

Reading in pure alexia

The effect of strategy

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SUMMARY

A number of investigators have demonstrated that patients with pure alexia comprehend briefly presented words which they are unable to explicitly identify. We suggested previously that these patients may read by means of two distinct procedures: a laborious letter-by-letter method and a ‘whole-word’ procedure which, at least initially, does not support explicit word identification. We report a test of this proposal in a patient with pure alexia. We reasoned that if the patient had access to two distinct and incompatible procedures, he might be induced to switch from one to the other by changing task demands. We found that when instructed to name words, the patient employed a letter-by-letter strategy; in contrast, when instructed to make lexical decision or semantic judgements about rapidly presented words, he appeared to use a ‘whole-word’ strategy. These data support the hypothesis that two distinct procedures are available to this patient. We argue, further, that it is necessary to suppress use of the letter-by-letter strategy to demonstrate whole word reading capability in pure alexics, and that failure to do so may account for negative findings in other cases reported in the literature.

INTRODUCTION

First reported by Dejerine in 1892, pure alexia or alexia without agraphia is a syndrome characterized by the inability to read aloud or for comprehension in the absence of aphasia or agraphia. The traditional account (Dejerine, 1892; Geschwind and Fusillo, 1966) of this disorder attributes the syndrome to a ‘disconnection’ of visual information, assumed to be restricted to the right hemisphere, from the left hemisphere word recognition system.

Most reports of pure alexia have emphasized the profound nature of the reading deficit, often concluding that patients were utterly incapable of reading without recourse to a letter-by-letter procedure (Geschwind and Fusillo, 1966). However, a number of investigators have reported data demonstrating capacities which would not be expected if this view of pure alexia was correct. Kreindler and Ionășescu (1961), for example, described a 62-year-old man who noted the sudden onset of pure alexia and right homonymous hemianopia as well as complete ‘word blindness’. But when shown a picture and asked to point to the appropriate word from a list of words he responded correctly

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on 16 out of 20 trials. He also performed well when asked to indicate which of a list of written words had been spoken by the investigator (100% correct) and he correctly matched a written word to one of a series of spoken words (>90% correct). Another patient with pure alexia who was able to match spoken to written words which he was unable to explicitly identify was reported by Grossi *et al.* (1984).

Caplan and Hedley-Whyte (1974) described a 68-year-old woman who had suffered an extensive posterior left hemisphere infarction. Although able to write and name spelled words, the patient was impaired at naming letters and was unable to read aloud any words. When shown a letter string containing a real word as well as extraneous letters, however, she was able to indicate which letters were not part of the word. And while she was unable to read even one of a list of 13 words, she pointed to the named word correctly in all cases. Perhaps most interestingly, when asked to indicate if any of the words signified a temperature, she pointed to RED, COLD and WARM while saying 'warm', 'cold' and 'hot', respectively.

Albert *et al.* (1973) described a patient who, although able to read aloud only a small proportion of short, high frequency words, was nonetheless able to match written words to objects with 90% accuracy and match written and spoken words perfectly on 10 trials. The patient also performed perfectly on a number of lexical decision tests. Interestingly, like the patient reported by Caplan and Hedley-Whyte (1974), this patient also made semantic errors on oral reading and reading comprehension tasks.

Another example of at least partial access to semantic information appropriate to words which could not be explicitly identified was provided by Landis *et al.* (1980). These investigators described a 39-year-old man with a left occipital tumour who exhibited pure alexia with letter-by-letter reading. Of greatest interest was the patient's performance with tachistoscopic presentation of words and the change in this performance over time. Initially, though unable to identify words or even letters at 30 ms, he successfully matched the stimulus word to an item from a large array of objects on five out of seven trials. When tested again 7 weeks later, he was able to read letters at 10 ms and correctly read four out of 10 words at 20 ms. On the other six trials, he selected the matching object only once; intriguingly, this was the only trial on which he did not identify any letters.

The first comprehensive demonstration of preserved reading capacities in a patient with pure alexia was reported by Shallice and Saffran (1986). Their patient, M.L., explicitly identified words quite readily by means of a letter-by-letter strategy; of particular interest, however, was the demonstration that the patient performed better than chance on lexical decision tests and some (but not all) semantic categorization tasks in which words were presented too briefly to be explicitly identified. One additional striking aspect of the patient's performance was the apparent use of alternative reading strategies for the different tasks; whereas M.L. used a serial letter identification approach when asked to name words, he stated that he used a very different approach in his attempts to derive semantic information from written words. M.L.'s introspection appeared to be supported by his behaviour on these tasks; when asked to name words he scrutinized the stimulus for the entire 2 s period during which it was present, whereas when making a semantic category judgement he often averted his eyes after only a quick glance at the stimulus.

We have reported four pure alexics who performed imperfectly but well above chance on a variety of lexical decision and semantic categorization tasks with stimuli which they were unable to explicitly identify (Coslett and Saffran, 1989a). Two of the patients

ultimately regained the ability to explicitly identify rapidly presented words; both patients read nouns better than functors and high better than low imageability words. We suggested that the implicit and 'recovered' reading of these patients was mediated by the right hemisphere.

