examiner immediately said, "No, trace it and then try again." In this case, M.R. was required to trace the letter with her finger one or two times and then to attempt to name the letter again. If her second attempt was correct, the examiner would give her immediate positive feedback as above and M.R. was required to trace and repeat the letter as above.

If M.R.'s second attempt was incorrect, the examiner said, "No, it's a ____." The examiner then traced the letter and described its shape, and M.R. was required to trace the letter with her finger and to repeat its name three times.[7]

Treatment Results

Results: Phase I

Results are displayed graphically and were analyzed using the C statistic, which allows quantitative evaluation of abrupt changes in the level of a time series of data points as well as gradual changes in its slope (Tryon, 1982). As seen in Figure 2, the letter naming treatment resulted in improvement in M.R.'s oral naming of letters for the trained Set 1 (i.e., from 0–13% accuracy at baseline to 75% accuracy in final treatment sessions; $C = .546$, $p < .01$). In subsequent training of Set 2, M.R. demonstrated change in oral naming of trained letters from zero to 25% accuracy at baseline to 88% accuracy in the final treatment sessions ($C = .683$, $p < .001$). It is important to note that M.R.'s naming of Set 2 did not improve until it became the target of treatment, confirming that the change was secondary to treatment.

Results: Phase II

In Phase II training, Set 2 items continued to be trained, now along with Set 1 items; presentation of training items was randomized across the two sets. Despite the larger set of training items, M.R. continued to show improvement in oral naming of training Sets 1 and 2, reaching 88% accuracy across the final two treatment sessions ($C = .413$,

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[6] The relationship of the tactile input systems to visual recognition systems is not clear. However, we incorporated tactile–kinesthetic cues to maximize potential cues during training, and with the hypothesis that M.R.'s knowledge of ALIs activated top-down during writing (demonstrated to be relatively intact in writing to dictation) might assist her in recognizing those ALIs bottom-up in reading.

[7] After the first treatment session, M.R. had decided on her own to try to name written letters without feedback, but had found it very confusing and frustrating. Therefore, we specifically instructed her not to attempt to practice on her own.

