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The treatment of anomia using errorless learning

Joanne K. Fillingham, Karen Sage, and Matthew A. Lambon Ralph

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In the contemporary literature, errorless learning is thought to have benefits over more traditional trial-and-error methods. The most prominent investigations of errorless learning are those designed for rehabilitation of severe memory impairments, including numerous demonstrations of effective amelioration of word-finding difficulties (Baddeley & Wilson, 1994; Clare, Wilson, Breen, & Hodges, 1999; Clare et al., 2000; Evans et al., 2000). Despite this, there are very few reports on the application of purely errorless learning to people with aphasia (Fillingham, Hodgson, Sage, & Lambon Ralph, 2003). The aim of this study was to compare directly the efficacy of errorless and errorful learning in a case series of 11 aphasic people with pronounced word-finding difficulties. Previous studies of errorless learning and, more recently, studies of rehabilitation have suggested that cognition is an important factor for determining outcome (Helm-Estabrooks, 2002; Robertson & Murre, 1999). Therefore, a thorough language and neuropsychological assessment battery was completed with each participant. Naming therapy was carried out to contrast errorless and errorful therapy in a case series analysis. Errorless learning proved to be as effective as the more traditional, errorful approach in the majority of cases in terms of both immediate improvement and at follow up assessment. Without exception, the patients preferred the errorless learning therapy. Strikingly, it was found that language skill did not predict therapy outcome. Participants who responded better overall, had better recognition memory, executive/problem solving skills and monitoring ability. This replicates recent findings that frontal executive skills are crucial for rehabilitation (Robertson & Murre, 1999). Also, participants who did better at errorful treatment were those with the best working and recall memory, and attention. It is probable that these factors are essential cognitive components for
providing effective monitoring and feedback systems to a more general learning mechanism.

INTRODUCTION

Our ability to function effectively in the modern world is highly reliant upon language both for employment and recreation. Acquired language deficits are, therefore, extremely debilitating and distressing for the people concerned and those around them. Patients with aphasia often have more than one language impairment but perhaps the most common and frustrating of these is anomia. There has been a considerable amount of clinical time devoted to the amelioration of anomia. A recent review of the anomia treatment literature found that, while there is no doubt that anomia therapy can be highly successful, predicting the precise result of a treatment task with a specific individual is not possible. Nickels (2002) argued that future treatment studies need to dissect tasks, impairments and their interactions across a series of single cases.

The principal aim of this study was to test the efficacy of a specific form of remediation known as errorless learning for the treatment of anomia. The principle of errorless learning is that therapy may be more effective if patients are prevented from reinforcing their own errors. This contrasts with traditional anomia therapies that encourage experimentation (trial-and-error), increasing the risk of errors in the belief that you can learn from your mistakes. While the effective treatment of anomia would be a significant achievement in itself, this investigation of errorless learning will add to a coherent academic–clinical interaction. The ability to facilitate cognitive processes through procedures like errorless learning is a current and important topic in basic, cognitive and computational neuroscience (Buonomano & Merzenich, 1998; Tallal, Merzenich, Miller, & Jenkins, 1998). Thus, information arising from these academic domains will inform the nature of the therapies adopted here and, in return, information gathered about the effectiveness of remediating cognitive functions in damaged systems will provide important constraints on theoretical accounts of learning and plasticity (McClelland, Thomas, McCandliss, & Fiez, 1999).

Errorless learning

Errorless learning was first studied and proved effective in the area of animal learning. Terrace (1963) found that if an errorless learning method was adopted, pigeons’ learning of a previously unknown red-green visual discrimination was much better. Since then it has been used as a rehabilitation method in a variety of areas. It is in the domain of amnesia that much of the recent literature has been focused. Wilson and colleagues have studied the use
of errorless learning extensively and compared this with errorful methods. Using this technique they have taught people with amnesia and memory impairment to do a variety of tasks including re-learning names of objects and people. In each case, errorless learning was superior to errorful learning (Baddeley & Wilson, 1994; Clare et al., 1999, 2000; Evans et al., 2000; Wilson & Evans, 1996; Wilson, Baddeley, Evans, & Shiel, 1994). Squires, Hunkin, Parkin and colleagues have also examined errorless and errorful learning. They taught a variety of tasks to people with amnesia, including re-learning names of objects and people, and all showed benefit of errorless over errorful methods (Hunkin, Squires, Parkin, & Tidy, 1998a; Hunkin, Squires, Aldrich, & Parkin, 1998b; Parkin, Hunkin, & Squires, 1998; Squires, Hunkin, & Parkin, 1997).

Theories of errorless learning

Within the neuroscience and psychological literature two closely related theories have emerged to explain why errorless learning can be beneficial. One approach to understanding the potential benefits of errorless learning arises from consideration of patients with amnesia. Baddeley and Wilson’s (1994) explanation was based on the assumption that there are two types of memory: implicit and explicit. As the terms suggest, implicit memory is subconscious and cannot be deliberately manipulated. Explicit memory has the opposite characteristics. The automatic nature of implicit memory makes it particularly vulnerable to interference from errorful responses as it has no mechanism for filtering out incorrect information. Explicit memory does not suffer from this kind of interference because this type of memory is open to conscious manipulation, allowing incorrect information to be filtered out. Baddeley and Wilson (1994) argued that amnesic patients have a specific impairment of explicit memory making them particularly vulnerable to interference. Errorless learning is, therefore, optimal for these patients because no memory manipulation or filtering is required. O’Carroll, Russell, Lawrie, and Johnstone (1999) found that errorless learning was beneficial for patients with schizophrenia. Like Baddeley and Wilson (1994), they suggested that this could be attributed to impaired explicit memory. In an attempt to elucidate the nature of the impairment, O’Carroll et al. (1999) argued that the patients had a source monitoring difficulty. They demonstrated that the patients were unable to determine whether the correct answer was their own self-generated, incorrect guess or the experimenter’s correction.