Additional evidence that some patients with pure alexia are able to comprehend words which they are unable to explicitly identify has been reported by Howard (1991). Two pure alexics were tested on a cued word definition task in which they were asked to define a polysemous word that was preceded by a briefly presented word which, if processed semantically, would bias the patient's definition. On one trial, for example, the word 'TREE' was presented for a brief interval (either 150 or 250 ms) and was overwritten by the word 'PALM' which remained in view until the patient responded; on another trial, the target 'PALM' was preceded by 'HAND'. Neither patient reported seeing any of the cue words. One patient (K.W.) exhibited a significant biasing effect of the cue, though the other (P.M.) showed no such effect. Also of note is that K.W. performed well on a task in which he was asked to categorize rapidly presented words which he was unable to explicitly identify; P.M. performed at chance on this task.

A different type of evidence supporting the claim that at least some patients with pure alexia are able to access stored lexical information for words they are unable to identify has been provided by the reports of Bub *et al.* (1989) and Reuter-Lorenz and Brunn (1990). These investigators tested the ability of their patients to identify letters in familiar words, orthographically legal 'pseudowords' and random letter strings. Reuter-Lorenz and Brunn (1990) found that their patient with pure alexia performed significantly better in identifying letters in words as compared with 'pseudowords' or random letter strings. The patient described by Bub *et al.* identified significantly more letters from words as compared with random letter strings but did not differ with 'pseudowords' and words. The words (or orthographic) superiority effect suggests that these patients are, indeed, able to access stored lexical information. It should be noted, however, that other alexics tested on this paradigm have not shown this effect (*see* Behrmann *et al.*, 1990).

Indeed, a number of investigators who have sought evidence of implicit reading in pure alexics have failed to find it. Warrington and Shallice (1980) reported a patient (R.A.V.) with letter-by-letter reading who read aloud 42 out of 50 words presented for 500 ms; he performed at chance on this and another task, however, when asked to match to a picture words he had been unable to read. Patterson and Kay (1982) evaluated four patients with pure alexia and letter-by-letter reading on a variety of lexical decision and word comprehension tasks; they found no compelling evidence that their patients were able to comprehend words which they could not explicitly identify. In a similar vein, Behrmann *et al.* (1990) reported a patient with pure alexia and letter-by-letter reading who performed at chance on a series of three investigations in which she was asked to categorize a word presented for 3 s.

There are a number of possible explanations for the discrepancies in performance exhibited by these patients. One potential explanation, of course, is that there is variability in competence in this regard, perhaps as a function of degree of literacy or hemispheric representation of language capacities. [It should be noted in this context, that investigations of split-brain patients are consistent with the notion that patients differ with respect to the linguistic competence of the right hemisphere (Gazzaniga *et al.*, 1984).] A second possibility is that the discrepancies reported in the literature may reflect differences in

reading 'strategy'. We have argued elsewhere (Shallice and Saffran, 1986; Coslett and Saffran, 1989a; *see also* Landis *et al.*, 1980), for example, that these patients read by means of two distinct procedures: patients may attempt to explicitly identify words by means of an often slow and cumbersome letter-by-letter strategy; alternatively, they may process letters in parallel by means of a 'whole-word' procedure. The latter procedure does not, at least initially, support explicit word identification; in these patients, lexical-semantic information may be contacted without awareness.

Here we report a test of the 'two reading procedures' hypothesis in a patient with pure alexia. We reasoned that if the patient does indeed have access to two distinct and incompatible procedures, the patient might be induced to shift from one procedure to another by changing task demands. Thus, for example, when asked to name words, we predicted that the patient would employ a letter-by-letter procedure which would not provide access to lexical-semantic information for those words not explicitly identified; when asked to make lexical-semantic judgements about briefly presented words, we predicted that the patient would perform well on judgement tasks but fail to identify the words explicitly. Below we report data demonstrating that the patient, like our previously reported cases (Coslett and Saffran, 1989a), was able to access lexical-semantic information for words he could not identify. Subsequently, we present data consistent with the hypothesis that the patient may employ two distinct reading procedures.

CASE DESCRIPTION

The patient (J.W.C.) is a 62-year-old right-handed man who noted the sudden onset of mild right-sided weakness and loss of vision on the right. He had finished eleventh grade and had worked as a labourer until retiring several years previously. J.W.C. stated that he scanned the newspaper most days but read little else. He rarely wrote.

Neurological examination performed ~5 weeks after the onset of symptoms revealed the patient to be alert, cooperative and socially appropriate. There was no weakness, pyramidal clumsiness or reflex asymmetry but a dense right homonymous hemianopia was noted. Cutaneous sensation and gait were normal. The patient was not apraxic. The clinical diagnosis of stroke was confirmed by a computerized axial tomography (CAT) scan performed 8 days after the onset of symptoms which demonstrated a left occipital lobe infarction (*see* Figs 1, 2).

Language function was assessed by the Boston Diagnostic Aphasia Examination (Goodglass and Kaplan, 1972) 1 month after the stroke. As indicated in Table 1, J.W.C. exhibited a mild impairment in pointing to named words; most errors occurred when he was asked to point to a named colour. A mild impairment was also observed on the Complex Ideational Material subtest. Naming of objects, actions and body parts was normal; he misnamed most of the numbers and all of the colours. Digit span was 3-4.