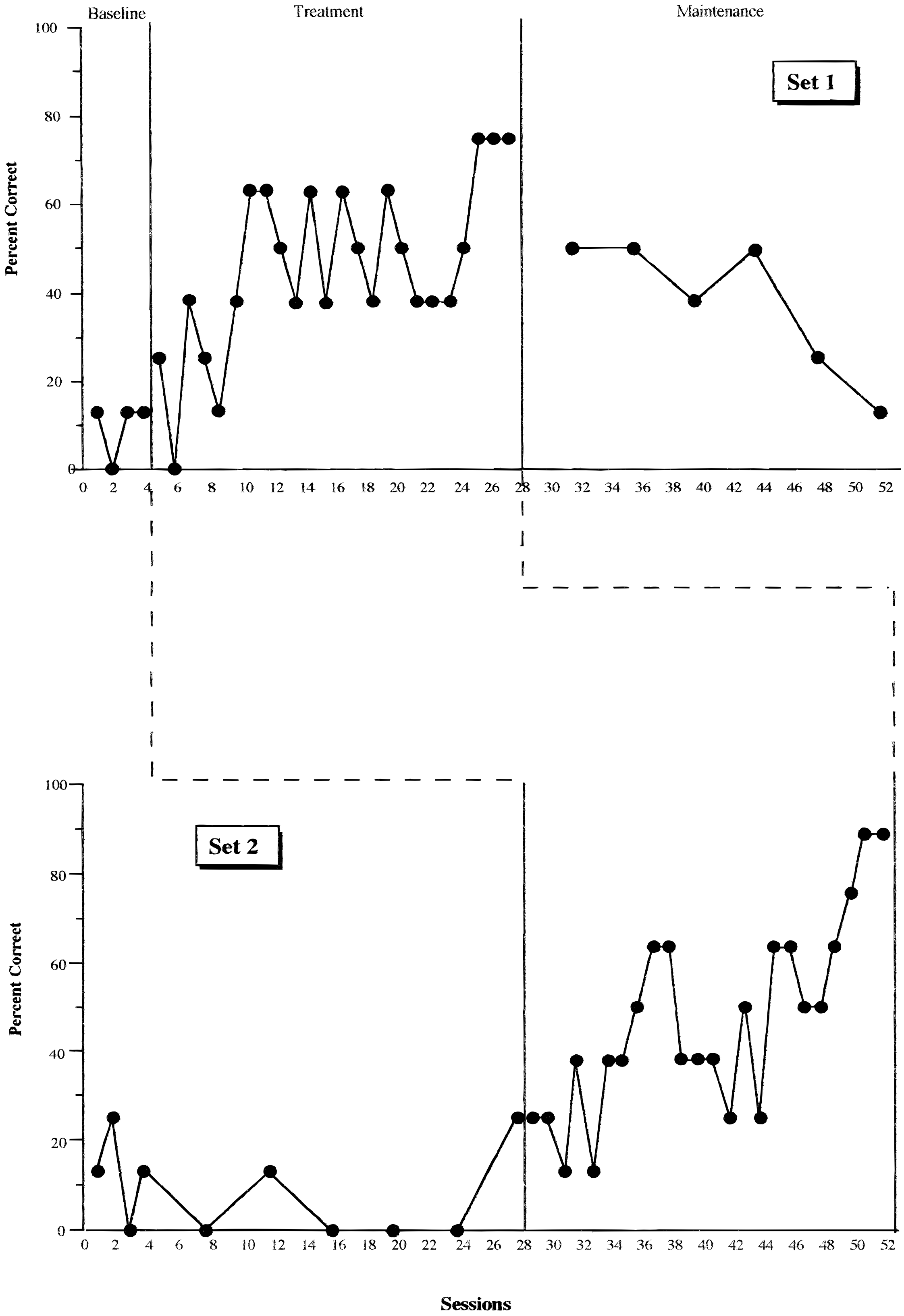

Fig. 2. Proportion correct in naming written letters aloud, for Phase I trained items in Sets 1 and 2. First, Set 1 was trained while Set 2 remained in baseline; subsequently, Set 1 training was discontinued while Set 2 letters were trained.

$p < .09$). M.R.'s performance in oral naming of trained items during Phase II is displayed graphically in Figure 3, along with oral word reading data, as reported in the following section.

Generalization: Phases I and II

Generalization of letter naming treatment to the untrained oral word reading task is depicted in Figure 3. It should be noted that as M.R.'s letter naming improved, she was often able to correctly name the majority of constituent letters in the three- and four-letter words tested, but an error in naming even one letter could result in an incorrect word reading response. For Set 1 words, M.R. read one word correctly during Set 1 letter training, but was unable to read any Set 1 words correctly during subsequent training on Set 2 letters. For Set 2 words, there was no generalization to oral word reading during Set 1 letter training, but obvious improvement in oral reading of Set 2 words (from zero to 56%) during Set 2 letter training. In Phase II, M.R.'s improvement in oral reading of Set 2 words rose to 69% accuracy and reached statistical significance ($C = .733$, $p < .008$, two-tailed). Oral word reading for Set 1 words also improved during Phase II training (from zero to 31% accuracy), but the observed improvement did not contain a sufficient number of data points to be statistically analyzed with the *C* statistic (Tryon, 1982). There was no generalization of Phase I or Phase II treatment to oral reading of words from the untrained letter set.

Further, there was no generalization of treatment to oral naming of arabic numerals or written symbols. There was a trend toward improvement in letter sounding for Set 2 letters during Set 2 letter training, which did not reach statistical significance ($p = .08$). In the letter sounding task, M.R. reported using a strategy of attempting to name the written letter first before attempting to retrieve its corresponding sound.

Letter naming treatment also resulted in generalization of M.R.'s naming improvement to settings outside the clinic. During Phase II treatment, we observed M.R. spontaneously attempting to read signs in the hospital corridors with some success. She also reported that she had read several product labels and name tags correctly.

Follow-Up

One week following the end of letter naming treatment, M.R. maintained her high level of success in letter naming and in reading aloud the words from Sets 1 and 2, though word

