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### Treatment of anomia using errorless versus errorful learning: are frontal executive skills and feedback important?

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## Research Report

# Treatment of anomia using errorless versus errorful learning: are frontal executive skills and feedback important?

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### Abstract

*Background:* Studies from the amnesia literature suggest that errorless learning can produce superior results to errorful learning. However, it was found in a previous investigation by the present authors that errorless and errorful therapy produced equivalent results for patients with aphasic word-finding difficulties. A study in the academic literature of phoneme discrimination learning found that errorful learning produced equivalent results to errorless learning when feedback was given. In the authors' previous study, feedback was available to the participants in the errorful therapy. It is possible, therefore, that this feedback may have improved the results from errorless learning — thereby reducing an underlying difference between the two techniques. Generally, feedback is thought to aid learning, however, there is little information in the speech therapy literature about this factor.

*Aims:* The present investigation was conducted as a follow-up to authors' original study to compare errorless and errorful therapy for the amelioration of aphasic word-finding difficulties. The second aim was to replicate key findings from the original study: namely, that recognition memory, executive/problem-solving skills and monitoring ability predict immediate and long-term naming improvements but not the participants' remaining language ability.

*Methods & Procedures:* Seven of the original 11 participants took part in a multiple baseline, crossover, case series design.

*Outcomes & Results:* The previous results were replicated: errorless and errorful therapy produced equivalent results immediately post-therapy and at follow-up. There was no effect of omitting feedback — the participants learnt equally well without therapist's feedback about whether or not their response was correct. In addition, executive/problem-solving skills and monitoring ability again predicted immediate naming improvements not language ability.

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*Conclusions:* The findings support the view that cognitive abilities and in particular executive function are important contributors to rehabilitation.

*Keywords:* anomia, errorless, errorful, frontal, executive, word-finding, cognition.

## Introduction

The key notion behind errorless learning is that for some situations errant behaviour can be self-reinforcing. Therefore, the act of producing an error for a certain stimulus can strengthen this incorrect association such that the likelihood of making an error will be greater the next time the stimulus is presented. The definition of errorless learning and consequently how this has been applied clinically has varied (Fillingham *et al.* 2003). Our current understanding of errorless learning is heavily influenced by the literature on rehabilitation of severe memory impairments. Two generalities emerge from this literature. The first is that errorless learning is a type of intervention whereby the task is manipulated to eliminate/reduce errors. This contrasts with traditional approaches where patients' errorful responses are corrected by the therapist and guessing is advocated in the belief that this will encourage better performance (O'Carroll *et al.* 1999). Second, tasks are often gradually made more difficult even at the potential cost of introducing errors into the training. The motivation for this is two-fold: gradual approximation to real life and maintenance of effort/attention. Studies can be classified, therefore, into those in which errors are removed completely (error elimination) or are reduced somewhat (error reduction; Fillingham *et al.* 2003).

Errorless learning has a long history. It was first studied and proved effective in the area of animal learning (Terrace 1963). Since then it has been used as a rehabilitation method in a variety of areas, including; behaviour modification training with children and adults (Brownjohn 1988, Ducharme 1996, Cipani and Spooner 1997, Ducharme *et al.* 2000), teaching auditory discrimination skills to children with language-based learning impairments and to children and adults with Down's syndrome, and non-native phonemes to Japanese adults (Duffy and Wishart 1987, Brownjohn 1988, Duffy and Wishart 1994, Merzenich *et al.* 1996, Tallal *et al.* 1998, McCandliss *et al.* 2001, 2002); and teaching a variety of tasks including naming to people with mental illnesses (Kern 1996, O'Carroll *et al.* 1999, Wykes *et al.* 1999). The successful application of errorless learning for people with amnesia was such that Baddeley (1992) suggested errorless learning as a possible principle for the practice of memory rehabilitation. 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 learning names of objects and people. In each case, errorless learning was superior to errorful learning (Baddeley and Wilson 1994, Wilson *et al.* 1994, Wilson and Evans 1996, Clare *et al.* 1999, 2000, Evans *et al.* 2000). The positive outcome for errorless learning has been replicated by a number of other groups (Squires *et al.* 1997, Hunkin 1998a, b, Parkin *et al.* 1998).

These studies include numerous demonstrations of effective treatment of word finding difficulties using errorless intervention. It is surprising, considering the reported success of the technique for the amelioration of anomia in the domain of

memory impairment, that there appears to be little reported about the use of errorless learning for the rehabilitation of aphasic symptoms. However, a more detailed examination of the aphasia literature reveals studies that can be classified as error reducing in nature (Fillingham *et al.* 2003). For example, Morris *et al.* (1996) conducted a study designed to treat word deafness. They studied a patient with pre-speech and speech-level perceptual deficits. Using a variety of tasks, Morris *et al.* delivered a phonological discrimination therapy in which the patient began with contrasts that varied in three phonetic features (voice, place and manner of articulation: known as 'maximal pairs' tests). Once the patient's performance on this task had improved, he was then moved onto contrasts varying by two features and eventually on to single feature discriminations (known as 'minimal pairs' tests). Morris *et al.* found that the patients' discrimination skills improved significantly and had generalized to spoken word recognition and comprehension. Although not described as such, this staircase method is inherently error reducing and similar in style to the interventions used in the developmental and Japanese studies (Tallal *et al.* 1998, McCandliss *et al.* 2002).

