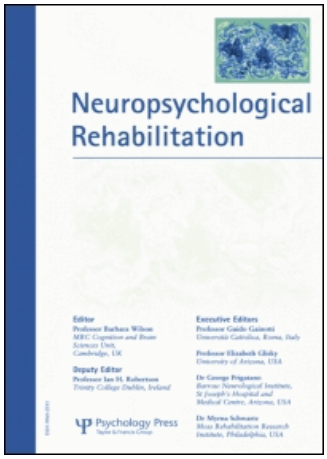

Neuropsychological Rehabilitation
An International Journal
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713684225

Using errorless learning to treat letter-by-letter reading: Contrasting word versus letter-based therapy

Karen Sage; Anne Hesketh; Matthew A. Lambon Ralph

Online Publication Date: 01 December 2005
To cite this Article: Sage, Karen, Hesketh, Anne and Ralph, Matthew A. Lambon (2005) 'Using errorless learning to treat letter-by-letter reading: Contrasting word versus letter-based therapy', Neuropsychological Rehabilitation, 15:5, 619 - 642
To link to this article: DOI: 10.1080/09602010443000155
URL: http://dx.doi.org/10.1080/09602010443000155

NEUROPSYCHOLOGICAL REHABILITATION
2005, 15 (5), 619–642

Psychology Press
Taylor & Francis Group

Using errorless learning to treat letter-by-letter reading: Contrasting word versus letter-based therapy

Karen Sage, Anne Hesketh, and Matthew A. Lambon Ralph

University of Manchester, UK

Some pure alexic readers have been shown to activate lexical and semantic knowledge under brief presentation conditions. This ability is not seen when letter-by-letter reading accuracy is high or the reading impairment is very severe. It is also unlikely to occur under normal untimed presentation because the pure alexic will make deliberate use of their letter-by-letter strategy. This paper presents data from a moderately severe letter-by-letter reader, FD, who had visual processing problems affecting reading. He also had other mild aphasic characteristics. FD showed implicit reading abilities under brief presentation conditions, being able to make lexical decisions and semantic categorisations well above chance.

FD was given two therapy programmes, the first, whole word therapy to exploit this implicit ability and the second to improve letter-by-letter accuracy and speed. FD showed some improvement in reading ability after both therapy programmes, particularly for words of personal interest to him. His letter naming accuracy and reading of visually similar words were the most resistant to change. A striking effect of therapy was the cessation of FD's letter-by-letter reading and the emergence of some of the characteristics of deep dyslexia. Even when therapy concentrated on letter accuracy, FD did not revert back to his original letter-by-letter reading strategy.The results are discussed with reference to the two theories of pure alexia. Some conclusions are drawn about the need for therapists to examine and exploit all residual reading skills when devising therapeutic programmes.

Correspondence should be sent to Karen Sage, Human Communication and Deafness, Faculty of Education, University of Manchester, Oxford Road, Manchester, M13 9PL, UK. Tel: +44 (0) 161 275 3369, Fax: +44 (0) 161 275 3373, Email: karen.sage@man.ac.uk

We are indebted to FD and his family for their generous donations of time and effort.

http://www.tandf.co.uk/journals/pp/09602011.html DOI:10.1080/09602010443000155

INTRODUCTION

Normal single word reading is achieved efficiently and accurately by carrying out parallel letter processing in order to recognise the word as a whole. Letter-by-letter reading (or pure alexia) describes a well-documented disorder (see Behrmann, Plaut, & Nelson, 1998a for a review of published cases) following brain trauma typically in the left occipital lobe whereby the reader is unable to read single words quickly. Instead, reading is achieved by looking at each letter individually, identifying the letters serially and building these into words. This method of reading is inevitably slow with longer words taking much longer to recognise than shorter ones. There is general agreement that the deficit at the heart of letter-by-letter reading is in early visual-orthographic processing, which may reflect a more generalised visual impairment (Behrmann, Nelson, & Sekular, 1998b, Farah & Wallace, 1991, Mycroft, Behrmann & Kay, in press).

The clinical presentation described above suggests that these patients do not have any word level recognition abilities and thus resort to the compensatory letter-by-letter strategy to identify each word. Yet there have been a number of cases described in the literature which demonstrate evidence for at least partial activation of lexical and semantic representations. This includes the influence of frequency and imageability on the patients' reading times (Behrmann et al., 1998a), the word superiority effect (better letter recognition in word than nonword contexts: Bub, Black, & Howell, 1989) and standard Stroop interference (slower naming of ink colour when the word corresponds to a different colour name: McKeeff & Behrmann, 2004). In addition, a few patients exhibit above chance performance when making lexical decisions and semantic judgements despite being unable to identify the words explicitly (the Saffran effect: Lambon Ralph, Hesketh, & Sage, 2004; Saffran & Coslett, 1998). In order to demonstrate this effect, pure alexics are prevented from carrying out their usual letter-by-letter analysis of the word by using brief presentation (typically 250 ms). Although this duration is ample for normal readers, pure alexics are unable to report any letters from the word and often claim not to have seen anything at all. The above chance performance on brief presentation is, itself, subject to lexical influences such as frequency and imageability as well as to the difficulty of the decision the client is asked to make (Lambon Ralph et al., 2004; Shallice & Saffran, 1986). The ability to demonstrate partial lexical/semantic recognition in the absence of explicit identification of the word has not been found in all pure alexic patients (e.g., Patterson & Kay, 1982). Lambon Ralph et al. (2004) argue that the presence of the Saffran effect is linked to the severity of the patient's reading disorder—only patients with very slow and often errorful reading tend to show the Saffran effect. Likewise, Behrmann et al. (1998a) found that the size of frequency/imageability effects in their case series

of pure alexic patients was correlated with the severity of their reading impairment.

Remediation for letter-by-letter readers

The full therapeutic implications of the Saffran effect and other evidence for partial lexical/semantic access in pure alexia have not been explicitly explored in the remediation literature for letter-by-letter reading. These therapy studies can be divided into those which have tried to improve the speed and accuracy of the letter-by-letter strategy and those which have encouraged the reader to abandon this technique and to improve whole word recognition.

Among those methods that retain the letter-by-letter approach are therapy programmes which involve additional kinaesthetic information. Patients have been asked to copy out characters (Kashiwagi & Kashiwagi, 1989), to trace over textured letter shapes (LaPointe & Kraemer, 1983) or to trace letters onto the palm of the hand (Lott, Friedman, & Linebaugh, 1994) while saying them aloud. All these techniques have led to significant improvement in reading speed. Lott and Friedman (1999) described a patient severe enough to require work on letter accuracy prior to this type of therapy. Their patient DL improved his letter identification accuracy such that, by the end of therapy, he was able to read non-treated words.