The most obvious and disabling language impairment was a severe dyslexia. In almost all instances, J.W.C. spoke words only after explicitly naming the constituent letters; he frequently misnamed letters with a resultant failure in word identification.

EXPERIMENTAL INVESTIGATIONS

The following experiments were performed to investigate the patient's reading. The patient gave his informed consent to participate in these experiments.

Letter naming

Naming of single block letters was assessed on a number of occasions commencing 3 weeks after his stroke. Initially he named five out of 10 upper case letters but only three

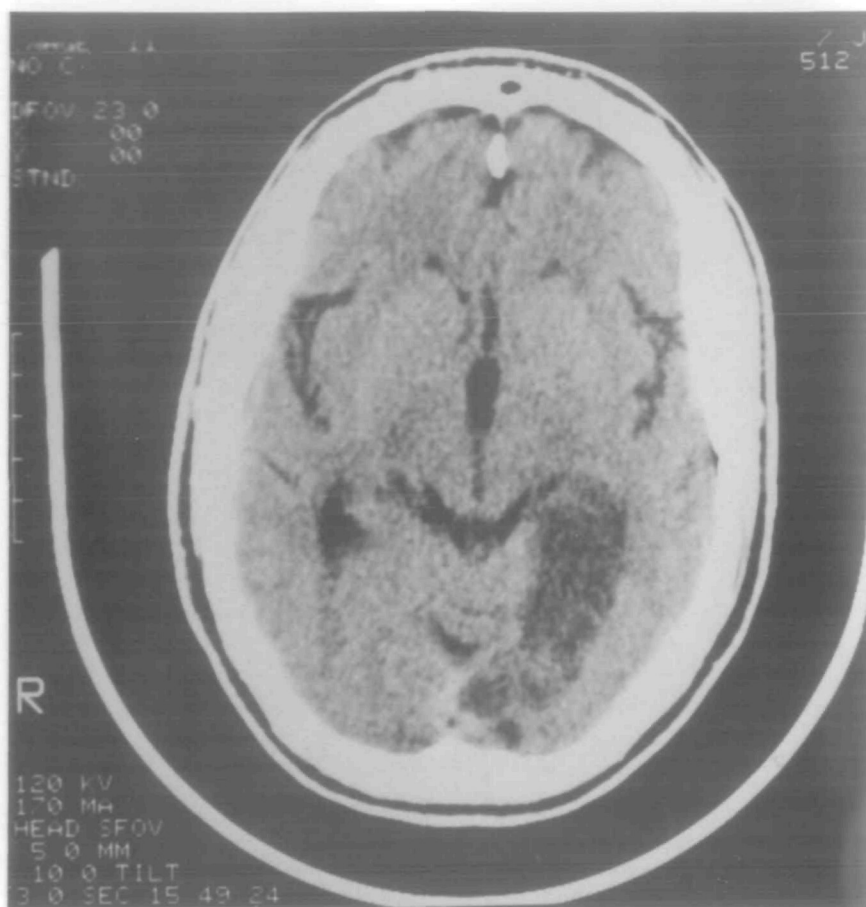


FIG. 1. A low ventricular CAT scan image demonstrating an infarction involving the left medial occipital lobe, portions of the hippocampal gyrus and, perhaps, the lateral geniculate body.

out of 10 lower case letters. One week later he named eight out of 10 upper and six out of 10 lower case letters. Letter naming continued to improve so that 6 weeks after the stroke he named upper case letters perfectly (24 out of 24), though he continued to misidentify ~20% of lower case letters. Letter misidentifications, which typically involved visually similar letters such as 'b'/'d', 'm'/'n' and 'h'/'n', appeared to be more frequent when attempting to name letters in a word context.

Single word oral reading

J.W.C. was asked to name a total of 60 words of three, four, five, six and seven letters; words were printed in large, bold lower case letters on 5×7 inch cards and presented free-field. Words of different lengths were matched for frequency. Five words of the same length were printed on each card but only one word was left uncovered at a time.



FIG. 2. A mid-ventricular CAT scan image demonstrating infarction involving the occipital lobe and portions of the posterior limb of the internal capsule.

TABLE 1. PERFORMANCE OF THE BOSTON DIAGNOSTIC APHASIA EXAMINATION

Auditory comprehension	
Word discrimination	66 (72)
Body-part identification	20 (20)
Commands	15 (15)
Complex ideational material	10 (12)
Oral expression	
Repetition of words	10 (10)
Responsive naming	29 (30)
Visual confrontation naming	91 (114)
(Naming colours)	[7 (18)]
Animal naming	11

Maximum possible score is given in parentheses.

The time required to identify correctly each word (in seconds) was measured with a stopwatch; all responses were recorded and each trial was terminated only when the patient responded correctly or gave up.

For 57 of the 60 stimuli, J.W.C. attempted to identify the word by means of serial letter naming. In most instances, he named the letter aloud; on a few occasions he stated that he subvocally named the letters. Responses to three of the stimuli ('horse', 'express' and 'country'), however, were provided in <2 s; in these instances, J.W.C. stated that he 'saw the whole thing'.

J.W.C. tended to be more accurate and faster with short words. He correctly identified 18 out of 20 (90%) three-letter words, 15 out of 20 four-letter words, and six out of 10 five-letter words and nine out of 10 six- and seven-letter words.