In practice, designing a therapy such that the person with aphasia would only ever produce the correct response can be hard, if not impossible, to do — especially if the aim is to eliminate errors altogether. Miceli *et al.*'s (1996) single case treatment study could be described as error eliminating. They used a cognitive model of lexical processing to assess impairment and target therapy. GMA was described as anomic due to damage to phonological lexical forms. Therapy was targeted at this damage by using reading and repetition. Although the authors did not report on accuracy during therapy sessions, accuracy on repetition and reading assessments prior to therapy were excellent. If GMA performed flawlessly when repeating during therapy then the therapy could be termed error elimination. GMA improved on the treated items and the effects were long lasting, however, there was no generalization.

### *Anomia review*

There has been a considerable amount of clinical time devoted to the amelioration of anomia — one of the most dominant and frustrating aphasic symptoms. Fillingham *et al.* (2003) reviewed the anomia literature (dated from Howard *et al.*'s 1985 seminal paper) to investigate the use of errorless learning techniques. This literature contains no studies that have deliberately investigated errorless learning. However, the treatment methods used in the studies can be categorized post-hoc into one of the three types: error elimination, error reduction, and errorful learning. The number of therapies utilizing errorful techniques far outweighed those with some form of errorless learning. Although the number of studies prevented formal statistical analysis, the review found evidence to suggest that errorless approaches are just as likely as errorful approaches to achieve a positive outcome (in terms of immediate effect, follow-up testing and generalization). This did not seem to vary if the studies were split by therapy type, principal impairment or patient type. However, the review provided limited information on which to judge whether this technique is advantageous for treating word-finding difficulties. Equally, very little is known about the effects of the technique on untreated items (generalization) and whether there is a lasting effect of training.

In summary, the review suggested that errorless learning may be as effective as errorful methods yet there was a need for targeted studies to investigate this technique more directly.

### *Empirical study*

Nickels (2002) proposed a need for treatment studies that dissected tasks, impairments, and their interactions across a series of single cases. The Fillingham *et al.* (2003) review highlighted the lack of information about the application of errorless learning to the treatment of anomia and other aphasic disorders. To begin to bridge these gaps Fillingham *et al.* (2005) compared the efficacy of errorless and errorful learning in a case series of 11 people with anomia. Language and neuropsychological assessments were completed with each participant and a naming therapy was carried out in a case series analysis. Errorless therapy consisted of providing the subject with both the spoken and written picture name to ensure the correct response was made. 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. Performance was assessed at the end of each therapy block and at a 5-week follow-up appointment. 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. There were two participants who did not respond to either treatment and one participant who demonstrated greater benefit from errorful therapy immediately and in the longer term. It was also found that those participants who exhibited greater improvement with an errorful treatment were those with the best working and recall memory, and attention. These results suggest that the outcome of errorless relative to errorful learning may reflect the degree of memory and attentional-executive dysfunction as suggested by studies of people with amnesia (Clare *et al.* 1999, O'Carroll *et al.* 1999). It is probable that these factors are essential cognitive components for providing effective monitoring and feedback systems to a more general learning mechanism (McClelland *et al.* 1999, McCandliss *et al.* 2002, Fillingham *et al.* 2003). The most surprising result was that none of the language assessments predicted therapy outcome. Instead, immediate naming improvements, irrespective of treatment type, were related to the participants' executive skills, recognition memory and self-monitoring ability (the ability to monitor the accuracy of their own naming responses). Over the long-term, executive skills and recognition memory continued to be related to therapy outcome. In her review of the anomia literature, Nickels (2002) noted that, while there is no doubt that anomia therapy can be highly successful, predicting the precise result of a specific treatment task with a specific individual is not possible. The results of Fillingham *et al.* (2005) show that predicting therapy outcome for a specific individual is possible — the critical factor appearing to be that outcome is related to executive/problem-solving, recognition memory and monitoring tasks, rather than language status itself.

### *Learning and feedback*

Neural plasticity, that is the ability of the brain to change its function, is a fundamental issue in neuroscience (e.g. Buonomano and Merzenich 1998, Tallal *et al.*

1998). Work at this level of basic science has shown that the mature brain is, in principle, capable of 'rewiring' itself so that new functions can be learnt by brain areas, which previously performed other processes (Buonomano and Merzenich 1998). One model of errorless learning arises from consideration of the Hebbian learning rule. At the synaptic level, Hebbian plasticity refers to increases in synaptic strength between neurons that fire together. At a higher level of neuronal organization, Hebbian-based learning rules refer to the detection and influence of temporally correlated inputs. A fundamental notion in neuroscience is that synaptic efficiency between two neurons is a substrate for learning and memory (Buonomano and 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 prediction that Japanese adults' poor learning of the English liquids [r] and [l] even after years of exposure to English, was consistent with an underlying Hebbian learning process. Results from a computational model demonstrated that Hebbian learning reinforced perceptual categories learnt early in life but prevented new learning, even in the face of new experience. Using this model, they were also able to demonstrate that plasticity and effective learning were possible given the right circumstances, i.e. errorless learning (McClelland *et al.* 1999). McCandliss *et al.* (2002) tested and confirmed the findings of the model in Japanese subjects who were able to learn the [r]–[l] discrimination after a period of error reducing training. Additionally, they also contrasted feedback versus 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 (such as 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). This suggests that there is some form of cognitive process that can filter out or inhibit the influence of erroneous responses both internally via Hebbian learning or externally via feedback.