Other researchers have discouraged the linear, letter-by-letter reading technique and attempted to enable more normal word recognition where the letters are subject to parallel processing. The therapy described by Behrmann and McLeod (1995) involved attending simultaneously to the two ends of a letter string, thereby encouraging parallel rather than linear processing. Following this therapy, although there was some change in the speed and pattern of the patient's letter processing, a significant length effect still persisted. Although Behrmann and McLeod (1995) aimed to achieve a more normal word recognition strategy, their therapy approach still concentrated on letter processing and did not specifically involve whole word recognition. This idea was tested by Friedman and Lott (2000) who hypothesised that concentration on semantic tasks rather than reading per se might encourage whole word recognition perhaps through a greater use of any right hemisphere reading ability. Their patient RS presented with a mild pure alexia. In therapy, he was asked to make semantic judgements to briefly presented words. RS showed improvement on the trained words but no generalisation. Friedman and Lott agreed that RS's improved reading resulted from strengthened links between whole word visual analysis and the orthographic lexical entry for the word and consequently, that improvement might be expected to be item specific.

Gonzalez Rothi, Greenwald, Maher, and Ochipa's (1998) patient MC showed the typical features of a letter-by-letter reader as well as implicit knowledge about words which was demonstrated through semantic priming

of lexical decision. The therapy consisted in asking MC to make semantic categorisations about briefly presented words. This prevented explicit letter-by-letter reading and encouraged attention to the whole item. The therapy did not improve MC's semantic categorisation accuracy nor did it reduce the length effect on his reading times.

With the exception of the case reported by Lott and Friedman (1999), all these patients had relatively mild alexia in that single letter naming was accurate and in some cases their single word reading was also accurate. The patient reported in this therapy study, FD, had a profound alexia along with other mild aphasic symptoms, which allowed us to investigate whether reading therapies can be effective for more severe cases in addition to the milder patients reported in the existing literature. Previous therapies either have concentrated on letter level interventions or have tried to improve whole-word recognition. As far as we are aware no previous study has compared these two approaches within the same patient. These two therapy types have added interest for FD given that he demonstrated a clear Saffran effect (Lambon Ralph et al., 2004). While he attempted a letter-by-letter strategy for many words, he also demonstrated partial lexical-semantic knowledge not only in formal, brief presentation experiments but also by offering partial definitions of words included in standard reading assessments. This suggests that there was room for improvement of both his letter-by-letter strategy and whole-word recognition.

In order to compare each arm of the therapy as closely as possible we utilised the same type of intervention method—in this case, errorless learning. This seemed particularly appropriate for FD given that both his letter-by-letter attempts and word recognition were peppered with frequent errors. It is possible that the errors themselves might be reinforced and thus limit the range of recovery—a situation which would be avoided by an errorless learning intervention. There are very few reports on the use of errorless learning as a rehabilitation technique in the aphasia literature (see Fillingham, Hodgson, Sage, & Lambon Ralph, 2003 for an overview) and this paper is the first to apply its principles to the remediation of a letter-by-letter reader. The key notion behind this form of therapy is that for some situations, errant behaviour can be self-reinforcing—that is to say, the act of producing an error for a certain stimulus can strengthen this incorrect association, such that the error will be even more likely the next time the stimulus is presented. This cycle can be broken if the learner is prevented from making errors, instead allowing only correct stimulus-response associations to be formed and strengthened. This case report is the first, to our knowledge, to use an errorless learning paradigm in the remediation of an acquired dyslexia. Both letter and whole word recognition therapy was given in order to contrast the two treatments and to ascertain whether one therapy was more effective than the other in enabling FD to read accurately and with speed.

CASE HISTORY

Social background

FD was a 73-year-old man. He had previously held a variety of jobs including running a grocers shop and working for a tyre company. He had recently become a Jehovah's Witness and was keen to continue his evangelistic work which required considerable reading of the associated literature. In order to function well within the Witness group, FD needed to return to door to door evangelism, distributing Witness literature where possible.

Medical history and onset

FD's main neurological problems arose in the latter half of 1997. He had previously experienced two neurological vascular incidents which did not involve hospital admission, where a left hemiparesis resolved and there were no apparent cognitive or communication symptoms. In August 1997, he was admitted to hospital with speech difficulty and memory loss. CT scan showed a extensive haemorrhagic infarct in the left parietal lobe extending inferiorly into the left temporal lobe (see Figure 1). Evidence of previous old cerebral infarcts was seen in the right parietal and right occipital region. He underwent a right carotid endocardectomy in September 1997, but one week later was readmitted to hospital with a frontal headache and loss of vision. Medical examination revealed a right hemianopia, low visual acuity on the right and unsteady gait. A further CT scan showed a left occipital haematoma and a fresh bleed in the occipital horn of the right lateral ventricle (see Figure 1). At the time of his discharge home in November 1997, he still had some right visual field difficulties,

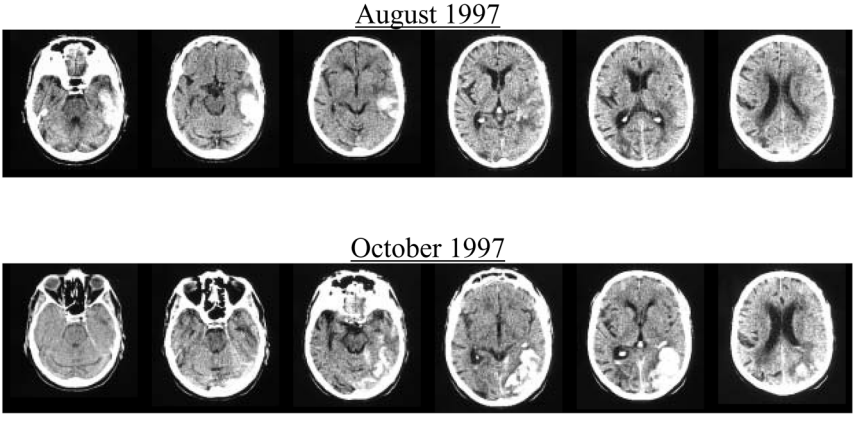

Figure 1. CT scans for patient FD

an improving gait with some residual unsteadiness and persisting communication difficulties for which he was referred for rehabilitation.

Neuropsychological information

An assessment of FD's reading and related language skills was made using psycholinguistic measures. The tests and results are described in detail below. These showed that FD had good auditory comprehension but severely impaired reading ability. His spoken output revealed moderate word finding difficulties with semantic paraphasias evident in naming tests and occasionally in connected speech. Although these paraphasias did sometimes disrupt communication, FD was not concerned about his speech and wanted to put all his efforts into reading. In view of this, more in depth assessments of his visual skills were undertaken and are reported below.