The issue of whether errorless learning is better characterised by implicit or explicit memory processes has been the centre of some debate (Kalla, Downes, & van den Broek, 2001). Although maintaining the distinction between implicit and explicit memory, Squires et al. (1997) argued that errorless learning may operate by facilitating either implicit or explicit memory, or
both. Hunkin, Squires, Parkin, and Tidy (1998a) agreed that residual explicit memory functioning may play a role as they failed to find any correlation between improved errorless learning performance and preserved implicit memory functioning.

Irrespective of the exact status of the underlying memory system(s), these studies suggest that there may be some form of cognitive process that can filter out or inhibit the influence of erroneous responses, a mechanism that is absent for amnesic and schizophrenic patients. If we consider results from beyond the amnesia literature, however, it is clear that errorless learning is advantageous for people other than just those with impaired memory. For a complete account, other aspects of the processes that underpin learning (and re-learning) will need to be considered.

The field of cortical plasticity and cortical representational reorganisation has been guided by Hebbian plasticity and Hebbian based learning rules. One model of errorless learning arises from consideration of the Hebbian learning rule. At the synaptic level, Hebbian learning refers to increases in synaptic strength between neurons that fire together. At a higher level of neuronal organisation, Hebbian-based learning rules refer to the detection of temporally correlated inputs. A fundamental notion in neuroscience is that synaptic efficiency between two neurons is a substrate for learning and memory (Buonomano & Merzenich, 1998). According to Hebb (1961), if two neurons fire together, the strength of the connection between them will be increased. Therefore, if an input elicits a pattern of neural activity, Hebbian learning will strengthen the tendency to activate the same pattern on subsequent occasions. This means that learning will increase the likelihood of making the same response in the future, whether correct or incorrect (McClelland et al., 1999).

McCandliss et al. (2002) conducted an empirical study with Japanese adults in order to test the simulations more directly and found that the prediction of the computational model was upheld. Moreover, they also contrasted feedback to participants vs. no feedback and found that feedback was crucial; subjects in the errorful condition who received feedback learnt as well as those people in the errorless condition. McCandliss et al. (2002) concluded, therefore, that a model based solely on Hebbian learning (like McClelland et al., 1999) required an additional mechanism to capture the positive effects found in the feedback condition. Two possible mechanisms were proposed; Hebbian learning combined with error-correcting learning methods or Hebbian learning...
modulated by outcome information as in reinforcement learning (McCandliss et al., 2002).

Treatment of anomia through errorless learning

A recent literature review found that there have been no aphasia treatment studies that have deliberately investigated errorless learning techniques, despite the fact that the original amnesia literature includes the application of errorless techniques to the domain of language. Instead, Fillingham et al. (2003) categorised the treatment method used in a series of anomia treatment studies into one of three types: error elimination (patient errors are completely eliminated from the therapy), error reduction (the therapy is designed to reduce or minimise patient errors) and errorful learning (no control is exerted over patient errors). The relative merits of each approach were considered in terms of three efficacy measures: improvement immediately after therapy, residual benefit after a period of no therapy (follow up testing), and generalisation to untreated items. Studies were then split by aphasia type (fluent vs. nonfluent aphasia), principal impairment (expressive vs. receptive and expressive aphasia) and therapy method (receptive or expressive therapy) to test for variation in outcome for these important factors.

The review highlighted a reasonable number of studies that could be classified as error reducing or errorful learning. Rate of success was equivalent for both types of therapy even though the number of therapies utilising errorful techniques far outweighed those based on errorless learning. Errorless approaches were just as likely to achieve a positive outcome in terms of immediate effect, follow-up testing and generalisation. This result did not vary when the studies were split by therapy type, principal impairment or patient type. There were, however, a number of areas where there was very little information. For example, there were very few examples of errorless learning for treating anomia with a receptive technique. It was also notable that many errorless learning studies did not report long-term effects and generalisation. Overall, the review indicated that errorless learning could have positive effects for patients with word-finding difficulties. There were, however, no direct comparisons of errorful and errorless learning and very limited information about long-term treatment effects and generalisation (Fillingham et al., 2003).

The impact of cognition on rehabilitation

It is becoming increasingly recognised that cognition is an important factor for determining recovery outcome (Helm-Estabrooks, 2002). Robertson and Murre (1999) argued that not only are age and education determinants of recovery but there is now evidence that attentional control and level of awareness are also predictors. These cognitive factors may, in turn, reflect the integrity
of frontal lobe function. The aphasia and amnesia literatures are such that it is difficult to make comparisons and theoretical predictions about the role of cognitive processes in language recovery/rehabilitation. This is because aphasia studies rarely assess cognition while language testing is generally very limited, or non-existent, in investigations of amnesic patients (Hinckley, 2002). As noted above, previous studies of errorless learning suggest that memory, monitoring and feedback can be important determinants of therapy outcome. It is important, therefore, to assess the more general cognitive abilities of aphasic patients and to relate these to therapy outcomes.

The literature on rehabilitation of severe memory impairments has provided us with the most prominent investigations of errorless learning. These include investigations of paired-associate learning (Squires et al., 1997), which are clearly relevant to issues of learning and memory impairments in amnesic patients but not obviously so to the treatment of aphasic word-finding difficulties. However, there are also numerous demonstrations of re-learning object and face names—i.e., amelioration of word-finding difficulties—using errorless intervention which suggest that this approach might be useful for aphasic patients (Clare et al., 1999; Wilson et al., 1994). In contrast, there is a lack of information about the application of errorless learning to the treatment of anomia and other aphasic disorders, although a recent review suggested that this may be an effective intervention for aphasic patients (Fillingham et al., 2003). The aim of this study was to test the efficacy of errorless learning for aphasic word-finding difficulties and to begin to address some of the issues associated with the application and theory of errorless learning in this domain.