The results from this study have implications when the strategies used in the Fillingham *et al.* (2005) empirical study are examined. During errorless learning participants had to repeat the target word three times. No feedback was given whether the response was correct or not (although it often was, i.e. the therapy was error reducing). However, in errorful therapy the participant had an opportunity to name the picture with increasing phonological and orthographic cues. As the participants learnt the target pictures, they needed less attempts at naming and therefore less cues. When the correct word was accessed, whether it was after the first, second or third attempt, no other attempts were made. Therefore, by the nature of the therapy external feedback was given implicitly — the response was correct if no further cue was given, or incorrect if the therapist provided a longer cue. Consequently, it is possible that the errorful learning treatment may have been inflated by feedback (as per McCandliss *et al.* 2002). In turn, any such boost to

the errorful therapy may have eroded an underlying advantage for errorless learning.

The aphasia literature contains very little information about the role of feedback. There appears to be no studies that have manipulated the use of feedback or if they have it has not been the focus of such studies (Fink *et al.* 2002). Even discussions of therapy practice give contradictory advice about the utility of feedback. For example, Schuell's stimulation approach suggests that, 'Feedback about response accuracy should be provided when such feedback appears beneficial. The necessity for feedback may vary from patient to patient, but it generally is advisable' (Duffy 1986, p.150). However, it also argues that, 'It seems that confirmation of adequate performance may be helpful and encouraging and generally represents good clinical practice. Explanation and correction, on the other hand, should be carefully controlled and concise, bearing in mind that such feedback may be of little value, may waste time, and may be counterproductive' (Duffy 1986, p.165). Empirical studies for the role of feedback are clearly required.

The study reported here removed feedback during training so that errorless and errorful learning are directly comparable. The first aim of this study was to test whether errorless learning therapy becomes superior to errorful learning therapy if feedback is removed. The second aim of the study was to replicate the finding that non-language status predicts therapy outcome.

### *Background neuropsychology and aphasia assessments*

#### *Participants*

The same participants were used for this study as Fillingham *et al.* (2005) apart from FO, EW, RH and GP. Participants were recruited through local speech and language therapy services. In order to investigate the utility of errorless learning in a wide variety of aphasic patients, limited selection criteria were adopted. Patients were selected primarily on the basis that they had word-finding difficulties due to some kind of central language impairment, i.e. following damage to semantic and/or phonological representations. Patients were not selected for any specific sub-type of word-finding difficulties or anomia. Patients who failed to name pictures because they had perceptual deficits (agnosia) or had dysarthria, dyspraxia or speech-motor programming deficits were excluded. They were required to be at least 6 months post-onset, have an acquired neurological deficit, have a significant word finding problem (below 70/100 on a simple naming test: Lambon Ralph *et al.* 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 *et al.* 1992). Basic information about the participants is given below.

HF was 64-year-old widow and housewife before a left middle cerebral artery infarct and frontal lobe changes (as reported on computed tomographic scan) in 2001.

JS was a 76-year-old man who had a left-sided CVA in 1992 resulting in a severe aphasia and right hemiparesis. He was a retired electrician and lived with his wife.

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 company director.

ME was a 70-year-old housewife who lived with her husband. She had a left CVA in 1987 resulting in a right hemiparesis.

SC was a 74-year-old man 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.

RR was a 60-year-old man 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.

HA was a 74-year-old man 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 in the left parieto-occipital region.

### *Background assessment*

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

Assessment of the participants' language skills was focussed mainly on single-word processing (table 1). Picture naming tests were used to measure the degree of anomia: Boston Naming Test without standard systematic cueing (Kaplan *et al.* 1976), Graded Naming Test (McKenna and 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; Kay *et al.* 1992); repeating words (PALPA 9) and non-words (PALPA 8; Kay *et al.* 1992). 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 and Patterson 1992); a 100-item word-picture matching test in both spoken (SWPM) and written formats (WWPM: Lambon Ralph *et al.* 1998). Given that these are relatively insensitive 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 *et al.* 1997); Concrete and Abstract Synonyms (Warrington *et al.* 1998).

Table 1 shows the participants' results on language assessments indicated either by the raw score or percentile score. It indicates a wide range of aphasic impairments. Naming ability is highlighted with the total naming score (the sum of the three naming assessments), which ranged from 1/130 (JS) to 67/130 (ME). When the naming errors were analysed HF and RR had an equivalent proportion of