Auditory processing

FD's performance on an auditory lexical decision task suggests that he had no difficulty in this area. The ADA Comprehension Battery (Franklin, Turner, & Ellis, 1992) requires patients to listen to a word or nonword and say whether they recognise it as a real word. FD scored 75/80 which was within the normal range (normals make between 0 and 7 errors, Franklin et al., 1992). FD was also asked to complete an auditory synonym judgement task in which he listened to two words and made a decision about whether the two were similar in meaning (e.g., marriage–wedding). FD scored 55/60 with no imageability effect (PALPA 49, Kay, Lesser, & Coltheart, 1992). When assessments were purely auditory, FD was able to perform well. If picture material was involved in assessing his auditory skills, FD's performance became impaired. For example, on an assessment of spoken word to picture matching with all semantic distractors, FD scored 79/100 which is outside the normal range (normals range between 96 and 100). Overall, this suggests that FD did have good auditory skills but that his visual skills, not just for reading but also in picture recognition, were impaired.

Visual processing

To understand further the nature of FD's visual difficulties, the Visual Object and Space Perception Battery (VOSP; Warrington & James, 1991) was administered. This assessment involves four subtests of object and four of space perception. FD's performance was variable on both object and space perception tasks. He passed incomplete letters (16/20, a task requiring recognition of the letter), progressive silhouettes (recognition of a silhouette through pictures of gradually increasing clarity), dot counting (9/10, reporting the number of dots

on a page) and number location (7/10, selecting from a display of numbers the one corresponding to a dot on the sheet below the display). He was unable to perform to a satisfactory level (for people over 50) on silhouettes (9/15, recognition of silhouettes from a less obvious angle), object decision (13/20, identifying a real object from a choice of two, one of which is a similar shape but not a real object), position discrimination (14/20, selecting from a choice of two, which box contains the dot in the exact middle of the box) and cube analysis (3/10, stating the number of cubes in drawings of 3D constructions).

A number of subtests from the Birmingham Object Recognition Battery (BORB; Riddoch & Humphreys, 1993) were also carried out. Again his performance was variable. He was able to carry out normally Item Match (30/32, matching the same class of object, e.g., two different types of chair); Foreshortened Match (25/25, matching normal and foreshortened depictions of real objects) and Minimal Features Match (24/25, where three pictures are presented, one of the target shown in a standard viewpoint, the second of the same object from a different viewpoint and the third a different object which is visually similar to one of the other two pictures). His performance was not within normal range on any of the Object Decision tests where he scored 22/32 on the easy (mean for elderly controls 30.5, SD 1.4, range 28–30) and 21/32 on the hard items (mean for elderly controls = 27.0, SD 2.2, range 22–30). Scores on both these subtests were more than two standard deviations away from the norm.

The results from the VOSP and BORB tests indicate that FD did have some perceptual deficits and are consistent with the notion that letter-by-letter reading is underpinned by a general visual impairment (Behrmann, Plaut, & Nelson, 1998)

Semantics

FD scored 42/52 on the Pyramids and Palm Trees three picture version (Howard & Patterson, 1992) which was outside the normal range (49–52). FD's good performance on auditory semantic judgements (see auditory processing above) would suggest that the visual problems were a major cause of the low score. However, there is some suggestion that FD may have had mild additional semantic problems particularly when assessment of his naming skills are reviewed.

Naming

FD revealed moderately severe naming problems on the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1976) and the Graded Naming Test (McKenna & Warrington, 1983) scoring 11/60 and 3/30 respectively. In view of his visual processing difficulties, a comparison was made of naming to picture and naming to definition. This test consisted of 50 items which were

presented both as black and white line drawings and via verbal definitions (e.g., "queen—the wife of a king or a female sovereign"). The materials were counterbalanced over two sessions. FD named 44/50 words to definition (normal elderly controls score 47–50) and 33/50 pictures correctly (normal elderly controls score 48–50). The difference between the two presentation modes is significant (McNemar, one-tailed, $p < .01$) and suggests that FD's anomia was compounded by his visual difficulties whenever picture materials were used. The fact that his performance on naming to definition fell below the normal range together with his word finding difficulties in spontaneous speech suggest that FD had an additional impairment in the speech production system.

Repetition

FD had excellent repetition skills as shown by high scores on both word and nonword tasks. He scored 79/80 on the ADA (Franklin et al., 1992) word and nonword repetition (normal range is 52–80), at ceiling (24/24) on the PALPA (Kay et al., 1992) syllable length word repetition and 29/30 on the PALPA syllable length nonword repetition. He scored 87/90 on the morphologically complex word repetition (PALPA 11).

Writing

FD was impaired at both oral and written spelling. On oral spelling of words varying in length (PALPA 39, Kay et al., 1992) he scored 15/24 with a significant length effect (Jonckheere trend, $z = 1.85$, one-tailed, $p < .05$). On written spelling of the same words, FD scored 13/24 with a similar length effect (Jonckheere trend, $z = 2.51$, one-tailed, $p < .01$). There was no clear error pattern. FD was able to write his name and address on request with only one letter omission error and three letter stroke omission errors. A short sample of free writing showed a number of errors but he was able to write fluently at the sentence level in striking contrast to his reading:

> "On Ingham (*Sunday*), I went to the Knigsham (*Kingdom*) Hall and I ment (*met*) all thee (*the*) Brothers & Sisters welcoming me back"

Word and letter recognition

FD was able to carry out all the single letter cross-case matching (PALPA 20, a:A) but when five-letter material was used (dream: DREAM or gnria: TNRIA, PALPA 21) he scored 53/60 overall with no significant difference between word and nonword pairs.

Reading aloud

FD was inaccurate at letter naming (PALPA 22) with a score of 18/26 on lower case and 15/26 on upper case naming. A timed reading test was carried out on five sets of words varying in length. The sets consisted of 15 highly frequent two-, three-, four- and five-letter words and a set of 12 personally familiar words (see Appendix 1). This latter list held names of FD's family and important places. FD's performance on reading the sets significantly deteriorated as length increased both in the time taken to read correctly measured in seconds (Kruskall Wallis, K = 6.80, $n = 75$, df 1, $p < .05$) and the likelihood of accurate reading (Jonckheere trend, $z = 4.45$, one-tailed, $p < .001$). However, the personally familiar words were much more quickly recognised and accurately read than the other word sets, even though these words ranged in length from four letters to 11 letters.

Nonword reading (PALPA 36) was attempted and abandoned at the four-letter stage, with a score of 2/24. On three occasions in the four-letter nonwords, FD was keen to lexicalise the items having read correctly the letters involved. On the other three items, he was inaccurate at identifying correctly and in order, the letters involved.

Implicit reading skills

In untimed tasks, FD's reading was characterised by letter-by-letter attempts at identifying the word most commonly leading to omission errors. Occasionally, particularly for highly familiar words, FD gave an approximate definition without recognising the word (e.g., EXIT "a label you put on a door to get a way out of it"). FD also demonstrated some implicit lexical and semantic knowledge under brief presentation conditions. These are fully explored elsewhere (Lambon Ralph et al., 2004). FD's accuracy on these tasks was modulated by the difficulty of the task and by lexical-semantic factors. FD showed better than chance performance in nonword lexical decision, with better accuracy on the illegal versus legal version. He was also more reliable when making semantic judgements about concrete than abstract concepts, familiar than unfamiliar words and when asked to make a decision involving a two rather than a four choice alternative.