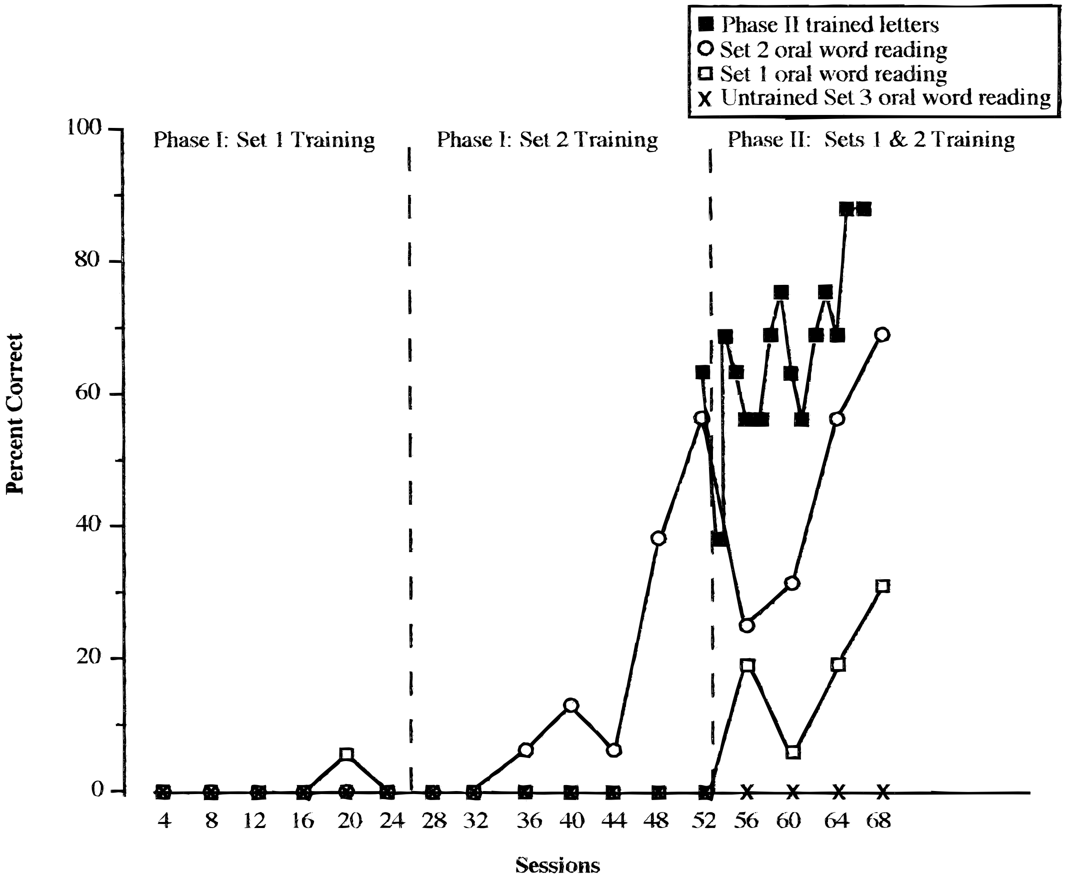

Fig. 3. Generalization of letter naming treatment to the untrained oral word reading task during Phases I and II. Improved naming of trained letters in Phase II is also shown.

reading was never directly trained. Approximately 6 to 12 months after the current study was completed, a separate group of investigators observed that, despite M.R.'s excellence in pronouncing orally spelled words, her visual imagery of spoken letter names was impaired (Shuren et al., 1996). Unfortunately, that additional report does not provide follow-up data for our reading treatment study, because the reading data reported there are based only upon reading of lower case letters (which M.R. was unable to read), rather than the upper case letters M.R. learned to name in the reading treatment. However, one possible result of our treatment observed in that additional report is that when M.R. was asked to write letters to dictation, she wrote 88% of upper case letters correctly, but only 46% of lower case letters (for which 71% of her errors involved writing the letter in upper case). Also, at that time M.R. no longer demonstrated difficulty in letter formation during written spelling, possibly one result of her extensive practice in pairing letter names with tracing of their written shapes during our treatment.

Summary of Treatment

In this study, we attempted to teach M.R. to name written letters aloud with the prediction that this training would allow her to read letter by letter by virtue of her excellent ability to pronounce orally spelled words. M.R.'s profound anomia was sensitive to this intervention, and she demonstrated significant improvement in oral naming of trained letters. As predicted, her improved oral naming of written letters resulted in significantly improved ability to read written words, which she accomplished in letter-by-letter fashion. M.R. was observed to use this new letter-by-letter reading ability functionally outside the clinical environment.

DISCUSSION

This letter naming treatment for Patient M.R. demonstrates that even severely impaired letter activation and letter naming are sensitive to intervention. Cognitive neuropsychological assessment of M.R.'s cognitive abilities directly motivated this reading treatment based upon her retained ability to pronounce orally spelled words. Therefore, her prognosis in this treatment was not based upon the severity of her general reading disorder (she read no words pretreatment), but on the specific type of her impairment to the reading system. More superficial assessment of M.R.'s naming and reading might have led to the conclusion that her multimodality anomia was too profound to support any manner of oral reading.

