Clinical Diagnosis and Treatment of Reading Disorders

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ASSESSING THE UNDERLYING COGNITIVE DEFICIT

The activity of reading depends upon the integration of many component processes, both linguistic and visual. Thus there are many different ways for reading to break down following injury to the brain. A thorough assessment of reading begins with an examination of elementary visual processing, and proceeds through analyses of orthographic, phonologic, and semantic processing of single written words, to a final assessment of reading comprehension of text.

Visual Processing

Neglect

In searching for the cause of a patient’s reading deficit, one must first ensure that the problem is not of a purely perceptual nature. That is, it is important to ascertain that the written letters are being perceived properly. One phenomenon that may interfere with the visual perception of the letters of a word is visual (hemispatial) neglect (Kinsbourne & Warrington, 1962). Since hemispatial neglect is usually associated with lesions of the right hemisphere, it most commonly has its effects on the left half of stimuli or stimuli that appear on the left side of the reader’s body or field of vision (see chapter 1 of this book, for discussion of various types of hemispatial neglect, and how they affect reading). Left-handed (and occasionally right-handed) patients with left hemisphere lesions may show right neglect, affecting only the ends of words. If the patient shows a tendency to make errors at the beginnings (or ends) of words, and neglect is suspected, the patient should be asked to read words that are presented vertically; that is, top to bottom rather than left to right. If the problem is one of viewer-centered or stimulus-centered neglect, errors will not predominate at the beginnings (or ends) of vertically presented words. However, if the problem is object-centered neglect, the patient will continue to make errors on the neglected side of the “canonical” orientation of the word (for example, the initial letters in patients with left neglect dyslexia).
Selective Attention Deficit

Patients with impaired selective attention may have difficulty segregating words from other words in space. As a result, letters tend to "migrate" from adjacent words (Shallice & Warrington, 1977). There is no specific test for this deficit, other than being aware of the possibility that letter intrusion errors may have their source in neighboring words. Thus, when single word reading appears to be intact, yet text reading is impaired, it is worthwhile to carefully examine the patient's text reading for such intrusion errors from neighboring words.

Letter Knowledge

Naming and Pointing to Letters Named

As an initial test of letter knowledge, individual letters—both upper- and lowercase—should be presented to the patient for naming. The ability to attach a letter's name to its physical form is a good indication that knowledge of the letter's identity remains intact. However, failure to name letters may reflect a problem with word retrieval, not letter identification. Patients who fail to name letters accurately should be given a sheet of paper upon which all twenty-six letters are scattered. The patient is asked to point to each letter as the therapist names it. Success at this task demonstrates that a letter's form is still associated with its name, even if the patient cannot retrieve that name.

Identity

Even if a patient can no longer associate the names of letters with their shapes, it might still be possible to demonstrate intact knowledge of letters' abstract identities. This can be done with a cross-case matching task. Two letters, one uppercase and one lowercase, appear together, and the patient is asked to determine whether or not they represent the same letter. Patients who can perform this task, even for letters with different upper- and lowercase shapes (for example, Rr), retain information about the letters' identities. This is important, as it is letters' identities, and not necessarily their names, that are the foundation of successful reading in most situations.

Recognition

The simplest level of letter knowledge is recognition: that is, knowing that a particular written symbol is an actual letter of the alphabet. One easy way to test for this knowledge is with a forced choice task in which the patient must distinguish correct letters from mirror-reversed letters. This task does not require explicit identification of letters, only recognition of the correct shapes of real letters of the alphabet. Patients who cannot perform this task adequately are not likely to be good candidates for alexia treatment.

Integrity of Orthographic Representations

Lexical Decision

Difficulty accessing the correct internal orthographic representation of a written word may be revealed with a lexical decision task in which the word and nonword stimuli are carefully
chosen. The real words should include words with regular spelling-to-sound correspondences—for example, *mint*—and words with irregular spelling-to-sound correspondences (orthography-to-phonology conversion)—for example, *pint*. The nonwords should include pseudowords that are homophonic with real words—for example, *sope*. Patients whose orthographic representations are not adequately activated tend to read all letter strings as they would be pronounced according to spelling-to-sound rules. Hence, they will have difficulty with such a lexical decision task. They will incorrectly accept the pseudohomophones (for example, *sope*) as being real words, because they sound like real words when pronounced; and they will incorrectly reject irregular words as being nonwords, because they do not sound like real words when pronounced according to spelling-to-sound rules (“/pInt/; that’s not a word”).

**Homophones**

A second means of assessing inadequate orthographic activation, related to the above lexical decision task, is a homophone definition task. The task is to present words that have homophones (for example, *oar, whole*) one at a time, and ask the patient to both read and define the words. Patients who are relying on the phonologic code derived from the orthography, rather than the orthographic representation itself, will have no way to distinguish *tacks* from *tax*, or *pray* from *prey*. This will be manifest in the patient’s reading the word correctly, but defining it as its homophone (for example, defining *tacks* as money collected from people by the government).