TABLE 1
Baseline two, three, four and five letter length, high frequency words and personally familiar words, with timings

	Two letters	*Three letters*	*Four letters*	*Five letters*	*Familiar*
Number correct	14/15	14/15	11/15	7/15	12/12
Mean time (secs)	17.46	20.33	36.92	50.06	4.83

Summary

FD presented with good auditory comprehension but impaired visual comprehension, reading, and naming. Further assessment of his reading skills showed good letter processing albeit not perfect. There was a noticeable contrast between his auditory and visual semantic scores and better naming to description than picture naming, both being consistent with his generalised visual perceptual deficit. There was also evidence of an additional anomia in these naming tests and spontaneous speech. FD's poor reading accuracy,

TABLE 2
Composition of therapy word lists

Word type	*Example*	*Matched for*
12 matched triads (of 4, 5, 6 and 7 letter words)	Fool, food, foot trace, tramp, trail expert, expire, export curious, currant, curtain	Length (mean 5.5, SD 1.13) Frequency *(mean 39.50, SD 44.21) Imageability **(mean 485.33, SD 83.01) Familiarity ***(mean 532.21 SD 45.27) AoA****(mean 338.00, SD 79.25)
24 words for Activities of Daily Living	Stop, exit, police, service, medicine, telephone, Tuesday, Friday	Length (mean 6.39, SD 1.72) Frequency *(mean 105.57, SD 119.11) Imageability **(mean 525.59, SD 85.51) Familiarity ***(mean 568.56, SD 21.07) AoA ***(mean 317.93, SD 64.68)
21 personal interest words	Faith, spirit, sermon, prophet, kingdom, religion, scripture	Length (mean 6.86, SD 1.28) Frequency *(mean 58.81, SD 83.25) Imageability **(mean 478.80, SD 94.65) Familiarity ***(mean 518.83, SD 54.89) AoA ***(mean 353.00, SD 91.25)
Includes 9 important place names	Bury, Oldham, Warrington	length (4–10 words)

*Kucera and Francis (1967), **Pavio, Yuille, and Madigan (1968), ***Gilhooley and Logie (1980).

NB. Each set (control, word therapy and letter therapy) contained four triads of three words each ($n = 12$), eight ADL words and 10 personal words, three of which were place names, giving a total of 30 words per set.

increased time taken to read longer words and habit of reading aloud each letter, points to the peripheral dyslexia known as letter-by-letter reading.

THERAPY METHOD

Three lists of words were drawn up, matched across lists for length, frequency, imageability, familiarity and age of acquisition as well as for number read correctly (see Appendix 2). In each experimental set, there were four sets of triads where the first three letters were the same. In order for FD to show improvement on these triads, attention would need to be paid to the endings of the words. A further eight words in each set were linked to activities of daily living (ADL). Finally there were 10 words in each set which were chosen by FD because he particularly wished to learn them (personal interest). Within each personal interest set were three place names and seven words related to his religious beliefs. These words are not highly frequent or familiar in the standard ratings.

A single baseline assessment of all words was undertaken three weeks before therapy began. Words were then assigned to the three experimental lists each consisting of 30 items to be used in treatment 1, 30 in treatment 2 and 30 as an untreated control. FD was given a 30 second limit to read each word throughout baseline and treatment.

TREATMENT

Two treatment methods were designed, one a "whole word" approach and the other an attempt to improve the accuracy of letter-by-letter reading. The whole word approach was carried out first because it was predicted that the effect of this might be word specific whereas an improvement in letter-by-letter reading should generalise to untreated items. In contrast to other clients in the therapeutic literature (Behrmann & McCloud, 1995; Friedman & Lott, 2000; Kashiwagi & Kashiwagi, 1989; LaPointe & Kraemer, 1983), FD was considerably poorer at both accuracy of his letter naming and word recognition. Asking FD to read aloud spontaneously was avoided so as to prevent reinforcement of the errors (Wilson, Baddeley, Evans, & Shiel, 1994). This is particularly important in an errorless learning paradigm (Fillingham et al., 2003). A regime of monitored daily practice was set up with FD's family. Both FD and his family were well motivated to carry out the therapy and FD participated actively throughout. Tailby and Haslam (2003) suggest that for errorless learning to be maximally effective, it requires the active engagement of the participants.

Treatment 1: Word therapy

In order to improve FD's ability to recognise whole words, repeated presentations were made using an error-free learning method. Each word was produced

in Arial 18 point on individual cards. The therapy took place over a four-week period during which he worked with his family on 10 words per week. The therapy was demonstrated by the therapist and a set of written instructions left for the family members to follow during the week. The therapy procedure was to go through the set of words with FD, showing him each card and telling him the word, without FD saying anything himself. In this task, FD participated by looking at and concentrating on each word as it was read to him. Each word was presented again. The therapist/family member said the word while FD looked at the card, then FD was asked to repeat the word five times while still looking at the card. FD was normally able to repeat words without difficulty. However, if at any time he made a mistake, the word was said to him again and he was asked to repeat it correctly a further five times. The family were encouraged not to test him on spontaneous reading of the words. The therapist visited once a week for a treatment and assessment session. Criterion for success was set at 80% correct reading within 30 seconds. FD scored 16/30 (53%) at the end of the four-week period and so an amendment to the therapy procedure was instigated which required the family to draw attention to the visual features of the word as well as reading the word aloud. For this therapy, the words had an outline shape drawn around them and FD was asked to focus on this and use his finger to draw round the shape as the family member commented on it. Features for comment were length, double letters and letters which went above or below the main word profile. Visually similar words had the final letters written in red and FD was asked to look particularly at the end of the word and its shape (see Appendix 3). The family were asked to practise this with FD over a further three-week period, following which progress was re-assessed to see if 80% criterion had been met.

During this period, FD was admitted to hospital for non-neurological medical problems and continuity of practice was disrupted. Reassessment again did not reach the 80% criterion (he scored 17/30, 57%) and given that FD's motivation to pursue this with the same set of 30 words was dwindling, it was agreed to move onto the second treatment approach (letter accuracy and speed). From start to finish, the word therapy took place over seven weeks.

Treatment 2: Letter therapy

The second therapy aimed to improve both accuracy and speed of FD's letter-by-letter reading. FD's letter naming had showed frequent errors, so training of accurate single letter naming was carried out, before treating the letter therapy word list. FD was presented with cards with a sequence of five letters. Each letter was traced on FD's palm by the helper who said the letter for him and then asked him to repeat it. Letter tracing by the helper was used rather than FD copying the letter with his own finger because FD did not always follow the normal motoric sequence when tracing the letter (e.g., "P" was

produced by tracing the semicircle first, starting from the bottom, and then the upright, again starting from the bottom). Each letter was tackled in turn until all five had been completed. Ten cards were presented giving a total of 50 letters. During the second week, both upper and lower case letters were used, though never within the same sequence. As well as single letter practice, FD tried three letter sequences, using the same procedure. FD was shown a card with three letters, the family member traced all three letters on his palm, saying each one as it was traced and then FD repeated all three together. If accuracy was compromised, FD and the family member reverted to the single letter procedure outlined above. Because letter identification was so disruptive to his word recognition, criterion for success was set at 80%. However, there was little change in accuracy after three weeks of practice and FD began the real word set with a maximum single letter accuracy of 76% (see Table 3).