**Table 1. Initial language assessment results for each participant**

Domain	Assessment	Maximum	HF	JS	RD	ME	SC	RR	HA	Norms
Naming	BNT	60	22	0	5	25	10	6	15	42–60
	GNT	30	2	0	1	6	0	0	3	12
	PON	40	14	1	10	36	20	25	35	39.80
	Total Naming	130	56	1	16	67	30	31	53	n/a
Phonology	Word reading	80	63	0	51	80	65	16	64	79.4
	Non-word reading	30	5	0	3	12	20	0	17	n/a
	Word repetition	80	79	36	75	79	78	76	65	78.81
	Non-word repetition	30	28	6	28	24	26	23	17	n/a
Semantics	PPT (pictures)	52	45	40	44	48	50	45	52	49–52
	PPT (words)	52	43	32	31	50	51	26	51	49–52
	SWPM	100	83	39	77	96	100	97	100	96–100
	WWPM	100	79	37	79	95	98	81	99	96–100
	BPVS — SWPM	168	104	86	88	137	135	87	156	n/a
	BPVS — WWPM	168	16	44	92	143	114	51	159	n/a
	WSJ — Aud/Con	25	5%ile	N/C	N/C	50%ile	5%ile	<1%ile	50%ile	n/a
	WSJ — Aud/Ab	25	5%ile	N/C	N/C	25%ile	<1%ile	10%ile	90%ile	n/a
	WSJ — Writ/Con	25	1%ile	10%ile	N/C	25%ile	<1%ile	<1%ile	90%ile	n/a
WSJ — Writ/Ab	25	10%ile	1%ile	N/C	25%ile	N/C	<1%ile	90%ile	n/a	

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, total correct for the three naming tests; Word reading (PALPA 31); Non-word reading (PALPA 8); Word repetition (PALPA 9) and Non-word repetition (PALPA 8); PPT, Pyramids and Palm Trees picture and written word versions; SWPM and WWPM, 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; Ab, Abstract items).

semantic and phonological errors in naming. RD, SC and ME's proportion of errors were predominantly semantic and JS and HA showed the reverse — predominantly phonological errors. There was variation in phonological skill with JS being the most severe overall to ME who was within normal range for both reading and repeating words. HF and SC were also within normal range for word repetition. Again, JS appeared to have the poorest semantic ability overall while HA was within normal range on all semantic tasks, including the graded Warrington Synonym Judgement test (Warrington *et al.* 1998). SC also scored within normal range on the easier semantic tests but showed marked difficulties on the more stringent tests.

In addition to providing important clinical data, neuropsychological assessments were given to test various non-language, cognitive processes that may underpin feedback and control mechanisms (table 2). These included assessments of episodic memory for verbal and non-verbal materials: Camden Memory Test (Warrington 1996), Rey Complex Figure Test (Meyers and Meyers 1995); working memory, digit span and the PALPA Auditory Digit Matching Span (Bachrach and Mintz 1974, Kay *et al.* 1992); non-verbal problem-solving and reasoning, Wisconsin Card Sorting

**Table 2. Neuropsychological assessment results for each participant**

Domain	Assessment	HF	JS	RD	ME	SC	RR	HA
Monitoring	Self-rating	49%	26%	86%	92%	91%	93%	100%
Episodic memory	CMTpic	100%ile	100%ile	100%ile	10%ile	100%ile	10%ile	100%ile
	CMTtop	<5%ile	75%ile	<5%ile	25%ile	95%ile	50%ile	75%ile
	CMTword	<5%ile	10%ile	<5%ile	25%ile	100%ile	25%ile	100%ile
	CMTface	25%ile	>5%ile	100%ile	25%ile	50%ile	>5%ile	75%ile
Working memory	WDSf	5	N/C	5	5	3	3	3
	WDSb	2	N/C	3	2	2	1	4
	PADMS	7	N/C	7	7	N/C	2	7
Non-verbal problem solving				11-				
	WCS — No. cat	<1%ile*	6-10%ile*	16%ile	>16%ile	>16%ile	>16%ile	>16%ile
	WCS — FMS	6-10%ile	16%ile	2-5%ile	16%ile	16%ile	16%ile	16%ile
Attention	TEA — elevator	7/7	6/7	5/7	7/7	7/7	6/7	7/7
		12.2-	6.7-	3.3-	6.7-	3.3-	3.3-	12.2-
	TEA — with dis	20.2%ile	12.2%ile	6.7%ile	12.2%ile	6.7%ile	6.7%ile	20.2%ile
Visuospatial ability and memory						11-		
	Rey — copy	<1%ile	<1%ile	2-5%ile	6-10%ile	16%ile	<1%ile	>16%ile
	Rey — Imm							
	Recall	<1%ile	5%ile	25%ile	54%ile	<1%ile	5%ile	99%ile
	Rey — Del Recall	<1%ile	4%ile	24%ile	34%ile	<1%ile	<1%ile	90%ile
	Rey — Rec Total	<1%ile	14%ile	1%ile	4%ile	4%ile	10%ile	14%ile

N/C, not able to complete due to memory problems, difficulty understanding task, repeating or refusal; \*patient did not complete the whole task and so scores are based on the cards that were sorted; Self-rating, ability of the 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, Weshcler 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).

(Grant and Berg 1993) and attention, both vigilance and divided attention: elevator counting with and without distraction from the Test of Everyday Attention (TEA: Robertson *et al.* 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). It may also be an important factor that determines the usefulness of feedback. Accordingly, we assessed the participants' ability to judge the accuracy of their own naming (assessment of monitoring). This was achieved by using a short picture naming assessment (Kay *et al.* 1992). After the patient had named the picture they were asked if they thought their response was correct or incorrect (the score in the table represents the patient's self-monitoring accuracy expressed as a proportion of total monitoring responses).