Knowing which techniques are advantageous for which patients would be extremely valuable knowledge to speech and language therapists (Nickels, 2002). The specific research aims were (1) to test formally if errorless learning is an effective therapy technique for anomia; (2) to compare errorless and errorful techniques directly; (3) to measure immediate and long-term effects, and generalisation; (4) to test which language and cognitive factors predict therapy results; and (5) to measure accuracy during therapy sessions to compare error rates between techniques.

BACKGROUND NEUROPSYCHOLOGY AND APHASIA ASSESSMENTS

Participants

Participants were recruited through local speech and language therapy services. They were selected primarily on the basis that they had word-finding difficulties due to a central language impairment. Patients who failed to name pictures because they had perceptual deficits (agnosia) or had significant dyspraxia or speech-motor programming deficits were excluded. They were
required to be at least six months post onset, have an acquired neurological
deficit, have a significant word-finding problem (below 70% on a 100 item
naming test: Lambon Ralph, Ellis, & Sage, 1998) and be able to repeat and/or
read with a degree of accuracy (preferably above 70% on PALPA 9 and/or
PALPA 31; Kay, Lesser, & Coltheart, 1992). Basic information about each
participant is given below, alongside a summary of their background neuro-
psychological results.

**Background assessment**

A thorough language and neuropsychological assessment battery was com-
pleted. All patients were asked to complete the same battery of tests so that
direct comparisons between patients could be made and severity of different
underlying impairments measured. The assessments took between four and
six sessions to complete.

Assessment of the patients’ language skills was focused mainly on single-
word processing (see Table 1). Picture naming tests were used to measure the
degree of anomia: Boston Naming Test without standard systematic cueing
(Kaplan, Goodglass, & Weintraub, 1976), Graded Naming Test (McKenna &
Warrington, 1983), and Picture Naming PALPA 53 (Kay et al., 1992). Single-
word reading and repetition were used to assess the integrity of phonological
representations (reading words, PALPA 31; and non-words, PALPA 8; repeat-
ing words (PALPA 9) and non-words (PALPA 8). Impairments of semantic
memory/comprehension were assessed using various measures of picture,
spoken word and written word comprehension (word and picture versions of
the Pyramids and Palm Trees; Howard & Patterson, 1992); a 100-item spoken
word–picture matching test in both spoken (SWPM) and written formats
(WWPM) (Lambon Ralph et al., 1998). Given that these are relatively insensi-
tive measures for detecting mild semantic impairments we also included two
psychometrically-graded tests of comprehension, again run twice for auditory
and written presentations (British Picture Vocabulary Scale, BPVS; Dunn, Dunn,
Whetton, & Burley, 1997; Concrete and Abstract Synonyms; Warrington,
McKenna, & Orpwood, 1998).

In addition to providing important clinical data, neuropsychological assess-
ments were given to test various non-language, cognitive processes that may
underpin feedback and control mechanisms (see Table 2). These included
assessments of episodic memory for verbal and nonverbal materials including
recognition for faces, pictures, words and landscapes (Rey Complex Figure
Test; Meyers & Meyers, 1995; Camden Memory Test; Warrington, 1996),
working memory (Digit Span; Bachrach & Mintz, 1974; PALPA Auditory
Digit Matching Span; Kay et al., 1992) nonverbal problem-solving and rea-
soning (Wisconsin Card Sorting Test; Grant & Berg, 1993) and attention
(both vigilance and divided attention: elevator counting with and without
<table>
<thead>
<tr>
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<th>Max.</th>
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<th>JS</th>
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<th>HA</th>
<th>GP</th>
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<td>N/C</td>
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N/C—not able to complete due to memory problems, difficulty understanding task, repeating or refusal; n/a—not available; BNT—Boston Naming Test; GNT—Graded Naming Test; PON—Picture Oral Naming PALPA 53; Total Naming—the total correct for the three naming tests; Word reading—(PALPA 31), Non-word reading—(PALPA 8), Word repetition—(PALPA 9) and Nonword repetition—(PALPA 8); PPT—Pyramids and Palm Trees picture and written word versions; SWPM and WWPM—a 100-item spoken and written word-picture matching test; BPVS SWPM and WWPM—spoken and written word-picture matching versions of the British Picture Vocabulary Scale; WSJ—Warrington Synonym Judgement (Aud—Auditory version, Writ—Written version, Con—Concrete items and Ab—Abstract items).

*The norms reflect either the range of normal performance or two standard deviations below the mean control performance. A score underlined indicates that it is within the normal range.
<table>
<thead>
<tr>
<th>Domain</th>
<th>Assessment</th>
<th>HF</th>
<th>FO</th>
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<td>5</td>
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<td>3</td>
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<td>11–16%ile*</td>
<td>6–10%ile*</td>
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<td>1.5–</td>
<td>3.3–</td>
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<td>4%ile</td>
<td>14%ile</td>
<td>69%ile</td>
<td>4%ile</td>
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</table>

N/C—not able to complete due to memory problems, difficulty understanding task, repeating or refusal; * denotes that the patient did not complete the whole task and so scores are based on the cards that were sorted; Self Rating—ability of patient to rate their own naming attempt using PALPA 53 picture naming assessment; CMT—Camden Memory Test (pic—pictographical, top—topographical, word—written word, face—faces); WDS—Wechsler Digit Span (f—forward, b—backward); PADMS—PALPA Auditory Digit Matching Span; WCS—Wisconsin Card Sorting (No. cat—Number of categories score, FMS—Failure to Maintain Set score); TEA—Test of Everyday Attention (elevator—elevator counting, with dis—elevator counting with distraction); Rey—Rey Complex Figure Test (copy—copying score, Imm Recall—immediate recall score, Del Recall—delayed recall score, Rec Total—recognition total correct score).
distraction from the Test of Everyday Attention (TEA; Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994). The errorless learning literature suggests that patients’ ability to monitor the accuracy of their own responses/behaviour may also be critical (O’Carroll et al., 1999). Accordingly, we assessed the patients’ ability to judge the accuracy of their own naming. This was achieved by using the PALPA 53 picture naming assessment. After patients had named the picture, they were asked if they thought their response was correct or incorrect.