Letter-by-letter therapy began with the shortest words (four and five letters). A hierarchy of cueing was used over the week:

1. FD looked at the card while the family member read aloud the word, one letter at a time. As each letter was read aloud, the letter was traced onto FD's palm. The family member then said the word and FD repeated it.
2. The same procedure was followed as in step 1 with the addition that following the tracing of the letters FD was asked to say the word (which he could usually remember from the previous step).
3. After approximately five words had been read, the cards were shuffled and step 2 repeated. This time he was unable to use immediate recall.
4. When FD became consistently successful at step 3, he was asked to read aloud the letters before saying the word himself, i.e., the helper's explicit support was withdrawn. However, if an error was made, then the helper took FD back to step 2, supplying the letters for him before he said the word. This procedure follows the staircase method procedure used in some error reducing studies (e.g., McCandliss et al., 2002) which may allow errors to occur but which seeks to reduce the possibility of an error

TABLE 3
Results of letter naming training

	Week 1	*Week 2*		*Week 3*
	Lower case	*Lower case*	*Upper case*	*Upper case*
Individual letters, $n = 50$	34 (68%)	37 (74%)	35 (70%)	38 (76%)
3 letter sequences, $n = 30$	22 (73%)	20 (67%)	23 (77%)	21 (70%)
Total letters correct, $n = 80$	56 (70%)	57 (71%)	58 (73%)	59 (74%)

by taking the task back to an earlier, easier step if any errors arise. FD worked for three weeks on the 30 items of the letter therapy set and by the end of that period reached 63% (19/30) success rate on them. From start to finish, the letter therapy period took place over seven weeks.

RESULTS

Accuracy measures

Data were analysed using either the Chi square (χ^2) or McNemar test of significance dependent on whether the samples were independent or repeated measures. One-tailed tests were used when the direction of the effect was predicted a priori. For example, therapy should lead to an improvement in performance, or reading accuracy should decrease in letter-by-letter readers when given longer words. Reassessment of all three word lists occurred after each phase of treatment and four months after the end of treatment. Figure 2 shows the overall results of the two therapy types on accuracy across all word sets. The three sets were closely related on performance at baseline. Following the whole word therapy task, significant improvement occurred on the treated items when compared with baseline performance of the same items (McNemar, one-tailed, $p < .01$) and when compared with the letter therapy items and control items ($\chi^2 = 7.7$, *df* 2, $p < .01$) which remained stable, as had been predicted. FD had achieved a maximum score of 14/30 on the treated items and this gain was maintained over the second treatment period (13/30) and at follow-up (13/30). The letter therapy items were the focus for the second period of treatment. They remained stable after the first treatment to the whole-word set (8/30 correct) and then showed significant improvement following specific intervention (18/30, McNemar, one-tailed, $p < .001$). This improvement was maintained relatively well at the follow-up assessment (15/30).

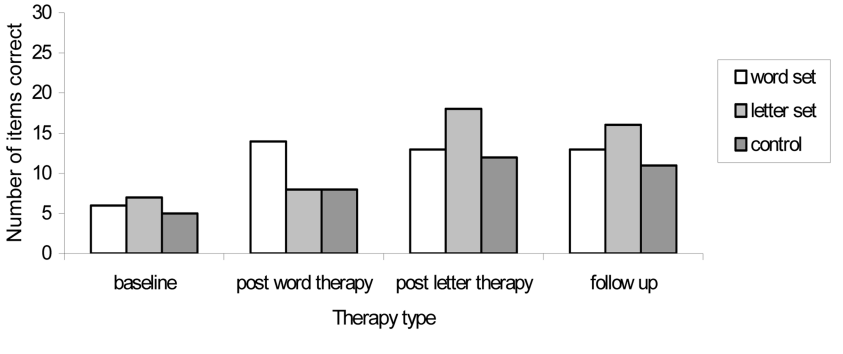

Figure 2. Results of the two therapy types on accuracy across all word sets.

Letter therapy might be predicted to generalise to untreated items in the control set and to boost performance on items in the first word therapy set. The control set changed from a baseline of 5 to 12 after the letter therapy (McNemar, one-tailed, $p < .05$). At follow up, the control list accuracy remained stable (11/30). Thus, as predicted, there was generalisation to the control set following letter-based therapy. We suggest that this generalisation occurred because of the letter therapy rather than a non-specific effect, since performance on the control set after letter therapy remained stable rather than continuing to increase.

Improvement was evident in both the word triads ($n = 12$) and in the words of personal interest and ADL ($n = 18$), although greater gains appeared to be made on the personal interest sets. However, the number of items for each therapy set was too small to be able to demonstrate this formally.

Timing measures

Measures of the reading times, whether correct or incorrect, were also taken. As FD improved, he sometimes read the word aloud before timing with a stop watch could begin. For these calculations the time awarded for this speedy reading was set at a conservative measure of one second. A 30 second upper time limit was used. The summary of FD's reading times for each word set are shown in Table 4. There was a significant change in reading times across the four time periods (F (3, 267) = 15.6, $p < .001$). Post hoc comparisons with Bonferroni correction showed that the reading times at baseline were significantly slower than all three other time periods. There were no significant differences in reading times after the different therapies or at follow up.

TABLE 4
Mean time in seconds for correct responses at baseline, during therapy and at follow-up

		At baseline	*After word therapy*	*After letter therapy*	*At follow up*
Word therapy	Mean	17.17	5.3	8.92	5.31
	SD	11.3	6.81	7.55	4.03
	Range	4–30	1–20	2–29	1–14
Letter therapy	Mean	8.29	6.5	8.11	6.40
	SD	6.75	6.38	7.98	5.82
	Range	3–22	1–15	2–29	1–20
Control	Mean	13.8	2.63	9.92	5.00
	SD	10.52	1.60	4.62	4.73
	Range	6–30	1–5	2–15	1–17
Overall	Mean	12.78	4.97	7.74	5.64
	SD	9.75	5.96	7.01	4.89
	Range	3–30	1–20	2–29	1–20

Reading strategy

The words from all three sets were coded according to whether FD used a letter-by-letter strategy or attempted to read the word as a whole. If FD tried to read aloud the letters at any point in his response, it was coded as a letter reading strategy. If FD made an immediate response or did not attempt to read the word, then it was coded as a whole word response. There was considerable change in the rate of each strategy used as the study progressed. At baseline, overt letter-by-letter attempts were high (see Figure 3a). Letter-by-letter use for words in all three groups (whole word therapy, letter therapy and control) reduced markedly following word therapy which is compatible with the therapy given (i.e., aiming to improve whole word recognition). However, FD's use of letter-by-letter reading remained low even after letter therapy which had focused exclusively on a letter-based strategy. Even when he could not recognise the word, he still did not use the overt letter-by-letter strategy which had been so pronounced at initial assessment. On the few occasions when FD did still use a letter-by-letter strategy, he then usually correctly named the item. In contrast, FD made only occasional use of whole word reading at baseline (see Figure 3b), making more use of that strategy after the word therapy treatment and he continued to use this strategy during the letter therapy and at follow up. A further striking change in response strategy was that, at baseline, FD made an attempt at all items but as therapy progressed, he began to respond by saying that he could not read certain words. This was particularly noticeable in the triad set.

