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The benefits of errorless learning in mild cognitive impairment

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The benefits of errorless learning in mild cognitive impairment

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The benefits of errorless learning in mild cognitive impairment

The aim of this thesis was to explore the benefits of errorless learning (EL) in comparison to learning by trial-and-error or errorful learning (EF) for people with mild cognitive impairment (PwMCI). The literature review was a meta-analysis of studies which compared EL and EF in neurodegenerative conditions, specifically mild cognitive impairment (MCI) and other dementias. Across the ten reviewed studies there was a moderate effect size for the benefit of EL over EF learning for people with MCI and dementia. Results were tentative as six of the reviewed studies had non-significant effect sizes which may have reflected small sample sizes or methodological issues, or indicate that EL may not be any more advantageous than EF for some individuals. Given that only three studies were identified in the review which explored EL with MCI participants, it seemed appropriate to explore the benefit of EL further with this population. The empirical study describes the results of an experimental study conducted with eleven participants with a clinical diagnosis of MCI. A word-list learning task was used and outcome was assessed by free recall, cued recall and recognition tasks. The findings of the empirical study showed that EL was not significantly superior to EF when undertaking a word-list task for PwMCI. A relationship was found between error-monitoring ability and the difference between EL and EF conditions. It was recommended that future research explore the role of error-monitoring further. A concluding discussion chapter focusses on the implications of these findings for future research and theory development as well as implications for clinical practice. Limitations of the thesis are considered and a concluding paragraph offers a personal reflection on the process of conducting this research.

Errorless learning in the rehabilitation of memory in Mild Cognitive Impairment and Dementia: a systematic review and meta-analysis.

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Abstract

Objective: It has been shown that errorless learning can benefit people with memory impairments resulting from brain injury yet the evidence from the literature for mild cognitive impairment, Alzheimer's disease and other dementias is unclear. In the absence of reviews systematically exploring the benefits of errorless learning specifically for these populations, a meta-analysis and systematic review of the relevant literature was conducted. This was done by identifying studies directly comparing errorless and errorful methods within an experimental design.

Method: A literature search was conducted in order to identify studies that were independent of each other, that utilised a within-subjects design with participants who had been clinically diagnosed with mild cognitive impairment or dementia. For the purpose of meta-analysis it was a requirement that either original data was reported or that exact *p, t* or *F* values were reported.

Results: Ten studies were included in the meta-analysis which comprised data from 110 participants. Participant ages ranged from 67-87 years with a mean age across studies of 77 years. The summary effect size of 0.65 (CI0.41-0.89) and respectable confidence interval range would be considered moderately significant.

Conclusion: Results are tentative as six of the reviewed studies had non-significant effect sizes which may reflect small sample sizes or methodological issues, or indicate that errorless learning may not be any more advantageous than errorful learning for some individuals. It is recommended that further experimental studies are carried out.

Keywords: errorless learning, trial-and-error, implicit memory, error-monitoring, meta-analysis

Cognitive rehabilitation aims to enable people with deficits in various cognitive domains to engage as fully as possible with their day-to-day lives, through supporting them to reach their maximum potential (Wilson, Gracey, Evans & Bateman, 2009). Cognitive rehabilitation is not just relevant for recovery from brain injury but can be applied in progressive conditions, and is a comprehensive approach which may include provision of specific techniques for learning or re-learning information (Clare & Woods, 2004). Such techniques could be of particular relevance to neurodegenerative conditions such as mild cognitive impairment (MCI), Alzheimer's disease (AD) and other dementias such as vascular dementia (VD), mixed dementia (Mix; a combination of AD & VD) and semantic dementia (SD). The most notable difficulty associated with MCI and dementia is memory impairment which can lead to lower self-confidence, disengagement from preferred activities, anxiety and depression (Apostolova & Cummings, 2008; Ballard, Bannister & Oyebode, 1996; Ballard, Boyle, Bowler & Lindesay, 1996). This review will therefore consider the emerging evidence-base for a method of supporting learning and subsequent recall which could be used in cognitive rehabilitation. Errorless learning (EL) has shown promising results for people with memory impairment across a range of aetiologies which include brain injury, Korsakoff syndrome, and dementia (for a review, see Clare & Jones, 2008).

The principal aim of EL is to eliminate the production of errors during learning. This is in direct contrast with trial and error or 'errorful' learning (EF) where the production of errors or 'guessing' is encouraged. Terrace (1963a; 1963b) is frequently cited as providing the theoretical framework for EL. Terrace demonstrated in his experiments with pigeons that discrimination between reinforced and non-reinforced stimuli could be achieved through exposure to the reinforced stimuli alone with a gradual fading in of the non-reinforced stimuli. Learning could therefore be described as ‘errorless’ rather than ‘trial-and-error’. Although these experiments were tightly controlled and a truly errorless performance was difficult to achieve, they did encourage others to apply these techniques to human participants, particularly in the learning disability field (Sidman & Stoddard, 1967). It is important to note that the work of Skinner (1958) also contributed to the study of EL in human participants with his programmed learning experiments. For a thorough theoretical review of this early work, see Clare and Jones (2008). EL techniques have since been applied successfully to the rehabilitation of amnesia resulting from brain injury or neurological illness (Glisky et al., 1986). An influential study by Baddeley and Wilson (1994) demonstrated that EL learning was superior to EF learning in a word-list task for people with memory impairment following brain injury. A great deal of evidence in support of EL in comparison to EF for memory impairments following brain injury has since been reported (Wilson et al., 1994; Squires et al., 1997; Hunkin et al., 1998; Page et al., 2006).