Table 2 shows the results of the neuropsychological testing for each participant (raw score, percent correct or percentile score is shown). HA is the only participant who was able to monitor his naming attempts correctly (100%). The weakest, JS, scored 26%. There is a great deal of variation in all memory assessments and all participants showed a deficit in at least one of the memory tests. HF, JS and RD were all poor at problem solving whereas the remaining four participants scored well. It was surprising to find that all participants had a mild to moderate deficit when requested to divide their attention (in a non-verbal task). In addition, all participants had some degree of difficulty with either visuospatial skills and/or visuospatial memory.

## Therapy

### *Method*

A multiple baseline, crossover study was carried out to contrast errorless and errorful therapies for word-finding difficulties. The 260 pictures from Snodgrass and Vanderwart (1980) were used for all participants for a baseline measure except HA for whom this test did not yield sufficient unnamed items for therapy. Therefore, items from the more challenging Category Specific Naming Test (CSNT) (McKenna 1997) were used. Three baseline measures were taken and the items were split into three groups of twenty matched for accuracy, 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.

There were some changes made to the method from the original Fillingham *et al.* (2005) study due to time constraints and the overall aim of preventing feedback in the errorful condition. First, both therapies were completed within the same session and the order of therapies was counterbalanced across sessions. Because of this, the number of items in each set was reduced from 30 to 20 so that the therapy sessions were not too long. As mentioned above, the main aim of this study was to prevent feedback in the errorful therapy and we wanted the number of naming attempts for each item to be equal for both therapies (reduced to one naming attempt per item).

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 participant with the picture along with its spoken and written name to ensure the correct response was made. The participant repeated and/or read the name once. In errorful therapy the participant was given the picture along with the

first phoneme and grapheme and asked to name the picture. For both therapies, whether the response was correct or not, no feedback was given and the next item was attempted. The 40 items (20 items for errorless treatment and 20 for errorful treatment) were cycled through three times in each therapy session, which lasted between 25 and 40 minutes.

Baseline measures were taken in the first 2 weeks. The next 5 weeks were taken up with both therapies running alongside each other, counterbalanced across sessions. Many of the previous errorless learning studies have given patients intensive periods of therapy, which continued until a predefined performance threshold was reached (Clare *et al.* 2000). We were keen to test the efficacy of the therapies within a schedule that might more realistically be found in a UK National Health Service (NHS) clinical setting. Accordingly, both therapies consisted of ten sessions, given twice weekly for 5 weeks (with breaks for unavoidable events, e.g. illness, holidays, etc.). Assessment was carried out after therapy (within the next week) to measure the immediate effect to treated and untreated items (generalization). A follow-up assessment was carried out after an additional period (on average 5 weeks post-therapy). The efficacy of each therapy was compared and also related back to each participant's background language and neuropsychological measures.

## Results

The research aims were as follows: 1) to compare errorless and errorful learning approaches without feedback; and (2) to identify which aspects of the participants' language and cognitive skills predict therapy effect. They will be discussed in this order.

### *Basic results*

Figure 1 shows the results of both treatments for each participant. Each box contains results for one participant. The *x*-axis indicates the time of assessment: at baseline (Baseline), immediately post-treatment (PostTx) and at follow-up (Follow-up). The unfilled 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, filled bars.

The results of the control items are shown as grey bars. As can be observed, there was no significant generalization for any of the participants. In addition, no participant showed a significant difference in favour of errorless or errorful therapy at post-treatment or at follow-up assessment.

The graphs are ordered according to the overall therapy effect immediately post-treatment. HF and JS both showed no significant therapy effect. RD exhibited a change in errorful items only (McNemar  $p=0.016$ , one-tailed) and when compared with the number learnt in errorless therapy the difference did not reach significance. The remaining four participants all showed a significant effect of both errorless (McNemar  $p=0.007$  to  $p<0.001$ , one-tailed) and errorful (McNemar  $p=0.007$  to  $p<0.001$ , one-tailed) therapy immediately post-treatment. The long-term effect of each therapy is revealed by comparing the results at follow-up against baseline accuracy. HF, JS, RD, ME and SC all exhibited no significant change as a result of either