The reliance on orthography-to-phonology conversion, resulting in better reading of regular words than irregular words and poor homophone comprehension, is commonly known as surface dyslexia. Surface dyslexia often results from impaired activation of orthographic representations (or impaired access to the orthographic lexicon), but may also result from damage at the level of the semantic system or at the level of accessing phonological representations for output. That is, any impairment in using the “lexical route” (orthographic representations → semantic system → phonological representations) to read can necessitate reliance on orthography-to-phonology correspondence to read aloud (see chapter 1 of this volume for illustrative cases).

**Access to the Lexicon through the Visual Modality**

Orthographic representations may remain intact, and other aspects of lexical knowledge may remain intact as well, in patients whose reading is impaired because they cannot access that knowledge through the visual modality. In these patients, whose reading disorder is known as pure alexia (or “alexia without agraphia,” or “letter-by-letter reading”), the integrity of orthographic representations can be demonstrated through intact spelling or through intact recognition of orally spelled words. These patients often spontaneously compensate for their deficit by naming each letter of the word aloud or silently, which often allows them to recognize the word (hence “letter-by-letter reading”).

**Length Effect**

Not all patients with pure alexia show outward signs of letter-by-letter reading. A second means of assessing difficulty with processing whole words as single units (or accessing the orthographic lexicon) is to examine for an effect of length on reading accuracy and/or reading speed. Patients should be asked to read a list of words that vary systematically in letter length. Words should be matched for frequency and part of speech across length, and should range from three letters to at least eleven letters. Substantial differences in accuracy as letter length increases is diagnostic of difficulty with accessing the orthographic representation. A more
sensitive means of assessing length effects, for patients whose accuracy is high given unlimited
time, is to look for increasing time required to read longer words. One way to do this is to create
lists of words of different lengths, ten words to a list, and time the patient’s reading of each
list. While normal readers will show a slight increase in time to read longer words, simply because
longer words take more time to articulate, patients with a whole word processing or lexical
access deficit will require considerably more time to read the lists with the longer words.

Spelling

A patient’s writing and spelling will likely be assessed as part of a comprehensive aphasia
battery. For the purposes of demonstrating intact orthographic representations in the face of
inability to access these representations visually, patients should be asked to write or orally
spell words and pseudowords (PWs) that she or he has been asked to read (preferably in a
separate testing session). Most patients with an alexic disturbance will perform more poorly on
spelling than reading. Patients with pure alexia will show the opposite pattern: relatively better
spelling than reading.

Recognition of Orally Spelled Words

Another means of ascertaining intact orthographic representations in a patient who cannot
access these representations visually is to spell the words aloud to the patient, one letter at a
time. Again, words and PWs that the patient has been asked to read should be used for this
task. Words should not be so long as to exceed a normal verbal short-term memory span
(approximately seven letters). Patients with pure alexia will perform normally on this task,
recognizing words without regard to part of speech, and PWs as well. Importantly, perform­
ance on this task will exceed performance on reading these same words for pure alexic
patients (or patients with damage to any component of visual processing of words, such as
most forms of neglect dyslexia), but not for patients with damage to the reading process at a
level beyond access to the orthographic lexicon.

Phonologic Processing

Reading Pseudowords

To evaluate the ability to access the phonology of written letter strings without regard to
semantic processing, patients should be asked to read pseudowords; that is, orthographically
legal, pronounceable nonwords. The key to identifying a phonological processing deficit is
demonstrating that PW reading is not just impaired, but is actually worse than real word
reading. It is recommended that a list of pseudowords be created from a list of real words, by
changing a single letter from each of the real words. Difficulty reading the PWs in the list far
exceeding any difficulty reading the real words in the matched list indicates a disturbance in
orthography-to-phonology conversion or other phonological deficit (see below). This is never a
modality-specific problem: a PW reading deficit seen for written words will also be apparent if
PWs are spelled aloud to the patient.

Pseudoword Repetition

Impaired PW reading may reflect a deficit that is specific to reading, or it may be part of a
more general phonological processing deficit. The most sensitive means of testing this is to ask
the patient to repeat multisyllabic pseudowords. Impaired performance on this task suggests a
general phonological processing deficit (for example, holding the sequence of phonemes in phonological short-term memory). Additionally, such a deficit may be picked up by asking patients to read and repeat real words of increasing syllable length and phonological complexity.

**Digit Span**

Patients with reduced short-term phonological memory may experience difficulty reading text, while showing little deficit in reading individual words. This disorder, termed phonological text alexia, is accompanied by difficulty reading PWs. To assess a patient’s ability to hold multiple phonological codes in short-term memory, variations of a standard digit span test, such as that contained in the Wechsler Memory Scale, should be administered. This includes normal digits forward and backward, single noun span, single functor word span, and single PW span.

**Semantic Representation**

**Word-picture Matching**

The most direct method of testing access to semantics from the written word (that is, comprehension of written words) is to use a word-picture matching task. A written word is presented, along with an array of pictures, one of which corresponds to the written word. The required response is to point to the picture corresponding to the word; no verbal output is required. Foils may be pictures that are unrelated to the target; this allows the patient to choose the correct picture even if she or he has access to incomplete semantic information about the word. To increase the difficulty of the task by requiring the patient to have more precise information about the word’s meaning, picture foils should be chosen from the same superordinate category as the target.