The patients’ language and cognitive profiles

HF was a 64-year-old widow and housewife before a left middle cerebral artery infarct led to frontal lobe changes in 2001. She presented with a moderate aphasia. Her speech was fluent but contained jargon features. She had a right hemiparesis. The test batteries revealed that HF was anomic, had very poor comprehension, and impaired phonology and semantics. Her unsuccessful naming attempts consisted of phonological and semantic errors. She demonstrated poor memory across a variety of tasks and had attentional and executive dysfunction. Clinically, she was difficult to engage in tasks.

FO was an 80-year-old gentleman who had a left cerebrovascular accident (CVA) in 1996 resulting in severe jargon aphasia. He was a retired company secretary and lived with his wife. In the year preceding this study, FO had been noting progressive short-term memory problems and was referred to old age psychiatry. Like HF, it was also difficult to engage FO in tasks. Background testing showed that he was very anomic and his naming errors were predominantly phonologically-related to the target word. He had impaired phonology and semantics, had a generalised amnesia and had attentional-executive dysfunction.

RD was a 40-year-old man who lived alone. In 2001, he had a left-sided cerebral infarct originating from occlusion of the left internal carotid artery. His CVA prevented him from returning to work as a company director. He presented with a severe aphasia, receptively and expressively. In conversation, he used a limited number of short social phrases only. He also had a slight right hemiparesis. RD was severely anomic and his naming errors were semantic in nature. He had very poor comprehension, phonology and semantics. He had some memory problems and poor attentional and executive skills.

EW was a 73-year-old retired builder who lived with his son. In 2001, a CT scan revealed a large low density in the left parietal lobe consistent with acute infarct. He presented with a severe expressive aphasia and only said “Yes” and “Bye” when prompted. His receptive skills were more reliable functionally but he would often need repetition to aid comprehension. He had a right hemiplegia and was wheelchair bound but could walk a few steps for transferring. The test batteries revealed a severe anomia that was characterised by both semantic
and phonological errors. He had poor comprehension and phonology. He performed well on non-linguistic memory tests but had poor attention and executive skills.

RR was a 60-year-old gentleman who took retirement in 1999 after a left middle cerebral artery infarct. After this he was wheelchair bound due to a dense right hemiplegia and lived in a residential home. His word-finding difficulties were evident in his expressive speech which was fluent but empty of content words. RR’s severe anoma was characterised by semantic and phonological errors. He had poor comprehension and phonology. He demonstrated poor memory on some tests and impaired attentional skills. He had good non-verbal problem solving skills.

JS was a 76-year-old gentleman who had a left-sided CVA in 1992 resulting in a severe global aphasia and right hemiparesis. He was a retired electrician and lived with his wife. His working vocabulary was approximately half a dozen words. Background testing revealed a severe anoma, which was characterised by phonological errors. In addition JS had very poor comprehension, very poor phonology, poor memory for words and faces, and attentional and executive dysfunction.

RH was a 68-year-old gentleman who had retired as a foreman and lived with his wife. A CT scan in 1998 revealed an infarct in the region of the left middle cerebral artery territory. RH had a right hemiparesis. He also presented with a severe expressive aphasia and was limited to a very small set of short social phrases. His comprehension was functional but he often needed repetition for clarification. The test battery revealed a severe anoma characterised by semantic and phonological errors. He also had poor comprehension and phonology. He performed well on non-linguistic memory tests and on non-verbal problem solving but poorly on tests of attention.

ME was a 70-year-old housewife who lived with her husband. She had a left CVA in 1987 resulting in a right hemiparesis. She presented with a mild aphasia. Word-finding difficulties were evident in her fluent speech. She was anomic and produced mainly semantic errors when naming. Her performance was abnormal on the more demanding semantic and phonological tests. She had good memory and executive skills but poor attention skills.

HA was a 74-year-old gentleman who lived with his wife and prior to his stroke, worked as a high court judge. In 1998, he had a cerebral infarction of the left post cerebral artery territory in the left parietal-occipital region. HA presented with a mild aphasia characterised by profound word-finding difficulties. Background testing revealed that he was anomic. His naming errors were characterised by phonologically-related responses. He had impaired phonology, good semantics, good executive skills but impaired attention.

GP was a 73-year-old retired policeman who had a left CVA in 1998. He presented with mild aphasia with word-finding difficulties. He was a competent communicator. Background testing revealed that he was anomic and his
naming errors were predominantly semantic. He had good phonology, memory and executive skills but impaired attention.

SC was a 74-year-old gentleman who lived with his wife and was the owner of a chain of florists. In 1999, he had a large acute haematoma in the left occipito-parietal region and a right fronto-parietal infarction secondary to previous haemorrhage. His receptive skills were good but he needed occasional repetition. His profound word-finding difficulties were evident in his conversation, however, he had adopted many strategies to help him. The test battery confirmed his anomia. His errors on naming tests were predominantly semantic. He had good memory except on visuospatial memory tasks, good executive skills but poor attention.