Error types

All errors were divided according to their relationship to the target using the following categories: visual, semantic, visual/semantic, omission, unrelated, and description. For an error to be classified as visually similar, at least 50% of the target letters had to appear in the response, for example, TRADE—"trace", EXPOSE—"expert", LIFT—"left". An error was classed as semantic if it was directly linked semantically to the target, for example OLDHAM—"Withington", CURRANT—"cake", TRADE—"plaster", SERVICE—"helper". If a word was both visually (at least 50% shared letters) and semantically related then it was classified as visual/semantic, for example SALE—"Hale", SERMON—"service", TRUTH—"trust". An omission classification was used when FD read aloud letters (correctly or incorrectly) but failed to say what the word was and for those responses where he said he could not read it aloud. An unrelated classification was given when the response was not related visually or semantically to the target, for example: ENTREAT—"shower", STOP—"help", TRACE—"test". FD made only two nonword errors throughout which were classified as unrelated (ENTREAT—"entrain" and EXPERT—"extrait"). A descriptive error was one where FD gave a partial

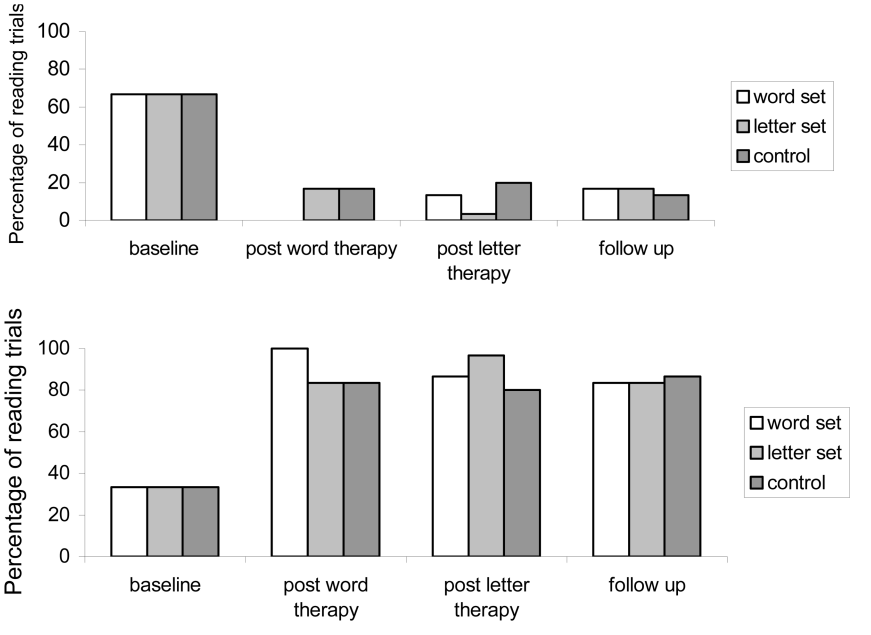

Figure 3. (a) The use of the letter-by-letter strategy at each stage of the therapy programmes. (b) The use of whole word reading strategy at each stage of the therapy programmes.

definition of the word, for example: SURGERY—"something to do with doctors", ECCLES—"where X lives", RELIGION—"something religious again".

Changes in error pattern

There was a steady decrease in errors overall as FD's reading improved. Figure 4 outlines the proportion of error types from baseline, following word therapy, letter therapy and at follow up.

Percentage changes in error types are reported so that comparisons between different numbers of errors can be shown across time. At baseline, omission errors were the largest error category (60%). Following word treatment, this percentage reduced to 10% while visually related errors increased from 19% to 40%. These errors reduced to 23% following the letter therapy and at follow up. Semantic errors, which accounted for 3% of errors at baseline, also increased to 17% after the whole word treatment. Semantic errors reduced to 4% following letter therapy but at follow up accounted for 12% of the errors made. The increase in both these error types might be considered a direct result of the attention to the whole word rather than individual letters with a resultant error pattern consistent with deep dyslexia rather than pure alexia (Coltheart, Patterson, & Marshall, 1980).

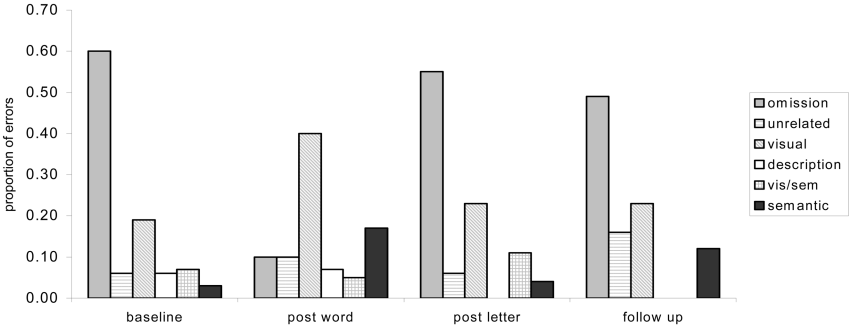

Figure 4. Proportion of error types at baseline, following word therapy, letter therapy and at follow up.

DISCUSSION

In summary, FD showed improvement on treated lists after word and letter therapy and altered his reading strategy after the first whole word therapy from that of letter-by-letter reading to attempted whole-word recognition. This is consistent with the significant reduction in his reading times after whole-word therapy.[1] Saffran and Coslett (1998) have suggested that the letter-by-letter strategy employed by pure alexics may in fact impede their implicit recognition skills and indeed their patient, ML, "seemed to consider the different strategies mutually exclusive in their efficacy" (p. 455, Shallice and Saffran, 1986; see also Coslett & Saffran, 1989). FD did not show the flexibility to alternate between strategies and did not revert back to his original letter-by-letter strategy when the treatment regime might have been expected to encourage him to do so (i.e., when a second therapy programme concentrated specifically on letter-by-letter accuracy). When asked at follow up whether FD had found any improvement in his ability to read his religious magazine, he reported that he was able to gauge the nature and content of some articles and use this when evangelising on the doorstep. He cited an incident where a woman at the door had a "cow" (a semantic paraphasia for "cat") in the hall and he knew that there was an article on pets in the magazine so he was able to direct her to this. FD's orthographic recognition problems did not improved with practice. FD was unable to improve his accuracy in letter identification (Table 3) and found work on the triads particularly difficult. On these words, he needed to pay particular attention to the ends of the words in order to disambiguate them. Even though his overall letter naming

[1]It is possible that FD might have been using a mixture of whole word reading and *covert* letter naming at this point. We think this unlikely given that FD's letter naming was inaccurate and very slow. This stayed the same even after letter therapy. Given his change in overt reading strategies and the significant reduction in reading times, we think the most plausible explanation is that FD was simply attempting whole-word recognition without any letter-by-letter reading.

accuracy did not improve, there was a positive improvement in reading after letter therapy even on the triad sets. This may have been due to FD's increased attention to providing an accurate answer rather than a string of letter names. At baseline, FD responded to every word he was asked to read, whereas at reassessment after the letter therapy, he was more likely to say he could not read an item than to attempt a letter-by-letter analysis. FD stopped using this as a strategy after baseline and so improvements in accuracy at the letter therapy stage may be due to FD applying a whole word strategy to the letter therapy set also.