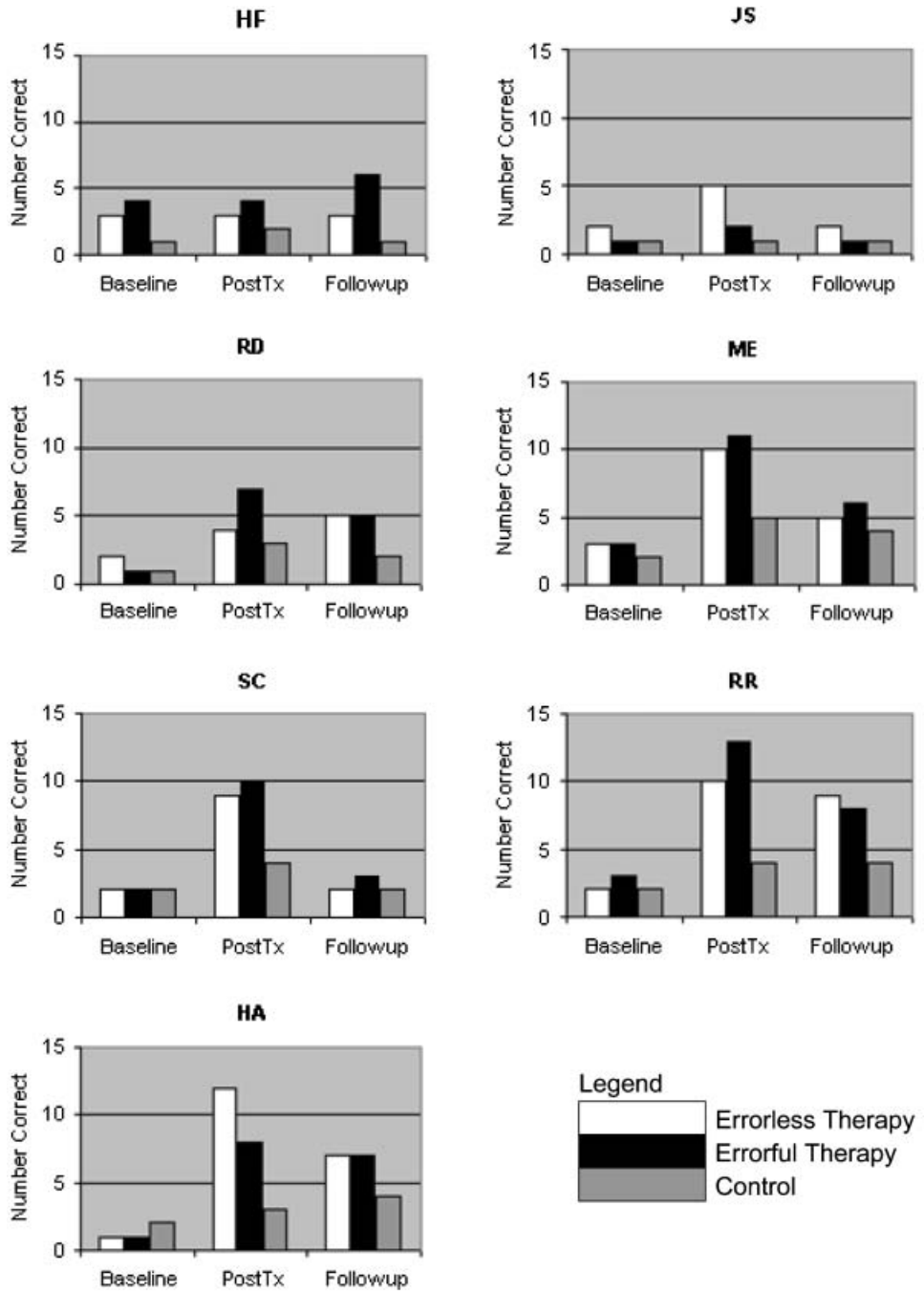


Figure 1. Results of errorless and errorful therapy without feedback.

therapy. RR and HA — those with the biggest post-therapy improvement — were the only two participants who showed a long-term benefit from both techniques (McNemar  $p=0.031$  to  $0.007$ , one-tailed).

Which aspects of the participants' language and cognitive profiles predicted therapy outcome? The overall therapy effect varied across participants. Two participants (HF and JS) exhibited no therapy effect and the remaining five participants demonstrated differing success rates immediately after therapy. RR and HA showed long-term retention for both therapies. One aim of this study was to see if the results from Fillingham *et al.* (2005), indicating that recognition memory, executive/problem-solving skills and monitoring ability predict therapy outcome, could be replicated. We used the same case-series design (in which each and every participant is assessed across the same battery of tests) so that a direct comparison between the size of the therapy effect and the participants' scores on the background assessments could be made. Two 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); and (2) which background assessments correlate with the long-term effect (baseline versus follow-up accuracies). All language and neuropsychological background results were correlated against these two measures using a non-parametric correlation across the case series of participants in this study (Spearman's  $\rho$ ). We replicated the previous results for immediate therapy effect but found no correlations for long-term effect (presumably due to floor effects in the follow-up data). Again, it was aspects of the participants' remaining non-language, cognitive skills that predicted therapy outcome for immediate therapy effect not language ability. Although these exploratory correlations are based on small sample sizes, the correlations between therapy outcome and non-language, cognitive skills are considerable — underlining the potential importance of these non-language skills in predicting therapy outcome. As noted by Fillingham *et al.* (2005), these important cognitive skills — highlighted in our studies of aphasic patients — are the same as those identified as critical cognitive factors in the rehabilitation literature (frontal lobe executive skills and monitoring (Robertson and Murre 1999)). This suggests that these factors are important ones for successful rehabilitation in general, rather than being specific to certain diseases or types of cognitive/language impairments.

Specifically, the neuropsychological tests that significantly correlated with immediate therapy effect were the number of categories completed on the Wisconsin Card Sorting test ( $\rho=0.8$ ,  $p=0.031$ ) and the test of Self-rating ( $\rho=0.85$ ,  $p=0.015$ ). This indicates that the participants who responded well to both therapies immediately post-treatment had better executive function and monitoring skills. In addition, two of the semantic tasks correlated with immediate therapy effect (auditory word to picture match and written word to picture match). Given that these all require problem-solving and decision making for accurate performance, it is possible that these correlations reflected the participants' varying executive skills. When scores on the Wisconsin Card Sorting and the self-rating test were partialled out, the partial correlation was no longer significant ( $\rho=-0.4$ ,  $p=0.5$  and  $\rho=-0.8$ ,  $p=0.1$ ). Fillingham *et al.* (2005) also showed a relationship between immediate therapy effect and subtests scores of the Camden Memory Test (Warrington 1996) indicating recognition memory as a predictor of therapy outcome. However, this was not found in this study.