The latency for correct responses, excluding the three trials on which the subject identified the word very quickly, is depicted in Fig. 3. First, it should be noted that J.W.C. was extremely slow to identify words in a letter-by-letter fashion; he required an average of 15.8 s to identify correctly three-letter words and 44.3 s to name six- and seven-letter words. Secondly, performance was quite variable; he named 'road' in 6 s, for example, but required 60 s to identify 'neck'. In most instances, long response latencies were attributable to letter misidentifications.

These data demonstrate that on 95% of trials J.W.C. was able to identify a word explicitly only after an abnormally long interval; his overt behaviour, his introspection regarding his behaviour, as well as the effect of word length on accuracy and response latency all suggest that he relied upon a laborious and often inaccurate letter-by-letter procedure for explicit word identification.

Naming spelled words

J.W.C. was also asked to speak orally spelled words; stimuli included a subset of the words which he had been asked to read aloud. He correctly identified 10 out of 10 three-letter words, eight out of 10 four-letter words, five out of 10 five-letter words and two and five six-letter words. Most errors were omissions. As he was often unable to repeat the letters in correct sequence, performance on this task was presumably hindered by a short-term memory deficit.

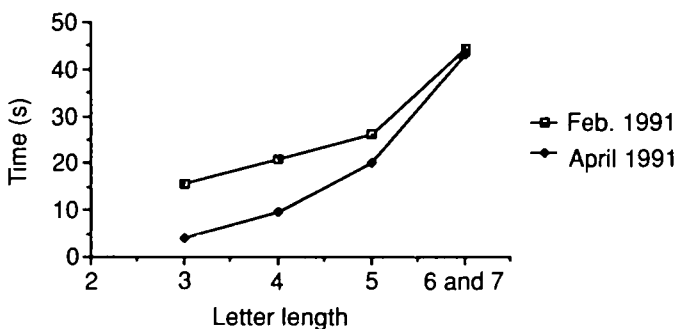


FIG. 3. A graph of the time (seconds) required to read aloud words of different letter lengths.

Lexical decision tests

Like previously reported patients, J.W.C. specifically denied that he could identify visually presented letter strings without using a letter-by-letter strategy. A series of lexical decision tests were performed to assess the possibility that letter strings were being processed without awareness. The ability to discriminate between words and non-word letter strings would suggest that the subject was able to access a catalogue of stored word entries.

Lexical decision with high and low frequency words. Stimuli included 60 high frequency words [mean frequency of 445.8 counts per million (Kucera and Francis, 1967)], 60 low frequency words (all 1 count per million), 60 'wordlike' non-words such as 'shart' (mean 'N' of 10.9; Coltheart *et al.*, 1977) and 60 non-words with unusual or illegal orthographic sequences such as 'twilk' (mean 'N' of 1.3) for a total of 240 stimuli. Stimuli were unaffixed and varied in length from three to five letters. Stimuli in the four experimental conditions were matched for length and presented in random sequence with an Apple MacIntosh microcomputer. For each trial, pressing the spacebar on the keyboard caused a centrally placed fixation point to be replaced by a letter string which persisted for 249 ms, for this and all subsequent experiments there was no post-stimulus mask.

J.W.C. was told that it was not necessary to identify the stimulus explicitly but to attempt to determine if the letter string was a real, familiar word. Prior to and on many occasions during the course of the experiment, he was reminded that he was simply to determine if the word looked familiar or to 'get a feel for the whole word' rather than to name the word. Despite these continued admonitions, the subject frequently attempted to identify the constituent letters and often reported seeing a single letter; J.W.C. was discouraged from reporting the individual letters but was asked to notify the investigator if he thought he could identify the word. He was required to guess if unsure.

J.W.C. responded accurately to high frequency words (56 out of 60 or 93%) but was at chance with low frequency words (29 out of 60 or 48%) and both high (34 out of 60 or 57%) and low (26 out of 60 or 43%) 'N' non-words. Although far from perfect, his overall performance was better than chance on this task ($d' = 0.553$, $z = 3.16$, $P < 0.05$). Further analysis with a χ^2 statistic revealed that J.W.C. performed significantly better with high frequency compared with low frequency words ($\chi^2 = 27.5$, d.f. = 1, $P < 0.1$) or non-words ($\chi^2 = 30.9$, d.f. = 1, $P < 0.1$). Performance with low frequency words did not differ from that of non-words. J.W.C. did not explicitly identify any of the stimuli.

Lexical decision with high and low imageability words. A second lexical decision test involving 20 words of high and 20 words of low imageability as well as non-words derived from these words by changing one or two letters were also performed. Non-words were orthographically and phonologically plausible. High (>5) and low (<3) (Paivio *et al.*, 1968) imageability words were matched for length and frequency; non-words and words were matched with respect to length.

Letter strings were presented for 249 ms using a microcomputer. As described above, J.W.C. was instructed to focus his attention on the entire letter string in an effort to determine if the letter string was a familiar word; additionally, he was told that it was not necessary to identify the letter string explicitly but that he should inform the experimenter if he believed he had identified the word.