The increase in semantic and visual errors, an imageability and frequency effect (Lambon Ralph et al., 2004) as well as a persistent difficulty in reading nonwords, suggests that FD's reading profile became more like that of a deep dyslexic but that this change was more profitable to him when trying to read for meaning. Buxbaum and Coslett (1996) have also described a case of a mixed pure-deep dyslexic who made increasing numbers of semantic errors under brief presentation conditions. Saffran and Coslett (1998) suggested that there are two parallel reading systems in operation, one moderated by the left hemisphere, the other by the right. The left supports the explicit identification of letters and words while the right contributes implicit recognition up to the level of word meaning. The relative preservation of each of these systems following brain injury will therefore be revealed by the extent of letter-by-letter accuracy and implicit reading skills, though whether or not right hemisphere reading would be possible for FD, given his pre-existing right hemisphere infarcts, is unclear. Under Saffran and Coslett's account, it would appear that FD's access to whole word semantic information was blocked by the letter-by-letter strategy he was using at the start of therapy. Other work proposes that pure alexia reflects damaged visual processing with a single, interactive word recognition system (Behrmann et al., 1998b). Under this formulation, letter-by-letter readers make use of any remaining semantic, lexical and letter information. FD clearly had severe letter recognition problems which were resistant to therapy and so a visual strategy such as letter-by-letter reading would be unlikely to provide a useful compensatory strategy for him in the long term. Dispensing with this strategy enabled him to gain some sense of meaning from text and yet such a counter-intuitive approach to improving reading behaviour, where what is required of the patient is a complete change of strategy away from letter-by-letter reading, is unreported within the therapeutic literature. The pattern is rather the reverse. For example, Landis, Regard, and Serrat (1980) described a case where implicit skills decreased as letter recognition skills improved.

In order to manipulate the two distinct chosen strategies (letter-by-letter or whole word reading), the study also needed to ensure that the targeted strategy would be carried out during the therapy programme. Errorless learning was an efficient way of doing this. FD and his family were active participants in the therapy programme, a key requirement for errorless learning methods

to succeed (Tailby & Haslam, 2003). When FD did not recognise what he was reading during therapy, he did not have to make an incorrect guess, an important difference to other studies treating letter-by-letter readers. Whole word recognition had previously allowed errorful reading attempts with corrections following the error (Friedman & Lott, 2000; Behrmann & McLeod, 1995). These clients were relatively mild, with accurate letter naming skills. However, FD's severity of letter naming accuracy meant that if errorful therapy had been used, then he would have been provided with an incorrect auditory model and so have been unlikely to identify the word. Switching strategies is hard to achieve when brain damage has occurred, especially following extensive damage such as incurred by FD (Lott & Friedman, 1999). Yet within the errorless learning paradigm, FD switched from inaccurate letter-by-letter reading to whole word reading, with no persuasion from the therapist. In this sense, his switch in strategy was effortless, even though reading remained a significant challenge for him. There are two possible reasons why this approach was effective in bringing about a switch from the letter-by-letter strategy: first, the whole word training removed the need to use that strategy and second, the alternative strategy was introduced in an errorless manner. It is worth noting here that, previously, when FD had been asked to attempt whole-word recognition in brief presentation experiments (Lambon Ralph et al., 2004)—an inherently errorful paradigm—he had been very reluctant to attempt reading in this fashion and preferred a letter-by-letter approach.

In conclusion, this study suggests that therapists should investigate both the letter recognition and the implicit reading skills of the pure alexic client in order to find out:

1. Where clients lie within the severity range of pure alexia, i.e., are they likely to show implicit reading skills (see Lambon Ralph et al., 2004).
2. Whether clients' visual recognition skills are able to improve (Landis et al., 1980) or are resistant to change.
3. Whether there are any semantic and visual errors to alert the therapist to using a whole word approach to therapy.
4. Whether clients will benefit from an errorless learning method which gives consistent repetitive feedback of the correct link between visual and lexical/semantic information.

REFERENCES

Baddeley, A., & Wilson, B. (1994). When implicit learning fails: Amnesia and the problem of error elimination. *Neuropsychologia*, *32*, 53–68.

Behrmann, M., & McLeod, J. (1995). Rehabilitation for pure alexia: Efficacy of therapy and implications for models of normal word recognition. In R. Berndt & C. Mitchum (Eds.), *Cognitive*

neuropsychological approaches to the treatment of language disorders (pp. 149–181). Hove, UK: Lawrence Erlbaum Associates Ltd.

Behrmann, M., Nelson, J., & Sekuler, E. (1998b). Visual complexity in letter-by-letter reading: 'Pure' alexia is not so pure. *Neuropsychologia*, *36*, 1115–1132.

Behrmann, M., Plaut, D. C., & Nelson, J. (1998a) Review and new data supporting an interactive account of letter-by-letter reading. *Cognitive Neuropsychology*, *15*, 7–52.

Bub, D. N., Black, S., & Howell, J. (1989). Word recognition and orthographic context effects in a letter-by-letter reader. *Brain and Language*, *36*, 357–376.

Buxbaum, L. J., & Coslett, H. B. (1996). Deep dyslexia phenomena in a letter-by-letter reader. *Brain and Language*, *54*, 136–167.

Coltheart, M., Patterson, K. E., & Marshall, J. C. (Eds.). (1980). *Deep dyslexia.* London: Routledge and Kegan Paul.

Coslett, H. B., & Saffran, E. M. (1989). Evidence for preserved reading in pure alexia. *Brain*, *112*, 327–359.

Farah, M. J., & Wallace, M. (1991). Pure alexia as a visual impairment: A reconsideration. *Cognitive Neuropsychology*, *8*, 313–334.

Fillingham, J., Hodgson, C., Sage, K., & Lambon Ralph, M. A. (2003). The application of errorless learning to aphasic disorders: A review of theory and practice. *Neuropsychological Rehabilitation*, *13* (3), 337–363.

Franklin, S., Turner, J. E., & Ellis, A. W. (1992). *ADA Comprehension Battery*. London: ADA.