The results of this study suggest that other patients with a similar pattern of spared and impaired cognitive function may benefit from a similar treatment. For example, pure alexic patients with poor letter naming may gain some functional reading if they can be taught to read letter by letter, assuming that they have retained the ability to combine abstract letter identities in the correct order (i.e., as in pronouncing orally spelled words). Pure alexics who already read letter by letter may benefit from letter naming treatment to make their use of this reading strategy more efficient (Nitzberg-Lott et al., 1994). An alternative approach to treating these letter-by-letter readers is to attempt to reduce reliance on this inherently inefficient strategy and to encourage reliance on residual whole-word reading ability. This approach has been variously successful (Gonzalez Rothi & Moss, 1992) or unsuccessful (Rothi et al., 1997), and logically its success would largely depend on the amount of residual whole-word reading capacity available to the individual patient. Patient M.R. represents an extreme impairment of prelexical processing in that she had no residual reading and no ability to read letter by letter. The results of this study suggest that patients with impairments this severe nevertheless have the potential to regain functional reading.

On a practical level, what would it take for a patient like M.R. to become a more efficient letter-by-letter reader? We have already noted that M.R. retained her high level of success in naming trained letters and in letter-by-letter reading for more than 1 week following the end of treatment. We also observed that it was detrimental for her to attempt to practice letter naming on her own with no feedback, because she could not be sure of the correct letter names and consequently became confused. However, if M.R. received practice with feedback (either from a caregiver, friend or a computer program) for even 15 min 1 or 2 times per week, it is likely that she would retain her ability to name letters. Although this small amount of practice in naming the letters of the alphabet may seem trivial in some ways, in fact for a patient like M.R. it could represent the difference between a life with some functional reading or a life of illiteracy. If M.R. were to receive additional training on letters in other cases or fonts, it is possible that she could also learn to name those letters and to retain that learning over time. This letter naming program is one type of language treatment for which computer feedback during practice would seem to be a highly promising option.

The results of M.R.'s treatment study have theoretical as well as practical implications. Although much current reading research focuses on the syndrome of pure alexia and its underlying causes (e.g., Behrmann et al., 1997a), the precise mechanisms underlying letter-by-letter reading remain unclear. For M.R., the ability to pronounce orally spelled words is virtually the *only* spared word naming ability—and when she learns to name a few written letters, she immediately and easily translates those letter names into a whole-word response. Given the severity of her overall deficits, it is unlikely that in letter-by-letter reading M.R. is using any translation procedure other than the same one that allows her to pronounce orally spelled words so easily. We know of no evidence that letter-by-letter reading involves a mechanism separate from pronouncing orally spelled words; possible evidence could arise if a patient were able to read letter by letter but was not able to pronounce orally spelled words (although in this case, other damage such as auditory processing impairment would have to be ruled out). The hypothesis that these two letter processing tasks involve the same underlying mechanism also receives support from the performance of Patient D.E.S. (Greenwald & Berndt, 1997), described in the Introduction. D.E.S.'s inability to read letter by letter is best described as another by-product of her specific deficit at the level of the Ordinal Graphemic Code, a deficit that also severely disrupted her ability to pronounce orally spelled words.

Finally, the case of M.R. highlights the value of incorporating the task of pronouncing orally spelled words into cross-modality naming assessments, in that performance in this task can allow deficits of phonological loss to be distinguished from deficits of phonological access. Interestingly, M.R.'s pattern of naming performance lends support to the hypothesis that the ability to pronounce orally spelled words can be accomplished without semantic mediation, as demonstrated in the performance of the severely aphasic Patient R.E. (Greenwald & Berndt, 1998). Although based upon the data in the current paper we cannot argue strongly that M.R.'s ability to pronounce orally spelled words occurs with little or no semantic mediation, it is clear that this retained ability is not affected by M.R.'s general impairment in accessing lexical phonology *via* semantics. In comparison to her impaired oral naming in spontaneous speech, naming to auditory definitions and across many input modalities, it does appear that M.R. requires relatively less semantic activation for accurate pronunciation of orally spelled words. Further work can examine these differences across tasks in other anomic patients.

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