**Other Semantic Tasks**

Milder impairments of semantic processing may affect only words of low imageability, or abstract words. Such semantic impairments may not be picked up with the word-picture matching task, which, by the nature of the task, uses only words that are high in imageability (that is, they are picturable). Other semantic decision tasks may be helpful in these instances. One such test is the odd-man-out test. Three words are presented (for example, faith, belief, anger), and the patient must point to the word that does not belong with the other two words. Alternatively, the patient may be asked whether the referent of a written word belongs to a particular category (for example, Is the word sadness an emotion?), or whether two written words are similar in meaning.

**Concreteness Effects in Oral Reading**

When semantic processing is impaired concurrently with phonological reading, the result may be an effect of concreteness in oral reading. Words with less stable or accessible semantic value—that is, words of lower concreteness—are read more poorly than words of high concreteness. To test for this effect, patients should be asked to read a list of words, half of which are high in concreteness and half of which are low in concreteness. High- and low-concreteness words should be matched for frequency and length. A significant advantage for reading highly concrete words is consistent with an impairment in semantic reading, although concreteness effects may also occur as a result of damage at different levels of processing, for different reasons, as discussed by Elaine Funnell in chapter 10 of this volume.
Semantic Paralexias

The production of a word that is related in meaning to the target word (for example, *dog* read as "cat") is known as semantic paralexias. Such errors sometimes reflect semantic processing that is close but not quite accurate. For instance, these errors may occur when the incorrect semantic representation is activated from the written word, or when an impoverished semantic representation is activated. However, they also sometimes occur as a result of difficulty accessing the correct phonologic representation of the word from the correct and intact semantic representation. One may attempt to tease apart these possibilities, using a two-step procedure (Friedman & Perlman, 1982). First, the patient is asked to read a written word aloud. Next, she or he is presented with an array of four pictures, and is asked to point to the referent of the word. The foils are all highly semantically related to the target. It is hoped that if the patient produces a semantic paralexia when reading the word, the referent of that paralexia will be among the picture foils. If it is, the patient’s picture choice provides the clue needed to determine the source of the semantic paralexia. If the patient points to the correct picture, despite having read the word incorrectly, the conclusion is drawn that the paralexia was the result of an impairment in accessing the target phonologic representation from the correct semantic representation. If the patient points to the picture that corresponds to the paralexic error that she or he produced, it is concluded that the paralexia represents inaccurate activation of the semantic representation. Note that it is not always easy to choose the appropriate foils, as one has no way of knowing in advance what semantic paralexias are likely to be produced. Thus, the successful use of this two-step task is partly dependent upon wise prognostication and partly upon chance. Often, though, a patient who makes a semantic paralexia (for example, *dog* → "cat") will be willing to point to any semantically related picture (for example, cat, horse, fox). Such patients are likely to have accessed an impoverished semantic representation (see chapter 1 of this book for discussion). An alternative method for evaluating access to semantics in the presence of semantic paralexias, in patients with adequate speech production, is to ask the patient to define the word that he or she just read aloud. For example, patient RGB (see chapter 1) read aloud *red* as "yellow" but defined it as "the color of blood." He apparently accessed an intact semantic representation, but then activated the incorrect phonological representation for output.

Patients who make semantic paralexias in reading often are observed to also show several other features of reading: a concreteness effect, impaired orthography-to-phonology conversion (with difficulty reading PWs), grammatical word class effects (nouns read better than verbs or functors), and morphological errors (for example, *write* → "wrote"). This collection of characteristics has been labeled "deep dyslexia." However, the label does not pin down the level of disruption in the reading process, since (as just discussed) semantic paralexias may arise at the level of semantics or at the level of access to the phonological output lexicon. Furthermore, some of these features have been observed in patients who do not produce semantic paralexias. For example, selective impairment in orthography-to-phonology conversion, with predominantly impaired PW reading, occurs without the other features; this pattern of performance has been labeled "phonological dyslexia." Most patients with deep dyslexia, and some patients with phonological alexia, exhibit selective difficulty reading functors, and these patients may or may not show an advantage of nouns over verbs. Thus, understanding what component processes are impaired in an individual patient, based on convergence of evidence from error types, parameters that do and do not affect reading (for example, word class, concreteness, frequency, word length), and performance across various reading and semantic tasks, is more useful than applying a label.
Part of Speech Effects

Difficulty reading words of certain form class can be uncovered by asking the patient to read a list of words that have been created specifically for this purpose. The list should contain nouns, verbs, adjectives, and functors (prepositions, conjunctions, pronouns, auxiliary verbs). Words of the different form classes should be matched for letter length. It is difficult to match for frequency, as functors tend to be higher in frequency than other words. However, one should at least ensure that all nonfunctor words are as high frequency as possible. Results should be scored for accuracy of reading words of the different classes.

The finding of a part of speech effect has typically been interpreted in a manner similar to that of the concreteness effect, with which it is commonly associated. That is, functors are not as strongly represented within the semantic lexicon as nouns are, and hence are less likely to be accessed in reading by the “lexical-semantic route,” particularly if there is an impairment within the semantic lexicon. However, selective impairment in accessing one grammatical class of words (for example, nouns or verbs) can also occur as a result of damage at the level of the phonological lexicon. In such cases, the patient reads aloud and orally names one class of words (say, verbs) poorly, but has no trouble comprehending written verbs or in written naming of verbs (see chapter 7, by Doriana Chialant, Albert Costas, and Alfonso Caramazza, in this volume, for illustrative cases and discussion). Furthermore, a part of speech effect may be the result of a syntactic processing deficit, particularly when the effect is seen solely within the context of text reading, a phenomenon that has been called phonological text alexia (Friedman, 1996). When a part of speech effect is seen in reading, one should always evaluate it within the context of the patient’s speech: the deletion of functors (agrammatism) likely indicates a grammatical processing deficit.