THERAPY

Method

A case series analysis was carried out to contrast errorless and errorful therapies for word-finding difficulties. A 100-item picture naming test (Lambon Ralph et al., 1998) was used for all participants for a baseline measure. This was repeated three times in order to ensure a stable baseline. The highest baseline score was used for comparison with the post-therapy and follow-up accuracy scores. The patients were given the option to include personally relevant items (e.g., pictures of family members, work-related vocabulary, etc.) as we wanted at least a part of the therapy to be directly beneficial for every patient. It is possible that this may also improve patients’ motivation in therapy. In practice, some patients and their carers found the process of selecting target items too demanding even with assistance from the therapist. For some of the milder participants the relatively simple 100-item naming test did not yield sufficient unnamed items for the therapy. These were supplemented, therefore, with items from the more challenging naming tests included in the assessment battery (Boston Naming Test; Kaplan et al., 1976; and the Graded Naming Test; McKenna & Warrington, 1983). Three baseline measures were taken and the items were split into three groups of 30, matched for accuracy, word frequency, number of phonemes and number of syllables. One set was treated using an errorless learning technique, one using an errorful technique, and the third acted as a control set.

The unelaborated errorless and errorful techniques were made to be as directly comparable as possible. Phonemic and orthographic cues were combined together with the picture so that all modalities were being used. Errorless therapy consisted of providing the patient with the picture along with its spoken and written name to ensure the correct response was made. The patient was told, “I am going to ask you to name the picture. First, I will tell you the name. Then I will show you the picture. The name will be written
underneath the picture. We will do this three times.” In errorful therapy the subject was asked to name the picture and if the response was incorrect they were provided with progressive phonemic and orthographic cueing (Herbert et al., 2001; Lambon Ralph, Sage, & Roberts, 2000). If the word was monosyllabic, then the first phoneme and letter was given initially. If they were still unable to name the item, then the first two phonemes and letters were given. If they were still incorrect then the whole word was given to repeat and/or read. If the word was multisyllabic, then the first phoneme and letter was given, then the first syllable (spoken and written) and finally the whole word spoken and written (repeat/read). The 30 items were cycled through three times in each therapy session, which lasted between 25 and 40 minutes.

Initial assessment and baseline measures were taken in the first five weeks. The next five weeks were taken up with the errorless learning therapy followed by a week break during which the post-therapy assessment was conducted. This pattern was then repeated for the errorful learning therapy. Many of the previous errorless learning studies have given patients intensive periods of therapy, which continued until a predefined performance threshold was reached. We were keen to test the efficacy of the therapies within a schedule that might more realistically be found in an NHS clinical setting. Accordingly, each therapy consisted of 10 sessions, given twice weekly for five weeks (with breaks for unavoidable events—e.g., illness, holidays, etc.). Assessment was carried out after each therapy block to measure the immediate effect to treated and untreated items (generalisation to the control set). A follow-up assessment was carried out after an additional period of time (on average five weeks post-therapy). The follow-up assessment for errorless learning treatment occurred at the same time as the initial post-therapy assessment for the errorful learning treatment. This means that the effect of each therapy was compared at exactly the same interval after therapy and so they are directly comparable (see the timelines in Table 3). As shown in Table 3 the timing of the two therapies was such that the follow-up period for errorless learning was filled by the errorful therapy itself. The patients were not engaged in active therapy during the follow-up period for errorful learning. The efficacy of each therapy was compared and also related back to each patient’s background language and neuropsychological measures in order to reveal some of the critical, underlying language or cognitive factors.

The order of therapies was not counterbalanced across the participants given that it was a case-series design. We chose the order of the therapy so that the participants were given an initial period of therapy in which no errors occurred and for them to get accustomed to this different form of therapy. This means, of course, that there might have been effects of this specific order on the results. We have addressed this potential confound in a more recent study in which the two therapies were given simultaneously (Fillingham, Sage, & Lambon Ralph, 2004). The pattern of results was unchanged and so
there is no indication that the order adopted here had any particular effect on the results.

RESULTS

The research aims were (1) to test if errorless learning is an effective therapy technique for aphasic word-finding difficulties; (2) to compare errorless and errorful learning approaches directly for people with aphasia; (3) to measure immediate and long-term effects, and generalisation; (4) to identify which aspects of the patients’ language and cognitive skills predict the therapy effect for each technique; (5) to measure accuracy during therapy sessions to compare error rates between the two therapy methods. The first three issues will be addressed together and the fourth and fifth will be answered separately. Finally, the effect of each therapy on the pattern of the patients’ errors is discussed.

Basic results

Figure 1 shows the results of both treatments for each participant. Each box contains results for one patient. The x-axis indicates the time of assessment: at baseline (Baseline), immediately post-treatment (PostTx) and at follow-up (Followup). The white bars show the accuracy for the items treated with an errorless approach while the corresponding data for the items in the errorful treatment are shown as black bars. The results of the control items are not
Figure 1. Results of errorless and errorful therapy. See text for explanation.
shown as there was only minimal generalisation for some of the participants. RD showed generalisation after errorful treatment from 2/30 to 7/30 (McNemar p = .0313, one-tailed) but then showed a significant drop back to baseline at follow up from 7/30 to 1/30 (McNemar p = .0156, one-tailed). Two participants showed generalisation after errorless treatment, HA from a baseline of 3/30 to 8/30 post-errorless treatment (McNemar, p = .0313, one-tailed) and SC from a baseline of 3/30 to 12/30 post-treatment (McNemar p = .002, one-tailed), which was maintained throughout the study. A further two participants showed generalisation at follow-up assessment which could be due to a build up of both treatments. EW’s performance increased from a stable score of 3/30 throughout both treatments to 9/30 at follow up (McNemar p = .0156, one-tailed) and RH from a stable baseline of 3/30 throughout both treatments to 8/30 at follow up (McNemar p = .0313, one-tailed). This generalisation was also reflected in an improvement, for two participants, in the errorful items after errorless treatment even though the errorful items had not been treated at that stage. RH showed a change from 2/30 items named at baseline to 7/30 post-errorless treatment (McNemar p = .0313, one-tailed) and SC showed a change from 1/30 at baseline to 8/30 post-errorless treatment (McNemar p = .0078, one-tailed).