J.W.C. responded 'yes' to 18 out of 20 high imageability words, 11 out of 20 low

imageability words, 13 out of 20 non-words derived from high imageability words and 11 out of 20 non-words derived from low imageability non-words. J.W.C. exhibited a significant effect of word imageability, responding more accurately to high as compared with low imageability words ($\chi^2 = 4.5$, d.f. = 1, $P < 0.05$). Although J.W.C. performed significantly better overall with words as compared with non-words ($\chi^2 = 7.3$, d.f. = 1, $P < 0.01$), analysis with a d' statistic demonstrated that he failed to discriminate reliably between words and non-words ($d' = 0.227$, $z = 0.77$, NS); his better performance with words may, therefore, have been attributable to a response bias. It should be noted that J.W.C. again failed to identify a single letter string explicitly.

Lexical decision with nouns and functors. A third lexical decision test was performed to assess the effect of word class. Stimuli for this task included 30 nouns and 30 functors matched for frequency, length and imageability as well as an equal number of non-words derived from the nouns and functors by changing one or two letters. All non-words were orthographically and phonologically plausible. Stimuli were presented using the apparatus and procedure described above.

J.W.C. responded 'yes' to 25 out of 30 nouns, 18 out of 30 functors, 17 out of 30 non-words derived from functors and 14 out of 30 non-words derived from nouns. He responded significantly more accurately with words as compared with non-words ($\chi^2 = 5.9$, d.f. = 1, $P < 0.01$) and discriminated words from non-words significantly better than chance ($d' = 0.553$, $z = 2.06$, $P < 0.05$). Perhaps the most informative aspect of the patient's performance, however, is the comparison between nouns and functors; J.W.C. responded more accurately with nouns as compared with functors ($\chi^2 = 3$, d.f. = 1, $0.10 > P > 0.05$). He failed to offer an explicit response to a single letter string and, when directly questioned, denied having identified any letter strings.

Discussion. Although J.W.C. was unable to identify a single word and insisted that he was guessing, he was able to discriminate words from non-words significantly better than would be expected by chance. Additionally, it should be noted that J.W.C.'s performance was influenced by the variables of frequency, imageability and part of speech. He exhibited a robust frequency effect, and responded significantly better than chance with nouns and words of high imageability but performed at a chance level with functors and words of low imageability.

Word comprehension

The following experiments were performed to assess J.W.C.'s ability to derive semantic information for words which he could not identify.

Animal names. In the first experiment J.W.C. was asked to indicate whether a rapidly presented word was an animal name. Stimuli consisted of 25 animal names (e.g. 'mouse'), 25 words judged to be visually similar to the animal names (e.g. 'mount') and 25 words judged not to be visually or phonologically similar to the animal names (e.g. 'rally'). Visually similar foils shared at least the first two letters with the matched animal name. The three types of stimuli were matched for frequency; mean frequencies (\pm SD) for the animal names, visually similar foils and unrelated foils were 12.6 ± 23.6 , 13.6 ± 22.1 and 12.7 ± 23.9 counts per million, respectively (Kucera and Francis, 1967). Animal names and foils differed in length by no more than one letter; mean letter lengths for the animal names, visually similar foils and unrelated foils were 5.96 ± 1 , 5.92 ± 0.9 and

5.96 ± 1, respectively. Stimuli were presented with a microcomputer for 249 ms. The subject was instructed to say 'yes' if the word was the name of an animal.

Prior to and during the administration of the test, the subject was encouraged to attend to the whole word and derive a 'feeling for' or an 'impression' about the word. Serial letter identification was strongly discouraged. As described above, emphasis was placed on the importance of the category judgement rather than explicit word identification; J.W.C. was asked to inform the investigator if he believed he had identified a word. The subject was not told the proportion of stimuli which were animal names and was not given feedback regarding the accuracy of individual responses. He was, however, given frequent encouragement to see the whole word.

J.W.C. responded correctly to 20 out of 25 (80%) animal names, 17 out of 25 (68%) visually similar words and 18 out of 25 unrelated words (72%); his overall performance of 73% correct was significantly better than chance ($\chi^2 = 15.4$, d.f. = 1, $P < 0.01$). He did not offer a name for any word but offered the following comments to five of the stimuli: TIGER—'stripes on it'; LOBSTER—'lives in water'; OYSTER—'funny name, body flat, like a duckbill, lives in water'; ZEBRA—'stripes, like horse'; TROUT—'fish-like, big, sharp teeth'; and ALLIGATOR—'awful long'. Even after offering these comments, J.W.C. was unable to identify the animal name.

Food names. A second forced-choice categorization experiment was performed in which J.W.C. was asked to indicate whether the referent of a rapidly presented word was edible. Stimuli consisted of 25 food items (e.g. 'grape'), 25 visually similar words (e.g. 'graph') and 25 unrelated words (e.g. 'shaft'). The three groups of stimuli did not differ in mean frequency [15 ± 15.5 , 25 ± 55.4 , 15 ± 15.5 counts per million, respectively (Kucera and Francis, 1967)] or length (mean letter length 5.76 ± 1.03 , 5.84 ± 0.97 , 5.76 ± 1.03 , respectively). Stimuli were presented with a microcomputer for 249 ms. The subject was instructed to say 'yes' if the rapidly presented word designated a type of food. Once again, he was encouraged to view the whole word and not to attempt to piece the word together using a letter-by-letter strategy.