Morphologic Paralexias

Closely tied to the part of speech effects seen in certain alexic patients is the phenomenon of the production of morphologic paralexias (also called derivational paralexias). These errors typically involve the substitution of one affix for another (for example, lovely for loving), or simply the deletion or addition of an affix (for example, play for playing). As with errors on functor words, morphologic paralexias are often attributed to a deficit in accessing phonology directly from orthography; the semantic pathway is simply unable to deal with these semantically weak morphemes. However, these errors may also be seen as orthographic errors; that is, errors in which the word produced is similar in spelling to the target word (and thus may occur as a result of hemispatial neglect or other visual processing deficit). Likewise, these errors may be seen as semantic paralexias; the meaning of play is certainly semantically similar to the meaning of playing. And, as with the part of speech effect, morphologic errors may be a reflection of a more pervasive grammatical problem.

As with all types of paralexias, it is difficult to devise a task specifically to elicit these errors. It is even more problematic to assess their prevalence, as it is difficult to know how many of such errors one should expect for a given set of words. One is best advised to include words with different affixes in a list of words presented to the patient, and to keep track of such errors (including additions of affixes to nonaffixed words) in all lists of words that the patient is asked to read. For details on how one might assess morphological errors in reading, see Badecker and Caramazza (1987).

Sentence and Text Reading

It is clearly the case that most patients who have difficulty reading single words will have difficulty reading text, although some patients may read text more accurately due to the
contextual cues provided by the text. However, it is more common to encounter a patient who complains of difficulty reading text yet appears to have no difficulty reading single words. This dissociation may be a reflection of grammatical difficulties, and can be examined by presenting sentences of increasing grammatical complexity. Difficulty with text reading may also be caused by hemispatial neglect or other visual processing/eye tracking impairments, or phonologic processing deficits (which may result in increased difficulty with increasing sentence length). To determine the extent to which reading comprehension deficits truly reflect a problem specific to reading, it is important to compare reading comprehension of sentences and paragraphs with auditory comprehension of comparable sentences and paragraphs.

**CLINICAL ASSESSMENT TOOLS**

The previous section of this chapter suggested ways to assess those aspects of reading that are most likely to be disturbed in patients with acquired alexia. Here, we review some of the best known of the clinical assessment tools that may be useful in performing such an evaluation.

**Psycholinguistic Assessment of Language Processing in Aphasia (PALPA),** by Kay, Lesser, and Coltheart, 1992

This test of language function contains the most comprehensive assessment of reading function that we are aware of in a published test. The PALPA contains sixty subtests, many of which are devoted to written language processing. Each subtest has normative data, clear descriptions of the parameters being assessed, and well-organized answer sheets for efficient data analysis. A large number of the assessments discussed in the previous section are represented in the PALPA in some manner.

One disadvantage to using the PALPA is that it was normed only for British English; thus, some of the items are not appropriate for speakers of American English (for example, pram, hosepipe). Another potential disadvantage is the brevity of the word lists. This is desirable as a screening for potential deficits, but is somewhat inadequate for definitive affirmation of the presence of a particular deficit. Longer lists controlled for various parameters such as grammatical word class, word length, frequency, concreteness, and regularity are found in the Johns Hopkins University Dyslexia Battery (Goodman & Caramazza, 1986; published with permission in Beeson & Hillis, 2001).

**New Adult Reading Test Revised (NART), by Blair and Spreen, 1989**

This is the American version of the National Adult Reading Test (Nelson, 1982; Nelson & Willison, 1991). This test was designed as measure of premorbid IQ in patients with dementia. It consists of sixty-one words with irregular spelling-to-sound correspondences. The words in the test are arranged so as to decrease in word frequency, making the later words less likely to be read correctly than the earlier words. This test may be a useful source of irregular words, if surface alexia is suspected. However, the number of irregular words that a reader of normal IQ would be expected to read correctly is rather limited, which limits the usefulness of the test.

**Gates-MacGinitie Reading Tests, by Gates and MacGinitie, 1965**

This test was designed to assess single word comprehension, comprehension of short paragraphs of increasing difficulty, and speed and accuracy of reading one- to two-sentence paragraphs. The single words were not chosen on the basis of any psycholinguistic parameters, and so this part of the test is of little practical value. The speed and accuracy subtest evaluates
accuracy by asking the subject to choose one of four written words that best completes a statement based on the short paragraph. It assesses speed by measuring how many such paragraphs can be completed in four minutes. This subtest, and the slightly longer paragraph subtest, can be useful in assessing oral reading and reading comprehension of text. As there are alternate forms of the test, it is also useful for comparing reading comprehension to auditory comprehension.


The original RCBA was designed to assess functional silent reading. Added to the second edition are tests of letter knowledge, lexical decision, and oral reading.