Underneath each patient’s initials, a general idea of how errorless learning compared to errorful learning immediately post-treatment is given: no effect for either therapy (no therapy effect); errorless and errorful learning had equivalent, positive effects (EL = EF); errorful learning produced a better result than errorless learning (EF > EL). There were no participants who did better with errorless learning than errorful learning.

The graphs are ordered according to the overall therapy effect immediately post-treatment. HF and FO both showed no significant therapy effect. RD exhibited a significant change in errorless items (McNemar p = .0313, one-tailed), while the improvement after errorful learning approached significance (McNemar p = .0625, one-tailed). GP was the only person who showed a significant difference in favour of errorful over errorless treatment immediately post-therapy, $\chi^2(1) = 7.42, p = .006$. The remaining eight participants all showed a significant effect of both errorless (McNemar p = .039 to p < .001, one-tailed) and errorful (all McNemar p < .001, one-tailed) therapy immediately post-treatment. Given the equivalence of the errorless and errorful therapy results it would appear that the variation in the nature of the follow-up (post-therapy) periods had no effect on outcome.

At follow-up assessment, the patients exhibited differing ability to retain treated items—i.e., comparing performance immediately post-treatment with scores at follow up. There was no significant change for HF with the errorless items but she showed a significant increase for the errorful items (McNemar p = .0313, two-tailed). This, however, was because at baseline she was naming 3/30 items, after treatment she failed to name any correctly and then at
follow-up she named 6/30. FO continued to show no significant change. RD, EW and RR, who exhibited a significant increase from baseline to post-treatment, maintained this improvement at follow-up. JS, ME and HA retained the errorful items at follow up but performance on the errorless items dropped significantly (McNemar $p = .0156$ to $p = .0002$, two-tailed). RH exhibited the opposite pattern; he did not show a significant change on the errorless items at follow-up but his accuracy reduced for the errorful items (McNemar $p = .0156$, two-tailed). GP’s and SC’s accuracy dropped significantly for both the errorless (McNemar $p = .0156$ and $p = .0001$, two-tailed) and errorful items (McNemar $p = .0156$ and $p = .0002$, two-tailed).

The long-term effect of each therapy is revealed by comparing the results at follow-up against baseline accuracy. HF and FO exhibited no significant change as a result of either therapy. RD, JS, ME and GP demonstrated a significant long-term improvement only for errorful therapy (McNemar $p = .0156$ to $p = .0001$, one-tailed). EW, RR, RH, HA and SC all showed significant long-term benefit from both techniques (McNemar $p = .0078$ to $p = .0001$, one-tailed). ME and GP were the only two patients to demonstrate a significant difference favouring errorful over errorless items at follow-up, $\chi^2(1) = 5.97$ and 7.57, $p = .015$ and $p = .006$.

Aspects of language and cognitive profiles that predicted therapy outcome

The overall therapy effect varied across patients. Some patients (HF and FO) exhibited no therapy effect while others demonstrated substantial improvements immediately after therapy. For example, SC had the greatest effect of both therapies—errorless learning items improved from a baseline of 3/30 to 26/30 post-treatment and errorful therapy from 1/30 at baseline to 24/30 post-treatment. We were keen to explore which aspects of the patients’ language and cognitive skills predicted therapy outcome. The case-series design—in which each and every patient is assessed across the same battery of tests—allows a direct comparison between the size of the therapy effect and the patients’ scores on the background assessments. Three comparisons were made: (1) which background assessments correlate with the size of the immediate therapy effect (i.e., the difference in scores at baseline and immediately post-therapy); (2) which correlate with the long-term effect (baseline vs. follow-up accuracies); and (3) which correlate with the difference between errorless and errorful therapy at follow up. All language and neuropsychological background results were correlated against these three measures (Spearman’s $\rho$). Perhaps most strikingly, we found that none of the language measures correlated with therapy outcome. In contrast, it was aspects of the patients’ remaining non-language, cognitive skills that did predict therapy outcome. Interestingly, the critical cognitive factors were the same as those
identified in the rehabilitation literature (frontal lobe executive skills and monitoring: Robertson & Murre, 1999) and highlighted in theories of errorless learning (memory: Wilson et al., 1994).

The neuropsychological tests that significantly correlated with the immediate therapy effect were the topographical ($\rho = .86, p = .001$) and word ($\rho = .7, p = .016$) subtests of the Camden Memory Test, the number of categories completed on the Wisconsin Card Sorting Test ($\rho = .62, p = .044$) and the test of self rating ($\rho = .61, p = .048$). This indicates that the patients who responded well to both therapies immediately post-treatment had better recognition memory, executive function and monitoring skills. In addition, a number of the semantic tasks correlated with the immediate therapy effect. Given that these all require problem-solving and decision making for accurate performance, it is possible that these correlations reflected the patients’ varying executive skills. When scores on the Wisconsin Card Sorting and the self-rating tests were partialled out, only one of the correlations with the semantic tests remained (the written version of the Pyramids and Palm Trees: $\rho = .95, p = .001$). When the counter partial correlations were computed (partialling out semantic test performance from the simple correlations with executive-monitoring skill), the relationship between therapy outcome and memory, executive function and monitoring skills remained.