*Comparison of error rates for errorless and errorful techniques.*

Although errorless therapies aim to eliminate errors from the participants' 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. Monitoring of error rates is important to confirm that the errorless technique does actually result in significantly less errors than the corresponding errorful treatment.

Figure 2 shows the participants' 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 participant and the graphs are ordered according to overall therapy effect, immediately post-treatment. Again, the unfilled bars show the results for errorless therapy and the filled bars for the errorful therapy. The results show that there was a significant difference between the two therapies with errorless therapy being the more accurate for each and every participant (i.e. comparing naming accuracy during each therapy across the ten therapy sessions, for each patient separately:  $t(9)$  between 5.8 and 19.4,  $p < 0.001$ ). None of the participants reached the optimal condition of complete error elimination. Although, RD and SC nearly reached this optimal condition.

**Discussion**

This investigation was conducted as a follow-up to Fillingham *et al.* (2005) to compare errorless and errorful therapy without giving participants feedback on their responses during treatment sessions. The present study had two main aims. The first was to repeat the original study but without giving feedback during therapy sessions to test whether there was an underlying superiority for errorless over errorful learning (therapy type and feedback had been confounded in the previous study). The second aim was to replicate important findings from the original study, namely that recognition memory, executive/problem-solving skills and monitoring ability predict outcome of therapy, and that language ability does not predict outcome of therapy.

Errorless and errorful learning, without feedback, was used to treat word-finding difficulties across a case series of seven people with aphasia. Four of the participants exhibited significant improvements for both techniques. The long-term effect of therapy was significant in two participants — the two who had demonstrated the greatest improvement immediately after therapy. Two participants did not improve with either therapy and there were no changes at follow-up assessment. There were no participants who showed an advantage for either technique and there was no generalization.

The results closely mirror the original study (Fillingham *et al.* 2005) and also the results from the review of the anomia literature (Fillingham *et al.* 2003). Errorless and errorful learning therapy produced equivalent results in terms of immediately post-treatment effect, retention at follow-up assessment and for generalization (none).

The results from the errorful therapy are interesting because it is unlikely, in a clinical situation, that only a single cue would be given in therapy and even more unlikely that feedback about the response would be omitted. People with aphasia are