There are several letter knowledge tasks contained within the RCBA-2. At the simplest level, perceptual processing is assessed with a physical matching task; the subject decides whether two uppercase letters are identical or not. Tests for neglect are incorporated into a test of letter naming and a test of pointing to the letter named. There is no assessment of letter identity (cross-case matching), nor mirror-image recognition.

In the lexical decision task, the subject is asked to choose the real word from among a triad of one word and two pseudowords. The PWs are not created to be pseudohomophones of real words, and the real words are not chosen to assess regularity; thus this test will not be adequate to completely determine the integrity of orthographic representations.

Single word comprehension is assessed with a word-picture matching task, in which a single picture must be matched to one of three words, which are either orthographically similar, phonologically similar (and possibly orthographically similar as well), or semantically similar. A synonym matching task is included as well. There is also an assessment of "functional reading," which includes different formats such as labels, signs, and entries in phone books.

Oral reading of single words is assessed for nouns only. Oral reading of sentences is assessed for sentences of subject-verb-object structure only. The effect of context is incorporated into this task by including words from the single word oral reading task.

In a sentence comprehension task, the subject chooses one of three pictures that corresponds to a written sentence. In one subtest, the sentences are chosen to assess morphosyntactic reading. Another task tests short paragraph comprehension. Longer paragraphs are presented for comprehension in a test containing both factual and inferential questions.

Gray Oral Reading Test, Third Edition (GORT-3), by Wiederholt and Bryant, 1992

The GORT-3 was designed for use with school-age children. It assesses oral reading, identifies reading strengths and weaknesses, and is used to document reading progress and as a research tool for studying reading abilities in school-age children. The test consists of two alternate, equivalent versions, each consisting of thirteen increasingly difficult passages, which are each followed by five multiple choice questions. The test evaluates oral reading rate, accuracy, and comprehension, total oral reading ability, and oral reading miscues.

Rate is measured in terms of time to read each passage. Accuracy is measured in terms of number of oral reading errors. The two scores are then added to compute the passage score. Multiple choice questions are used to assess comprehension. The examiner reads aloud the question and response choices while the examinee reads along. The total number of correctly answered questions is the comprehension score. Total oral reading ability is computed by combining the passage score and the comprehension score into the oral reading quotient.

The passages were written to control for a variety of features of words and sentences.
Vocabulary was chosen from three published word lists that were based on school textbooks. Content is general, and not academic in nature. The authors did a good job of altering vocabulary in the comprehension questions so that the examinee cannot simply match words in order to choose the correct answer. Many of the questions require subjective interpretation of the passage and, therefore, do not strictly assess linguistic abilities.

Boston Diagnostic Aphasia Exam (BDAE), Revised, by Goodglass and Kaplan, 2000

The BDAE contains several subtests of reading that may be of some use in evaluating possible alexias. Reading test A1 requires the patient to match single letters and short words across case and font. This test of letter identity contains too few items to make any real determination about the patient's abilities in this area; poor performance would certainly suggest a problem, but success on these few items would not necessarily mean that competence has been demonstrated.

Also included in the BDAE are subtests dealing with morphology. One advantage of these subtests is that they do not require the patient to produce verbal output; a word is spoken by the examiner, and the patient points to the corresponding word, from a multiple choice list. Included are functors and words with bound grammatical and derivational morphemes. However, performance on these items is not compared with performance on nongrammatical words, making it difficult to identify a relative deficit for grammatical words. Further, as this is a screening test of reading embedded within a much larger language test, the number of items are insufficient to be sensitive to milder problems.

TREATMENT OF THE ALEXIAS

Controlled studies of treatments for the alexias have only recently begun appearing in the scientific journals. This appears to have followed directly from the development of cognitive neuropsychological models of reading and reading disorders. Prior to the 1970s, alexic disorders were not well differentiated (aside from pure alexia), and so clinical treatments did not take into account the nature of the specific deficit. The identification of various types of alexias, such as surface alexia and phonological alexia (Marshall & Newcombe, 1973), changed the way that many speech-language pathologists considered remediating reading. The current trend, then, is to identify the specific cognitive deficits that underlie the reading problem in an individual patient, and to devise a treatment program accordingly. A description of some of the treatment studies that have been published in the last two decades follows.

Treatment for Letter Recognition Deficit in Pure Alexia: Tactile-Kinesthetic Approach (Greenwald & Gonzalez Rothi, 1998; Kashiwagi & Kashiwagi, 1989; Lott, Friedman, & Lincbaugh, 1994; Lott & Friedman, 1999; Maher, Clayton, Barrett, Schober-Peterson, & Gonzalez-Rothi, 1998)

As mentioned above, patients with pure alexia may recover some reading function by learning to read in a serial letter-by-letter fashion. Use of letter-by-letter reading may be taught by the therapist (see, for example, Daniel, Bolter, & Longs, 1992), though it is often discovered by the patients themselves. However, some patients with pure alexia also have difficulty recognizing individual letters. If letters are misidentified, it follows that the word in which they are contained will be misread. A fairly successful remedy for this problem involves tactile-kinesthetic (T-K) letter identification.