A very similar pattern was found when the overall therapy effect at follow up was compared with the patients’ language and neuropsychological profiles. The tests that correlated significantly were the topographical ($\rho = .67, p = .023$) and word ($\rho = .6, p = .05$) subtests of the Camden Memory Test, and the number of categories completed score ($\rho = .71, p = .014$) and failure to maintain set score ($\rho = .66, p = .028$) from the Wisconsin Card Sorting Test. This suggests that both immediate and long-term therapy effects are related, not to the aphasic patients’ remaining language skills but rather to their recognition memory and executive skills. Again there were simple correlations with some of the semantic test scores. As with the immediate therapy results, all but one of these were accounted for by the variation in the patients’ executive skills (only the correlation with the written version of the 100-item word–picture matching test remained: $\rho = .76, p = .049$).

Two of the 11 patients showed a significant difference between errorless and errorful therapy at follow up and one of these also showed this difference immediately after treatment. The difference between errorless and errorful therapy at follow up was compared with the participants’ language and neuropsychological profiles (HF, FO, and RD were excluded from this specific analysis as there was no therapy effect for either one or both types of therapy and therefore no comparison to be made). These correlations highlighted the importance of the patients’ working memory, divided attention and recall memory (errorful learning was better than errorless learning for the individuals with the best performance in these cognitive domains): the PALPA
Auditory Digit Matching Span ($\rho = .77, p = .026$), the divided attention subtest from the Test of Everyday Attention ($\rho = .86, p = .006$) and the scores for immediate ($\rho = .82, p = .013$) and delayed ($\rho = .92, p = .001$) recall on the Rey Complex Figure Test and Recognition Trial. The only language assessment that correlated was the written version ($\rho = .72, p = .043$) of the Synonym Judgement Test (Warrington et al., 1998).

Comparison of error rates for errorless and errorful techniques

Although errorless therapies aim to eliminate errors from the patients’ behaviour, in practice, it is hard to remove errorful responses completely (Clare et al., 2000). In reality, most therapies can be more accurately classified as error reducing (Fillingham et al., 2003). Often error rates during therapy are either not monitored or are not reported. In this study we measured error rate in therapy by monitoring the participants’ overall responses during each therapy trial. It is important to note that we didn’t give a naming assessment in each of the therapy sessions as this could contaminate the errorless therapy with a series of errors made by the participant in the naming assessment. Instead the participants’ accuracy was measured in terms of their actual responses during therapy. Monitoring of error rates is important for two reasons. First, it is important to confirm that the errorless technique does actually result in significantly less errors than the corresponding errorful treatment. Second, differences in outcome across errorless learning studies may be due, in part, to variation in the degree of error reduction.

Figure 2 shows the patients’ accuracy during each therapy session (i.e., the proportion of therapy trials on which the correct name was produced by the patient). Again each box shows the results for one patient and the graphs are ordered according to overall therapy effect, immediately post-treatment. Again, the white bars show the results for errorless therapy and the black bars for the errorful therapy. The results show that, as planned, there was a significant difference between the two therapies with errorless therapy being the more accurate for each and every patient, $t(9)$ between 3.14 to 59.0, $p < .0001$. Despite our best attempts, none of the participants reached the optimal condition of complete error elimination. There was, however, a substantial reduction in the rate of errors when compared against the typical cueing-based naming therapy.

Did the therapies change the patients’ distribution of naming errors?

Due to the small numbers, errors were grouped into four categories; omission, phonological, semantic and perseverative (collapsed across the three sets of items), and compared at baseline, post errorless treatment, post errorful
Figure 2. Accuracy during errorless and errorful therapies.
treatment and at follow up. The distribution of errors was compared at various stages for all participants. For the purpose of this study we used the following definitions: omission—no responses, circumlocutions or other partial responses; phonological—the response contained at least half of the phonemes found in the target in any order; semantic—a word was given from the same category as the target word; perseverative—the correct target word was repeated for the next item and/or subsequent items after.

EW, RR, and GP showed a change in distribution of errors at one stage, each reflecting an increase or decrease in omissions. EW from baseline to post errorful treatment, \( \chi^2(3) = 8.7, p = .034 \), reflecting a decrease in omissions from baseline (73/85) to post errorful treatment (45/65). RR’s change in distribution of errors also reflected a decrease in omissions but from baseline (66/82) to post errorless treatment (36/56); \( \chi^2(3) = 10.56, p = .014 \). GP’s change in distribution reflected a decrease in omissions from post errorful treatment (29/54) to follow-up assessment (49/67), \( \chi^2(3) = 6.01, p = .05 \).

HF showed a significant change in distribution of errors from baseline to post errorless treatment, \( \chi^2(3) = 40.16, p < .001 \), and from post errorless treatment to post errorful treatment, \( \chi^2(3) = 40.39, p < .001 \). This change reflects an increase in perseverative errors from baseline (2/82) to post errorless treatment (35/81) and then a drop after errorful treatment (2/84).

A change in the distribution of errors was shown throughout the study for JS; baseline to post errorless treatment, \( \chi^2(3) = 35.69, p < .001 \), baseline to post errorful treatment, \( \chi^2(3) = 13.72, p = .003 \), post errorless treatment to post errorful treatment, \( \chi^2(3) = 59.65, p < .001 \), post-errorful treatment to follow up assessment, \( \chi^2(3) = 8.51, p = .036 \), and baseline to follow-up assessment, \( \chi^2(3) = 50.38, p < .001 \). This reflects an increase in phonological, semantic and perseverative errors throughout the study at the expense of omissions.

HA shows a change in phonological errors, however due to the small numbers in other categories this did not reach statistical significance. His phonological errors decreased from 57/81 at baseline to 29/54 post errorless treatment and this was maintained throughout the study. These phonological errors were split into four categories; real word phonologically related, real word phonologically unrelated, non-word phonologically related and non-word phonologically unrelated. The decrease in the phonological errors as a whole was due to the large decrease in the amount of non-word phonologically unrelated words from 27/81 at baseline to 4/54 post errorless treatment, and this was maintained throughout the study.