Friedman, R. B., & Lott, S. N. (2000). Rapid word identification in pure alexia is lexical but not semantic. *Brain and Language*, *72*, 219–237.

Gilhooly, K. J., & Logie, R. H. (1980). Age-of-acquisition, imagery, concreteness, familiarity and ambiguity measures for 1,944 words. *Behaviour Research Methods and Instrumentation*, *12*, 395–427.

Gonzalez Rothi, L., Greenwald, M., Maher, L., & Ochipa, C. (1998). Alexia without agraphia: Lessons from a treatment failure. In N. Helms-Esterbrooks & A. Holland (Eds.), *Approaches to the treatment of aphasia*. San Diego, CA: Singular.

Howard, D., & Patterson, K. (1992). *Palm Trees and Pyramids*. Bury St Edmunds, UK: Thames Valley Test Company.

Kaplan, E., Goodglass, H., & Weintraub, S. (1976). *Boston Naming Test*. Boston: Veteran's Administration.

Kay, J., Lesser, R., & Coltheart, M. (1992). *Psycholinguistic Assessments of Language Processing in Aphasia* (PALPA). Hove, UK: Lawrence Erlbaum Associates Ltd.

Kashiwagi, T., & Kashiwagi, A. (1989). Recovery process of a Japanese alexia without agraphia. *Aphasiology*, *3*, 75–91.

Kucera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English.* Providence, RI: Brown University Press.

Lambon Ralph, M. A., Hesketh, A., & Sage, K. (2004). Implicit recognition in pure alexia: the Saffran effect—A tale of two systems or two procedures? *Cognitive Neuropsychology*, *21*, 401–422.

Landis, T., Regard, M., & Serrat, A. (1980). Iconic reading in a case of alexia without agraphia caused by brain tumour: A tachistoscope study. *Brain and Language*, *11*, 45–53.

LaPointe, L. L., & Kraemer, I. T. (1983). Treatment of alexia without agraphia. In W. H. Perkins (Ed.), *Current therapy of communication disorders: Language handicaps in adults*. New York: Thieme-Stratton.

Lott, S. N., & Friedman, R. B. (1999). Can treatment for pure alexia improve letter by letter reading speed without sacrificing accuracy? *Brain and Language*, *67*, 188–201.

Lott, S. N., Friedman, R. B., & Linebaugh, C. W. (1994). Rationale and efficacy of a tactile-kinaesthetic treatment for alexia. *Aphasiology*, *8*, 181–195.

McCandliss, B., Fiez, J., Protopapas, A., Conway, M., & McClelland, J. (2002). Success and failure in teaching the /r/–/l/ contrast to Japanese adults: Tests of a Hebbian Model of

plasticity and stabilization in spoken language perception. *Cognitive*, *Affective and Behavioural Neuroscience*, *2*, 89–108.

McKeeff, T. J., & Behrmann, M. (2004). Pure alexia and covert reading: Evidence from stroop tasks. *Cognitive Neuropsychology*, 21, 443–458.

McKenna, P., & Warrington, E. K. (1983). *Graded Naming Test*. Windsor, UK: NFER-Nelson.

Mycroft, R. H., Behrmann, M., & Kay, J. (in press). Evidence for a causal role of a visual processing impairment in letter-by-letter reading? *Cognitive Neuropsychology*.

Pavio, A., Yuille, J. C., & Madigan, S. A. (1968). Concreteness, imagery and meaningfulness values for 925 nouns. *Journal of Experimental Psychology*, *76*, 1–25.

Patterson, K., & Kay, J. (1982). Letter-by-letter reading: Psychological descriptions of a neurological syndrome. *Quarterly Journal of Experimental Psychology*, *34A*, 411–441.

Riddoch, M. J., & Humphreys, G. W. (1993). *Birmingham Object Recognition Battery*. Hove, UK: Lawrence Erlbaum Associates Ltd.

Saffran, E. M., & Coslett, H. B. (1998). Implicit vs. letter-by-letter reading in pure alexia: A tale of two systems. *Cognitive Neuropsychology*, *7*, 1–20.

Shallice, T., & Saffran, E. M. (1986). Lexical processing in the absence of explicit word identification: Evidence from a letter-by-letter reader. *Cognitive Neuropsychology*, *3*, 429–458.

Taily, R., & Haslam, C. (2003). An investigation of errorless learning in memory-impaired patients: Improving the technique and clarifying theory. *Neuropsychologia*, *41*, 1230–1240.

Warrington, E., & James, M. (1991). *Visual Object and Space Perception Battery.* Bury St Edmunds, UK: Thames Valley Test Company.

Wilson, B. A., Baddeley, A., Evans, J., & Shiel, A. (1994). Errorless learning in the rehabilitation of memory impaired people. *Neuropsychological Rehabilitation*, *4*, 307–326.

Manuscript received December 2003
Revised manuscript received July 2004

APPENDIX 1

Baseline words

Two letter words	*Three letter words*	*Four letter words*	*Five letter words*	*Familiar words*
OF	THE	THAT	WHICH	PHIL
TO	AND	WITH	THERE	CLARE
IN	WAS	THIS	WOULD	HOLLY
IS	FOR	FROM	THEIR	EGERTON
HE	HIS	HAVE	ABOUT	CHORLTON
IT	HAD	THEY	OTHER	MANCHESTER
AS	NOT	WERE	COULD	WITNESS
ON	ARE	BEEN	THESE	JEHOVAH'S
BE	BUT	WHEN	FIRST	GARETH
AT	ONE	WILL	AFTER	CAROLINE
BY	YOU	MORE	WHERE	HAYLEY
OR	HER	SAID	THOSE	FALLOWFIELD
AN	ALL	WHAT	STATE	
WE	SHE	INTO	WORL	
NO	HIM	THAN	STILL	

APPENDIX 2

Word qualities for experimental and control sets

		Word therapy items	*Letter therapy items*	*Control items*
K & F Freq	Mean	64.19	64.85	60.61
	SD	94.47	90.69	72.46
	Min	1	1	1
	Max	480	348	315
Length	Mean	6.17	6.03	6.03
	SD	1.62	1.48	1.48
	Min	4	4	4
	Max	10	9	9
Familiarity	Mean	553.10	501.07	548.07
	SD	29.94	55.64	39.21
	Min	477	416	479
	Max	598	581	616
Imageability	Mean	502.24	485.85	490.06
	SD	73.76	104.04	91.83
	Min	374	321	352
	Max	634	616	674
AoA	Mean	295.27	377.30	355.85
	SD	57.16	64.04	86.84
	Min	189	278	163
	Max	394	475	488
Number correct at baseline		6/30	7/30	5/30

Notes: K & F Freq = Kucera and Francis (1967) written frequency, AoA = Age of Acquisition ratings.

APPENDIX 3

Example of therapy card and instructions for the amended therapy in the first therapy treatment (whole word therapy)

- trace round word
- look at ending
- look and listen
- look, listen and repeat 5 times

* The last three letters were bright red