The rationale for this technique is straightforward. Because the deficit in pure alexia is one of access to the orthographic lexicon when stimuli are presented in the visual modality, the
T-K technique is designed to provide a means for accessing orthographic lexical representations through other modalities—tactile and/or kinesthetic.

In a typical T-K treatment, the patient is first trained to recognize single letters in isolation. A letter is presented on a computer screen or an index card, and the patient is asked to trace or copy the letter, and then to name it. If the letter is copied onto the table or a piece of paper, as in the Maher et al. (1998) and Kashiwagi and Kashiwagi (1989) studies, only kinesthetic feedback is obtained. If the letter is copied onto the palm of the patient's other hand, as in the Lott et al. (1994) study, the patient receives both tactile and kinesthetic feedback. Once the patient has mastered single letter recognition, training proceeds to whole words, and eventually to sentences.

After the patient's accuracy of letter-by-letter reading has reached an acceptable level, training can next be geared toward improving speed of reading. Lott and Friedman (1999) employed a three-stage approach, which focused first on single letter naming. The patient was encouraged to use the T-K strategy to name letters aloud as rapidly as possible. Feedback regarding speed of letter naming was provided to the patient after every block of trials, and training continued until the patient's speed reached a plateau. The next phase involved the naming of letters in a letter string. This stage was inserted prior to the word reading stage, so the patient would develop the habit of naming every letter in a string prior to attempting to read a word. The final stage was single word reading. As before, the patient received feedback about his speed, and was encouraged to try to do better on successive blocks. The result of this treatment was substantial improvement in reading speed, with no sacrifice in accuracy.

Treatment for Impaired Whole Word Recognition in Pure Alexia: A Semantic Approach (Friedman & Lott, 2000; Gonzalez Rothi, & Moss, 1992; Maher et al., 1998)

It has been reported that some patients with pure alexia may be able to recognize words as wholes if the words are presented rapidly (Coslett & Saffran, 1989; Shallice & Saffran, 1986). The explanation for this finding is that a secondary reading system, based upon semantics, is available to the patients but only becomes available when the patient is prevented from employing a letter-by-letter reading strategy. It has been suggested (Coslett & Saffran, 1989) that patients can be trained to employ this alternate reading mechanism by presenting words tachistoscopically and focusing on tasks that emphasize semantic processing, such as category decision or other semantic judgments. This notion has been put into practice in several treatment studies.

Gonzalez Rothi and Moss (1992) used the semantic approach in treating the reading deficit of a patient with pure alexia using three separate tasks, all of which made use of tachistoscopically presented written words. The homophone task required the patient to determine whether a written homophonic word (for example, reign) matched the meaning of the word in an orally presented sentence (for example, "She will reign"). In the semantic decision task, the patient determined whether a written word was a member of an orally presented semantic category. The third task was a lexical decision task. Results revealed improved accuracy for the stimuli presented in all three tasks. Reading of untrained words showed some improvement in speed, but not accuracy. The authors report some success with this approach in one subsequent case, but failure in another case.

Further investigation of the training of whole word reading (Friedman & Lott, 2000) suggests that focusing on semantic processing may not be necessary for this strategy to be successful. Using 50 msec presentations of words, presented over many sessions with feedback, these investigators were able to train a patient, RS, to make accurate semantic judgments for trained but not untrained words. However, their patient also learned to recognize rapidly presented words when the task was simple oral reading, not categorization. Further,
the patient learned words of lower semantic value (that is, functors) as rapidly as words high in semantic value (concrete nouns), again suggesting that the mechanism of learning may not be semantically based. This technique has since been used successfully with several other pure alexic patients; one patient failed to benefit from this therapy.

Given that it may be possible to train patients with pure alexia to recognize words rapidly, but that it is unrealistic to attempt to train all words of the language, a reasonable approach to treatment is to train the patient to recognize 125 to 150 of the most frequent words of the language, words that tend to appear repeatedly within typical sentences and paragraphs. Mastery of these words will take the patient a long way toward improved reading efficiency.

It is worth noting that this training paradigm has been implemented successfully on a computer (Friedman & Lott, 2000; Lott & Friedman, 1994), so that the patient can self-train at home between therapy sessions. The program is set up so that a word is flashed on the screen, and the patient reads the word. Following a key press, the computer presents the word auditorily, providing the necessary feedback.

**Treatment for Inability to Access Orthographic Representation in Surface Alexia** (Byng & Coltheart, 1986; Coltheart & Byng, 1989; Scott & Byng, 1989; Weekes and Coltheart, 1996)

A patient who consistently reads regular words (home) better than irregular words (come) and who defines words solely according to their derived pronunciation (come → “you use it to fix your hair”) has difficulty accessing lexical orthographic representations of known words. In an attempt to ameliorate this problem in such a surface dyslexic patient, Byng and Coltheart (1986) developed a technique in which targeted irregular words were paired with semantic cues. For example, the word through was presented with an arrow drawn through it. The patient was given a set of cards with such pairings, and practiced reading the words at home. The patient’s reading of words paired with semantic cues improved more than his reading of words that were not included in the treatment, but some generalization may have occurred as well. These results were replicated in a subsequent study by Weekes and Coltheart (1996).