**DISCUSSION**

This study directly contrasted two different techniques for treating aphasic word-finding difficulties. Errorless and errorful learning were compared in a case series of 11 aphasic patients covering a wide range of severities. Nine of
the 11 patients exhibited significant improvements in naming after therapy. For eight of these nine patients, errorless learning was equally effective as a traditional cue-based therapy (which is inherently errorful in nature). The pattern remained unchanged for five of these patients when the long-term benefit of each therapy was assessed after a five-week follow up period. These results mirror the findings of a previous review of the anomia treatment literature (Fillingham et al., 2003). The review found that studies utilising error reducing techniques were as likely to produce positive results as those based on errorful learning in terms of immediate effect and follow-up assessment. In the current empirical study, only one patient demonstrated greater benefit from the errorful therapy immediately and in the longer term. One other patient exhibited greater improvement for errorful over errorless learning at follow-up testing, although exhibited similar benefits immediately after therapy. There were no patients who showed an advantage for errorless over errorful therapies.

The over-riding results from this study is that errorless and errorful therapies are equally likely to be effective for most patients who themselves respond to therapy. There is little in this empirical study to predict which of the two therapies is likely to be best for a specific patient, although there is an indication that, for patients with good attention and recall memory, therapies based on errorful learning may produce slightly better long-term improvements. However, if a clinical judgement had to be made about which technique to use then it is important to take into account the fact that all participants reported errorless learning as the preferable technique. Fillingham et al. (2003) noted that errorless learning is inherently monotonous and might suffer from being a passive treatment. Our experience from this study suggests that patients were as likely to engage in the errorless learning therapy as any other. Indeed, the patients strongly preferred errorless treatment as they found it less frustrating and more rewarding. This is probably because the errorless learning technique removes the need for patients, with sometimes severe expressive difficulties, to provide a spoken name repeatedly through each therapy trial. In this study the participants were not bored by errorless therapy. There is, however, a danger that it may be inherently tedious for the therapist. If the positive results of errorless learning found here are replicated in future studies then alternative methods such as computer-assisted therapy may prove to be the most effective way to deliver this type of intervention (see Fink, Brecher, Schwartz, & Robey, 2002 for an example).

Another striking result from this study was found when we attempted to relate therapy outcomes to the patients’ background language and cognitive profiles. This was only possible because aphasia and neuropsychological measures were taken across a case-series of patients (Lambon Ralph, Moriarty, Sage, & Group, 2002). Perhaps surprisingly, we found that the status of the patients’ language skills did not predict therapy outcome. Instead, immediate and long-term naming improvements, irrespective of treatment type, were
related to the patients’ frontal executive skills and recognition memory. Those participants who responded better overall had better recognition memory, executive/problem-solving skills and monitoring ability. Perhaps the most striking example of the lack of a relationship between language skills and therapy outcome was found in the results of patient JS. He was the most severe aphasic in our series (a global aphasic), yet he was in the middle of the range with respect to the size of his therapy effect. This interim position aligns closely with his performance on the Wisconsin Carding Sorting Test—an assessment that almost perfectly ranks the patients for therapy outcome. This result replicates a finding that has been shown previously for rehabilitation in other neurologically damaged patients, namely that frontal executive systems are crucial for rehabilitation (Robertson & Murre, 1999). Robertson and Murre (1999) argue that, from a rehabilitation perspective, awareness of deficits is critically important in recovery. If self-awareness is impaired then attending to stimulation, experience or activity will also be impaired. They argue that attention is important as it modulates synaptic connectivity thus facilitating repair and reconnection in damaged circuits (Robertson & Murre, 1999). Reconzane, Schreiner, and Merzenich’s (1993) study of experience-dependent plastic reorganisation in the brains of monkeys is consistent with this notion. They found that the brain required attention to be paid to the activity or experience in question for cortical reorganisation to occur.

Two patients showed a statistically significant difference for errorful learning over errorless learning at follow-up. It was found that those patients who do better at errorful treatment are those with the best working and recall memory, and attention. This appears to link directly with theories of errorless learning. Errorless learning may be particularly effective for those individuals whose learning system is unable to filter out errorful trials. Some proposals suggest that basic learning mechanisms (e.g., Hebbian learning) are gated by feedback about the outcome on each learning trial or through some kind of additional error-based learning mechanism (McCandliss et al., 2002; McClelland et al., 1999). Other theories assume that explicit memory is used to filter out errorful trials. Whichever theory is correct, it would seem likely that the factors highlighted in this study (executive skills, memory and attention) are probably essential cognitive components for providing effective monitoring and feedback systems to a more general learning mechanism (for further discussion see, Fillingham et al., 2003; O’Carroll et al., 1999). Although memory and attentional-executive skills are highlighted in the errorless learning literature, we did not find any aphasic patients for whom naming improved more after errorless learning. It is possible that this may reflect the fact that none of these patients had profound amnesia—at least, not of the same order as that found in patients with Alzheimer’s disease, herpes simplex encephalitis or head injury who have been the target of previous errorless learning studies (Clare et al., 1999, 2000; Evans et al., 2000; Hunkin
et al., 1998a). This would suggest that the outcome of errorless relative to errorful learning may reflect the degree of amnesia and attentional-executive dysfunction. Patients with dense amnesia may respond better to errorless techniques as they do not have the necessary cognitive systems required to filter out or inhibit learning during errorful trials. People with moderate memory difficulties will be able to respond to both errorless and errorful techniques. In contrast, patients with good recall memory and attentional-executive function have the necessary cognitive systems to learn effectively even in an errorful environment. Indeed, it is possible that these cognitive systems may provide the foundation for an error-based learning mechanism and thus such patients might even demonstrate enhanced learning in an errorful environment (McCandliss et al., 2002).

REFERENCES


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