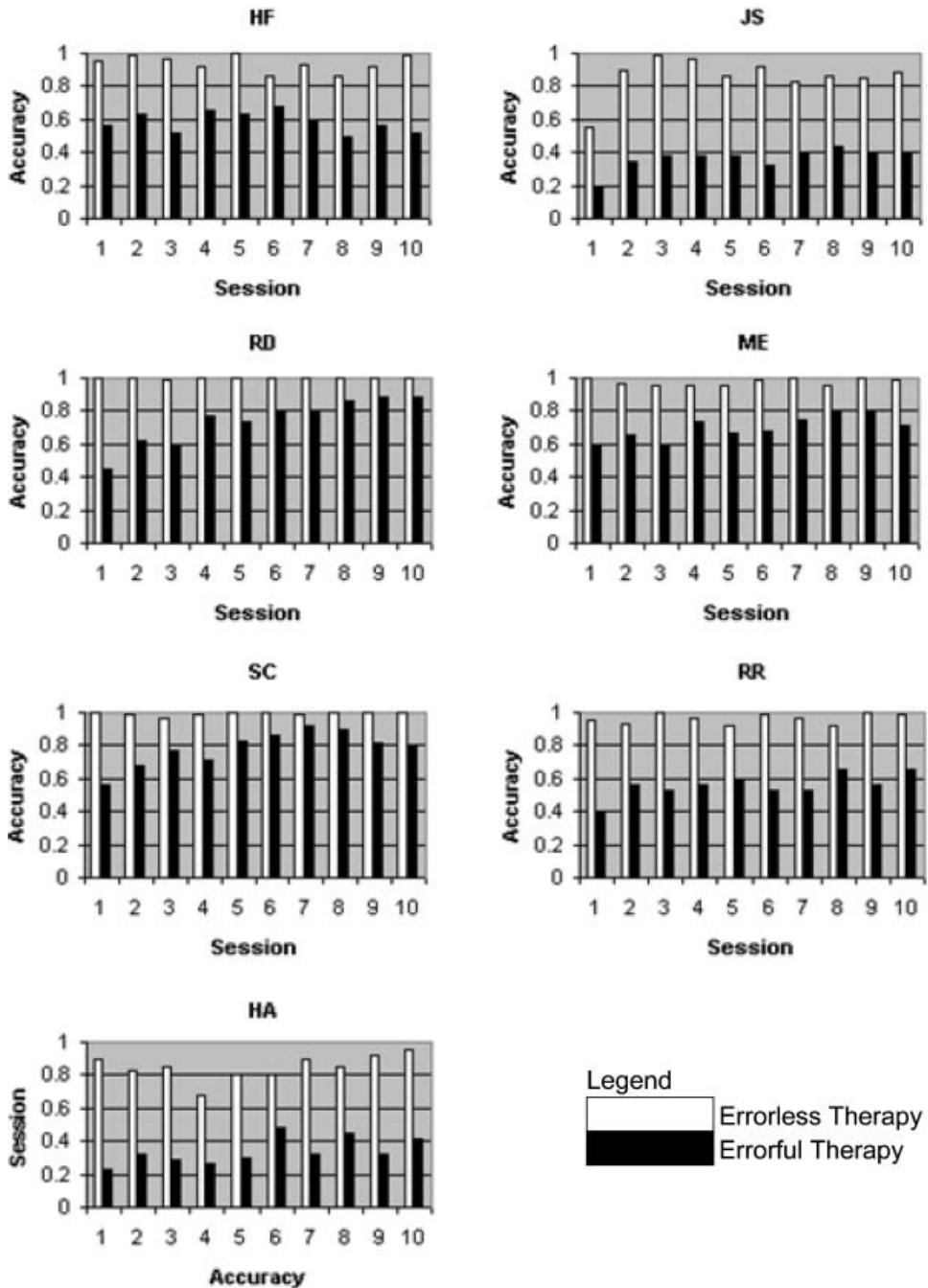


Figure 2. Accuracy during errorless and errorful therapies.

more likely to access words with the aid of a multiple cue (Sage 2003) and feedback is generally given to aid learning (Duffy 1986). However, this form of therapy (one phoneme and no feedback) proved to be as effective as the errorless learning (in which the whole name is given). It should be noted, perhaps, that although only one



phoneme was given in the errorful therapy, this was sometimes sufficient to cue the name of the picture, especially as therapy progressed. This can be seen in figure 2 in that accuracy during errorful therapy (picture and cue) — around 50% — was much higher than during baseline assessment (<10% for all cases).

During errorless learning, the participants generally did not seek feedback — presumably because they were already provided with the correct name. During errorful therapy, particularly in the initial sessions, the majority of participants requested feedback. It is natural that people request feedback, but this study, compared with the original investigation, shows that giving or omitting feedback does not make a difference to therapy outcome.

If a clinical judgement had to be made about which technique to use, then it is important to take into account the fact that as in the original study 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 the original study and again from the present one suggests that participants were as likely to engage in the errorless learning therapy as any other. Indeed, the participants strongly preferred errorless treatment as they found it less frustrating and more rewarding. As Fillingham *et al.* (2005) noted, 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. The participants in this study were not bored by errorless therapy, but there is a danger that it may be inherently tedious for the therapist. Given that the participants were able to relearn the names with no therapist feedback, a method such as computer-assisted therapy may prove to be the most effective way to deliver this type of intervention (see the recent special issue of *Aphasiology* dedicated to the topic of computers and aphasia; Petheram 2004).

The results of the original Fillingham *et al.* (2005) study showed that the status of the participants' language skills did not predict therapy outcome. Instead, immediate and long-term naming improvements, irrespective of treatment type, were related to the participants' executive skills and recognition memory. Those participants who responded better overall had better recognition memory, executive/problem-solving skills and monitoring ability. This study was able to replicate these findings. Immediate naming improvements, irrespective of treatment type, were again related to the participants' executive skills. Those participants who responded better overall had better executive/problem-solving skills and monitoring ability. When the participant's long-term naming scores were related to their language and neuropsychological profiles, no correlations were found. The lack of a relationship between language skills and therapy outcome can be seen in tables 1 and 2 (the participants are ordered by size of overall therapy effect). For example, HF had good overall language scores (when compared with the rest of the group) but she did not respond to treatment in either the original study or this one. Also RR had some of the poorer language scores (when compared with the rest of the group) but was the second best learner. Instead, this interim position aligns closely with their performance on the Wisconsin Carding Sorting test. This is an important clinical result and mirrors other findings in current rehabilitation literature. Hinckley and Carr (2001) correlated the cognitive performances of 18 adults with aphasia, who were randomly assigned to skill-based and context-based aphasia treatment, with their language performances at post-treatment and follow-up. They found that subjects with higher cognitive abilities including ability on the Wisconsin Card Sort

test generally maintained or improved their performance speed at post-treatment and follow-up, while subjects with lower cognitive profiles required much more time to accomplish these tasks.

Another replication of this finding has been shown for rehabilitation in other neurologically damaged patients, namely that executive systems are crucial for rehabilitation (Robertson and Murre 1999). Robertson and Murre argue that from a rehabilitation perspective, awareness of deficits (monitoring ability) 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 and Murre 1999). Recanzone *et al.*'s (1993) study of experience-dependent neural reorganization is consistent with this notion. They found that cortical reorganization is dependent on the animals attending to the target activity.

The findings from our two studies are consistent with the position argued by Hinckley (2002). Hinckley notes that linguistic, cognitive neuropsychological, compensatory and social approaches to language rehabilitation tend to focus on components of language processing without considering other cognitive factors. Hinckley suggests that cognitive/learning theories (detailing the cognitive mechanisms of change) in conjunction with neurological approaches (which offer behavioural evidence of change) offer the best current step towards a theory of therapy.

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