A study focusing specifically on comprehension of homophones (Scott & Byng, 1989) employed context-rich whole sentences for training the meanings of homophonic words in a patient with surface alexia. On each training trial, a sentence appeared on the screen with the homophone deleted. Below the sentence were six choices, which included the correct word, its homophone, and a pseudohomophone of the correct word. The patient chose a response, and received feedback regarding accuracy. Following ten weeks of training, the patient showed improvement of the trained words. However, improvement of the untrained words on two of the three post-tests made interpretation of the results of this study problematic. In contrast, Hillis (1993) reported improved oral reading and comprehension (and spelling) of trained homophones (for example, stake and steak), without generalization to untrained homophones in a similar study. Hillis (1993) trained a patient with impaired access to the orthographic lexicon to read homophones, by having him read each trained word and its definition and then write it in a sentence.

**Treating a Deficit in Accessing Phonology from Orthography by Training Grapheme-Phoneme Correspondence Rules** (dePartz, 1986; Laine & Niemi, 1990; Mitchum & Berndt, 1991; Nickels, 1992)

Patients with “deep dyslexia” have difficulty reading many words that are low in concreteness, and are unable to use orthography-to-phonology correspondences to decode these words. One approach to reading remediation in these patients is to retrain the use of such correspon-
iences. Therapy of this sort has been implemented by several investigators, with mixed results.

Several studies have focused on the retraining of grapheme-phoneme correspondence rules. In one such study, dePartz (1986) was successful in teaching her patient to use these rules. In the first stage of therapy, the patient was taught to associate one “relay” word with each letter of the alphabet (for example, “boy” for b). In the second stage, the patient was taught to elongate his pronunciation of the first phoneme in the relay word, and then to pronounce only the phoneme. After three months of practice, he was encouraged to produce only the initial phoneme, without first pronouncing the relay word. In the third stage, the patient produced short nonwords by first sounding each letter individually. This procedure was then employed for short real words.

At the end of this therapy program, which lasted a total of nine months, the patient’s word reading accuracy had improved to 98 percent, compared with 28 percent prior to therapy. The success of this therapy program is impressive, yet three subsequent therapy programs for deep dyslexic patients (Laine & Niemi, 1990; Mitchum & Berndt, 1991; Nickels, 1992), modelled after this one, all met with considerably less success. The patient of Laine and Niemi and the patient of Mitchum and Berndt both learned to produce the appropriate phonemes for given graphemes with little difficulty. However, they were never able to successfully blend the phonemes into syllables, despite considerable attempts to teach them to do so. The authors of both studies consider the possibility that the problem with phoneme blending is attributable to a deficient phonological short-term memory. The interaction of short-term memory with success/failure of therapy of this type has yet to be systematically addressed. Another difference between these two patients and the patient of dePartz is that the former had nonfluent aphasia, while the latter had fluent aphasia. Thus, aphasia type (and lesion location) may also be relevant to success/failure of this therapy technique.

In noting that one result of the therapy was to reduce the number of semantic paralexias produced, Mitchum and Berndt (1991) suggested that a combination of lexical and nonlexical training may be beneficial to some patients. Such an approach was taken by Nickels (1992), who also used the relay word strategy to teach her patient to translate graphemes into phonemes. Like the others, Nickels’s patient learned to assign the appropriate phonemes to graphemes, but could not learn to blend them into syllables. In the next phase of treatment, the patient was instructed to produce the initial phoneme of a word, then think about its meaning, then attempt to say the word. The patient learned this strategy promptly, and used it with success. Assessment two weeks after the end of therapy revealed a significant improvement in the reading of high imageability words. This approach, then, may be of some value in training a patient to read high imageability words; however, patients who have trouble decoding phonology from orthography tend to have more trouble with low imageability words than high imageability words, a fact that renders this approach less useful.

Treating a Deficit in Accessing Phonology from Orthography by Training Bigraphs (Friedman & Lott, 1996, in press)

The failure of the grapheme-phoneme therapy discussed in the above section was the result of the patients’ inability to blend individual phonemes into syllables. The therapy devised by Friedman and Lott (1996 & in press) was predicated on the premise that grapheme-phoneme conversion is not the most natural way to translate letters into sounds: in particular, many consonantal phonemes cannot actually be produced in isolation; a vowel (usually a schwa) must be produced as well. When blending these sounds, then, the schwa must first be inhibited, and this appears to be difficult for these patients (and for many young children as well; Rozin & Gleitman, 1977).

Friedman and Lott implemented a therapy that was based upon what they considered to be a more natural unit of pronunciation, the bigraph syllable. The patient was first trained to
associate a set of bigraphs with their corresponding sounds. This was accomplished using the "relay" procedure, much like the one used by dePartz (1986): When presented with a two-letter bigraph (for example, *ma*), the patient was trained to produce a word that begins with those letters (for example, *match*), then cut it short so that only the appropriate bigraph syllable is produced (/mæʃ/ → /mæ/). After learning consonant-vowel (CV) bigraphs and vowel-consonant (VC) bigraphs, the patient learned to put CVs and VC s together into CVC words; for example, /mæ/ + /æt/ = mat. Two patients were able to learn the trained bigraphs. Further, both patients were able to combine those bigraphs in such a way as to read a large number of words on which they had not been specifically trained.