J.W.C. responded correctly to 21 out of 25 food names, 16 out of 25 visually similar words and 20 out of 25 unrelated words for an overall performance of 57 out of 75 or 76% correct. This performance is significantly better than chance ($\chi^2 = 19.3$, d.f. = 1, $P < 0.01$). He offered only one response; to the stimulus 'coffee' he commented 'you can drink it, is it coffee?'.

Word-to-picture matching. Evidence for word comprehension in the absence of explicit word identification was also sought with a forced-choice task requiring the matching of a rapidly presented word to one of two pictures.

The names of items pictured in the Boston Naming Test (Kaplan *et al.*, 1982) or Peabody Picture Vocabulary Test (Dunn, 1985) were used to generate 31 pairs of words which shared the first two letters; this control was instituted to prevent the subject from using only information derived from a letter-by-letter analysis. Nine word pairs were matched for letter length (e.g. 'house'/'horse'), eight pairs differed in length by one letter (e.g. 'whistle'/'whale') and 14 pairs differed by two letters (e.g. 'propeller'/'pretzel'). The drawings appropriate to the word pairs were copied onto a single 11 × 8.5 inch piece of paper.

The 62 words were presented in random sequence for 249 ms using a microcomputer

as described above. Following the presentation, the subject was shown the sheet of paper on which the drawing appropriate to the stimulus and its matched word had been copied and was asked to point to the appropriate picture. Each word was presented once; no feedback regarding response accuracy was provided. With two exceptions ('snake'/'snail' and 'broom'/'brush'), pairs of words were drawn from different semantic categories.

This test was administered on two occasions. The first was in the second experimental session during which the subject received very frequent instructions to forego attempts to identify explicitly words using a letter-by-letter approach and to attempt to derive a 'feel for' the word. The patient appeared reluctant to forsake the attempt to identify words explicitly; despite suggestions to the contrary, for example, he provided information about the initial one or two letters on 25 trials. He pointed to the correct drawing on 37 out of 62 trials (60%), a performance which is not significantly different from chance ($\chi^2 = 1.95$, d.f. = 1, NS); he failed to name any target words.

The task was administered again 2 weeks later. During the interval the subject had been receiving daily speech therapy during which the therapist emphasized the importance of 'seeing the whole word' and attempting to obtain a feeling for or intuition about the word. In these sessions the patient was often asked to make category judgements about printed words presented across the table or for brief periods (249 ms) using a micro-computer. During this 2-week interval the subject was noted by his therapist to be improving in his performance on categorization tasks; he was also noted to be exhibiting an increased willingness to rely on his judgements made in the absence of explicit word identification.

On the second administration, the patient responded correctly on 52 out of 62 trials (84%), a performance which is well above chance ($\chi^2 = 27.12$, d.f. = 1, $P < 0.05$). J.W.C. did not name any word correctly and, in contrast to his performance on the previous administration, did not offer any information about letter identity.

Evidence for distinct reading procedures

J.W.C., like at least some other patients with pure alexia, demonstrated two different performance patterns with written words. The first involves serial letter naming and subsequent explicit word identification. The second appears to involve access to a lexical-semantic system in the absence of explicit word identification; on the basis of data reviewed previously, we have argued that this performance is mediated by the right hemisphere (Coslett and Saffran, 1989a,b). We contend that the improvement with rapidly presented stimuli that J.W.C. exhibited over the 2-week treatment period is attributable to a switch from a reliance upon a slow, effortful and inefficient procedure which, like 'normal' reading, provides explicit word identification, to a fast and less effortful procedure which, at least initially, fails to provide explicit word identification. Although some subjects such as Shallice and Saffran's subject M.L. (1986) may voluntarily switch between these procedures, most have been extremely reluctant to relinquish the certainty which accompanies letter-by-letter reading and only with repeated practice and coaching have proven willing to act upon knowledge not confirmed by the ability to explicitly articulate the word.

In an effort to test the hypothesis that J.W.C. employed two different procedures to access stored information from visually presented words a final experimental session was arranged ~6 weeks after the completion of the testing described above. We reasoned that if J.W.C. was indeed utilizing different reading procedures for purposes of explicit

identification and semantic access with briefly displayed words, then his performance with the same stimuli should differ as a function of task demands. More specifically, we predicted that when asked to identify words explicitly he would be able to name a proportion of stimuli but perform poorly on semantic judgement tasks. In contrast, when asked to make a semantic judgement about a stimulus, J.W.C. would be expected to perform well at that task but perform poorly in terms of explicit word identification.

The first task in this session was to indicate whether a rapidly presented letter string was a male or female name. Stimuli included 16 male names (mean letter length 4.8 ± 1.2 letters, range 3–7) and 14 female names (mean length 5.4 ± 1.3 , range 3–8). [The thirty names were a subset of the 100 item set previously described by Coslett and Saffran (1989a).] Stimuli were presented for 249 ms with a Macintosh microcomputer; the subject was told that all letter strings were familiar American first names and instructed to indicate if the name was appropriate for a male or female; he was also instructed to provide the name if he thought he recognized it. J.W.C. correctly categorized all 30 of the names; his only attempt at naming a word was his response of 'Andrew' to the target 'Andy' (see Table 2).