Bigraph therapy does appear to be a promising way to improve the phonological decoding skills of some alexic patients. However, it does have certain limitations. As with the use of any phonological decoding strategy with an irregular language such as English, there are many exceptions to contend with (producing /mæ/ at the beginning of the word *many* would lead to an incorrect reading). In addition, using such a strategy with multi-syllabic words may be problematic. Finally, the number of different bigraphs that must be trained is not insignificant. Despite these obstacles, providing patients with a means of decoding even short words or syllables may go a long way toward improving their overall reading, particularly if combined with other strategies, such as the semantic strategy employed by Nickels (1992).

## Treatment for Impairment in Reading Certain Classes of Words Using Paired Associate Learning

Patients with "phonological dyslexia" (predominant impairment in orthography-to-phonology conversion) often have difficulty reading functors and other words that are low in concreteness, while retaining fairly good reading of concrete words. Friedman et al. (2000) made use of two such patients' intact reading of content words to aid in their reading of functors and verbs. Words low in semantic value, and hence poorly read by these patients, are paired with words high in semantic value that are phonologically similar. The most perfect case of this type of pairing is the homophone: the word *be* is paired with the word *bee*. As most words do not have homophones, near-homophones were used as well (for example, *me*, *meat*).

In this treatment, the target word (*be*) was printed on the front of an index card; its homophone (*bee*), along with a picture of the homophone, appeared on the back of the card. During training, the patient was asked to read the target word. If the response was incorrect, the card was turned over, and the patient read/named the homophone (or near-homophone). In this way, the patients learned to pair the targets with their homophone or near-homophone, and eventually learned to read the target words before turning over the cards. No measurable improvement in overall text reading was seen following treatment. However, this study trained the patients on only sixty words, presented in isolation. Perhaps with a larger corpus of trained words, and possibly with the additional training of these words in sentences or text, a real improvement in functional reading might be achieved.

## Treatment Focusing on Text Reading: The Multiple Oral Rereading Approach

The multiple oral rereading (MOR) technique was developed by Moyer (1979) in an attempt to improve the reading speed of her pure alexic patient. The patient read aloud a simple (sixth grade level) six-hundred-word selection from a child's encyclopedia, then practiced reading it aloud for thirty minutes a day for one week. A new selection was introduced each week. Speed
of reading the practiced selection and speed of reading an unpracticed selection were recorded each week. At the end of three months, the patient's speed of reading new selections had improved significantly.

Moody (1988) tested the efficacy of the MOR technique with three patients, one with pure alexia and two with phonologic alexia. The procedure was the same as that used by Moyer, but passages as well as daily practice time were shorter. Like Moyer, Moody found increased speed of reading novel text for her pure alexic patient. One of the phonologic alexia patients also showed improvement, although less than that of the pure alexic patient. The other phonologic alexic patient showed no improvement in reading unpracticed text.

Tuomainen and Laine (1991) found the MOR technique to be successful with two of their three pure alexic patients. They attributed their lack of success with the third patient to his additional visuospatial and memory deficits, and suggest that at least partial functioning of the visual word form system is necessary for the success of MOR therapy. Further, only one of the patients showed increased speed of reading single words, leading the authors to conclude that MOR does not affect the “underlying defect in pure alexia” but rather serves to improve top-down processing strategies in text reading.

Beeson (1998) replicated the findings of the previous study. Beeson’s pure alexic patient showed improved speed of reading text following MOR therapy, but did not show improvement of single words. Beeson and Insalaco (1998) demonstrated successful use of the MOR technique with a patient whose alexia most resembled phonologic alexia, but with a significant word length effect. Following treatment, the patient’s reading speed for text improved. A new treatment was then begun, in which the patient practiced reading text that was divided into phrases. After seven months of this treatment, the patient no longer showed a word length effect, and her reading speed for single words increased relative to her speed at the beginning of the MOR treatment; the increase was particularly salient for functors. The authors concluded that the patient showed “a generalized improvement in whole word recognition and a specific improvement in associating written functors to their corresponding phonological representations." Because the single word reading was retested only after both MOR and phrase-formatted treatment, it is impossible to know which of these treatments produced the increased reading speed for functors. A second patient also showed improved reading speed following MOR and phrase-formatted treatment, and particular improvement with functors. However, the patient continued to show improved reading speed when doing nothing more than spending thirty minutes per day reading new text, making it difficult to determine what the effect of the specific treatments had been. Improvement in overall language scores contributed to the difficulty in determining treatments’ specific effects.

At present, then, the role of MOR therapy in the rehabilitation of pure alexia and phonologic alexia remains somewhat unclear. Its advantage over simply practice reading text has not yet been proven. In any case, therapy of this kind, whose beneficial effect is in speed but not accuracy of reading, is appropriate only for patients whose reading is already at a fairly high level of competence.

SUMMARY

Reading is a complex process that requires a number of relatively independent processing components. Individuals with focal brain damage often have impaired reading as a result of disruption of one or more of these processing components. A number of tests have been reviewed that allow the clinician to pinpoint which processing components are impaired in each case. Once the level of disruption has been identified, therapy can focus on specifically treating the impaired component, or can focus on using intact processing mechanisms to compensate for the impaired mechanism or level of representation. Such therapy is often, but not always, effective in improving reading, but the determinants of effectiveness have not yet been identified.
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