TABLE 2. PERFORMANCE AS A FUNCTION OF TASK TYPE

<i>Task sequence</i>	<i>Task</i>	<i>Exposure (ms)</i>	<i>No. of words</i>	<i>No. named</i>	<i>Percent correct*</i>
1	Categorization: male or female name	249	30	1–	100
2	Categorization: animal?	249	75	3+	85
3	Name word	Unlimited			
4	Name word, then categorize: edible?	2000	25 foods 25 vis. foils 25 unrel. foils	16+, 3– 0+, 12– 0+, 4–	51
5	Categorization	249	25 foods 25 vis. foils 25 unrel. foils	3+ 1+	86

+ = indicates number of correct responses; – = incorrect responses; *based only on items not named.

The second task was the animal categorization test described above which had been administered 7 weeks previously. The 75 randomized stimuli were presented for 249 ms each and the subject told that the primary task was to indicate if the word was the name of an animal. As before, he was asked to name the word if possible. J.W.C. responded correctly to 22 out of 25 animal names, 18 out of 25 words which were visually similar to the animal names and 23 out of 25 unrelated foils for an overall score of 64 out of 75 (85%) correct. He named three of the animal names correctly (alligator, goose, zebra) but failed to name any other words.

Next, J.W.C. was shown sets of five, three-, four-, five- and six-letter words printed on 5×7 inch cards and asked to name the words. Mean latencies for correct responses are given in Fig. 3. Although J.W.C. was somewhat faster than he had been 2 months previously, he was still pathologically slow and continued to display an obvious effect of word length. J.W.C. continued to employ an overt letter-naming strategy in his attempts to identify explicitly the words; the improvement relative to previous testing sessions

appeared to be related to more accurate letter identification. This task was performed not only to demonstrate that the patient continued to employ a letter-by-letter strategy for explicit word identification but also to induce him to revert from the 'whole-word' procedure with which he had become quite comfortable and re-engage the letter-by-letter procedure.

A second task requiring explicit letter identification was then performed. Stimuli for this task included the 75 words from the 'edible' categorization task described above. The instructions to J.W.C. on this administration were quite different, however. The subject was told that each letter string would be visible for 2000 ms and was instructed to attempt to name the target word. He was also told that if unable to identify the target, he would be asked if the word designated something edible; it was emphasized to the subject prior to and during the experiment that he should attempt to name the word and, failing in this task, indicate if the referent of the word was edible.

J.W.C. correctly named 16 out of 25 food items, 0 out of 25 visually similar foils and 0 out of 25 of the unrelated foils. Errors with the food names included three instances in which an incorrect (but visually similar) food name was reported and six errors in which one or two letters were named. Errors with the visually related foils included 12 word responses, 10 of which were names of food items (e.g. 'apple' to the foil 'apply') and 13 instances in which one or more letters were reported. Finally, errors to the unrelated foils included four words, all of which were names of food items and were visually similar to the target word (e.g. 'seafood' to the foil 'safer') as well as 21 instances on which one or more letters were reported.

Thus, performance on the word identification task with 2000 ms was poor; he correctly named only 16 words, all names of food. There was a strong bias to produce names of food items (16 of his 19 incorrect word responses were names of food); when unable to name a word, he always named one or more of the initial letters from the word string.

Performance on the judgement task was also analysed. Overall, J.W.C. correctly categorized the target on 39 out of 75 (52%) trials. Excluding all trials on which J.W.C. offered an explicit response (either correct or incorrect) he responded correctly on four out of nine trials with food names, four out of 13 trials with visually similar foils and 14 out of 21 trials with unrelated foils for a total of 22 out of 43 (51%). Thus, when asked to name a target word presented for 2000 ms, J.W.C. performed at chance in judging whether or not the target word is edible.

To insure that J.W.C.'s failure to categorize the words on the last task was not attributable to specific visual or semantic features of the stimuli, a randomized version of the same stimuli was presented once again after a 15 min rest. On this administration, he was told that words would be presented for a very brief interval and he was asked to judge whether the word referred to something that was edible; he was instructed to name the word if he recognized it but that the primary task was to judge whether the referent of the word was edible.

With 249 ms stimulus exposure J.W.C. correctly categorized 23 out of 25 food names, 17 out of 25 visually similar foils and 25 out of 25 unrelated foils for a total of 65 out of 75 (87%); he correctly named three food names ('sandwich', 'apple', 'fruit') and one unrelated word ('ocean'). Excluding the four trials on which he correctly identified the word, J.W.C. responded correctly on 61 out of 71 trials (86%), a performance far better than chance ($\chi^2 = 32.4$, d.f. = 1, $P < 0.01$). In contrast to his performance on the

previous task when asked to name the words, J.W.C. did not report information about initial letters on any trials.

Discussion

These data are consistent with the predictions described above; when asked to identify words explicitly, J.W.C. accurately reported words on 21% of trials and reported partial letter information on all trials on which he did not (correctly or incorrectly) report a word; of great interest in this context, he performed at chance when asked to determine if the referent of the word was edible. When asked to produce a semantic category judgement, J.W.C. performed well on three tasks, including one employing stimuli with which he had performed at chance when attempting to name words. When making judgements about the stimuli, he correctly named only 5% of words and never reported partial letter information. These data suggest that J.W.C. was, indeed, able to employ two distinct reading procedures.

GENERAL DISCUSSION

We report a patient with pure alexia who, like a number of previously reported patients, was able to access lexical and semantic information appropriate to visually presented words which he was unable to identify explicitly and, in some instances, claimed not to have even seen. J.W.C.'s performance was, in most respects, remarkably similar to that of our previously reported patients (Coslett and Saffran, 1989a).

The most significant data presented above deal with the effects of strategy differences and/or task demands on the patient's processing of written words. Thus, when instructed to identify rapidly presented words explicitly, J.W.C. correctly reported 21% of the words and on other trials reported initial letters of words; critically, he performed at chance when asked to categorize those words which he had been unable to identify. In marked contrast, when he was instructed to focus his efforts on the category judgement, his performance changed substantially; J.W.C. correctly identified only 5% of words, never reported letters from the string and performed far better than chance on word categorization.

This observation may provide, at least in part, an explanation for the failure to demonstrate implicit processing in some patients with pure alexia. We suggest that seemingly subtle differences in task demands or patient instructions may contribute substantially to these inconsistencies. Thus, on our analysis, a task in which patients are instructed to name a word, and failing in that endeavour to make a judgement about its lexical status or semantic category, differs in a crucial way from a task in which the emphasis is placed on the category judgement and in which explicit word identification is clearly a secondary aim. It is relevant to note that several investigators who have found evidence of implicit processing in pure alexia have employed tasks of the latter type (e.g. Landis *et al.*, 1980; Coslett and Saffran, 1989a), whereas those researchers who have not found evidence of implicit processing have frequently employed the former type of task (e.g. Warrington and Shallice, 1980; Patterson and Kay, 1982; Behrmann *et al.*, 1990).

Our own experience suggests, furthermore, that patients who initially employ a letter-by-letter approach are unlikely to relinquish this strategy on their own. J.W.C. like the four patients we reported previously (Coslett and Saffran, 1989a), had to be discouraged from applying the letter-by-letter procedure even under reduced exposure where this strategy

was unlikely to be successful. The evidence from these patients suggests that it becomes possible to inhibit letter-by-letter reading as the subject gains confidence in his performance on the implicit processing tasks. To our knowledge, the only patient who seemed to be aware of having distinct reading procedures at his disposal was M.L., the subject reported by Shallice and Saffran (1986).

Although we have attempted to account for failures to demonstrate implicit reading in pure alexia on the grounds of strategy preferences and task demands, we acknowledge the possibility that at least some of the apparent inconsistency between pure alexics may be attributed to individual differences in patients' processing capacities. Howard's (1991) demonstration that, when tested with identical and apparently appropriate experimental paradigms, one patient demonstrated evidence of implicit processing whereas the other patient did not, may be attributable to individual differences in processing efficiency at a number of possible stages (e.g. low-level visual processing, response threshold, etc.).

As noted earlier, we have hypothesized that the implicit reading performance of pure alexics reflects processing carried out by the right hemisphere (Coslett and Saffran, 1989a, *see also* Coslett and Saffran, 1989b, 1992). This proposal is based on similarities between performance patterns in these implicit reading tasks and those characteristic of the right hemisphere, as demonstrated by studies of commissurotomy and hemispherectomy patients (Gazzaniga and Sperry, 1967; Sperry *et al.*, 1969; Zaidel and Peters, 1981; Patterson *et al.*, 1989), as well as split field studies in normal subjects (Todorovic, 1988; Rayman and Zaidel, 1991). In addition, the right hemisphere is the locus of early visual processing in most patients with pure alexia, most of whom have right homonymous hemianopias. Many have also sustained damage to deep structures such as the forceps major or corpus callosum which can be presumed to impede transfer of visual information from the right hemisphere to language processors in the left.

We assume that letter-by-letter reading is an adaptive attempt by the left hemisphere language processor to make use of the reduced input available to it, a serial listing of letter names identified by means of a right hemisphere mediated object recognition system (it should be recalled that J.W.C. was able to name objects). Thus, enjoined to 'read' the word, which normally means to encode it phonologically, the left hemisphere system does it the only way it can, by means of the procedures which mediate recognition of orally spelled words.

We assume that the products of right hemisphere lexical and semantic analysis are not readily accessible to the language processors on the left. Indeed, there are striking parallels between the occasional descriptive responses of the alexic patients (e.g. J.W.C.'s response to ZEBRA as 'stripes, like horse') and those produced by split brain patients in picture description (e.g. Sergent, 1990). We suggest that as a result of repeated experience with tasks that are ill-suited to letter-by-letter reading, and frequent explicit discouragement of the use of this procedure by the investigators, the patient gradually learns to inhibit the letter-by-letter strategy which may, in fact, have been interfering with access to the right hemisphere mediated reading to the left hemisphere language processors. Additionally, we propose that an increasing reliance on right hemisphere mediated processing may enhance the efficiency and specificity with which this information accesses left hemisphere lexical-semantic systems.

'Pure alexia' is not as 'pure' as earlier supposed. We suspect that many patients given this diagnosis have the capabilities demonstrated by J.W.C. and the other patients previously

reported. We also believe that these capacities may underlie the partial recovery demonstrated by some alexic patients (Coslett and Saffran, 1989a). To demonstrate the presence of these capacities, however, it may be necessary to adhere to procedures such as those outlined here.

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