EL encompasses several different methods and techniques. This can cause some confusion as EL could either be a methodological principle (the reduction of errors in learning) or a method in itself. The EL condition used by Baddeley and Wilson (1994) involved the experimenter showing participants a word cue (verbally and visually) such as AR____ and immediately telling the participant what the word was e.g. ARTIST. In the EF condition the participant was encouraged to guess what the full word might be following the cue before being given the correct answer. Other techniques include the method of vanishing cues (MVC) and spaced retrieval (SR). MVC was first used by Glisky et al. (1986) and involved the experimenter showing the target word and following each successful recall attempt, a one letter cue was removed. SR (Camp, Foss, O’Hanlon & Stevens, 1996) is based on evidence that suggests that time scheduling of retrieval practice influences the degree to which benefits are observed during retrieval attempts, with greater benefits observed for gradually expanding intervals during test trials. Spaced retrieval involves progressively increasing the interval between each study phase which is based on the participant's performance. Errors are corrected immediately and the last successful interval is repeated. The MVC and SR can allow errors to occur during training by nature of their design, and there is some debate as to whether these techniques can truly constitute EL. It is also difficult to design an adequate EF condition for comparison (Middleton & Schwartz, 2012). For the purpose of this review therefore, the focus will be on studies where the EL technique adopted by Baddeley and Wilson (1994) is applied.

Glisky et al. (1986) and Baddeley and Wilson (1994) proposed a role for implicit memory as determining the relative success of EL in people with memory impairments. Neuropsychological models of memory distinguish between implicit and explicit memory processes which constitute distinct forms of long-term memory (Graf & Schacter, 1985). Explicit memory stores include semantic and episodic memories whereas implicit memory involves unconscious processes such as priming and procedural learning. Semantic memory is composed of knowledge about the world, facts, ideas and word meanings where there may be no recollection of when or where it was learnt (Tulving, 1972). Episodic memory relates to unique personal experiences which are tagged in time or place (Baddeley et al., 1995). It was hypothesised by Baddeley and Wilson that people with impairments in explicit memory rely during learning on implicit memory, which does not have the capacity for the individual to distinguish between errors and correct responses. This leads to the priming of errors as well as target stimuli, which inhibits learning in EF conditions. The evidence for the role of the implicit memory system is supported by the findings of Page et al. (2006), whereas others argue that it is residual explicit memory which leads to the benefits of EL (Tailby & Haslam, 2003; Hunkin, Squires, Parkin & Tidy, 1998). Clearly, whether it is the intact implicit memory system and/or the residual explicit memory store which is responsible for the effectiveness of EL, there is evidence to suggest that for people with impairments to their explicit memory, EL is superior to EF.

Impairments in episodic memory, and to a lesser extent semantic memory, are core features of MCI and AD whereas implicit memory is relatively spared (Grundman et al., 2004; Knopman & Nissen, 1987; Petersen, Smith, Waring, Ivnik, Tangalos & Kokmen, 1999). It is therefore logical to assume that for people with neurodegenerative conditions such as MCI and dementia, the application of EL learning to methods of rehabilitation would yield positive results. Relatively few studies have explored the benefits of EL in neurodegenerative conditions such as MCI and dementia. Lubinsky, Rich and Anderson (2009) compared EL and EF methods across people with MCI and healthy older people in a word learning task. Results were positive and EL was shown to result in better recall than EF. A clear advantage of EL over EF has been shown for face-name associations and novel procedural learning tasks in AD (Haslam, Moss & Hodder, 2010; Kessels & Olde Hensken, 2009). Metzler-Baddeley and Snowden (2005) taught four individuals with AD face-name and object-picture associations under EL and EF conditions. Although at group level, EL was significantly better than EF, this significance was not shown when examining individual participant data. The literature also shows, however, that EL may be beneficial for some individuals but not all (Haslam, Gilroy, Black & Beesley, 2006) and it is unclear what factors contribute to this.

There is therefore some debate as to the relative benefits of EL over EF for people with memory impairments resulting from neurodegenerative conditions such as MCI and AD. It has been shown that EL can benefit people with memory impairments resulting from brain injury yet the evidence from the literature for MCI, AD and other dementias is unclear. In the absence of reviews systematically exploring the benefits of EL specifically for these populations, a meta-analysis and systematic review of the relevant literature which examines

EL for people with MCI, AD and other dementias will be conducted. This will be done by identifying studies directly comparing EL and EF methods within an experimental design.

Method

Literature review

ProQuest and Web of Knowledge databases were searched for English language, peer reviewed journal articles. No limit on year of publication was set and the following search terms were used: 'Errorless Learning' OR 'Cognitive Rehabilitation' OR Memory Rehabilitation' combined with 'Mild Cognitive Impairment' OR 'Alzheimer's Disease' OR 'Dementia' (in Title). The inclusion criteria for this review were:

1. Studies should be independent of each other.
2. Studies should utilise a within-subjects design and compare EL versus EF performance.
3. Study participants should be diagnosed with either MCI or dementia.
4. Original data should be reported and exact scores for both EL and EF conditions (Mean and Standard Deviation) and exact *p, t* or *F* values should be given.

Procedure

Figure 1 shows a summary of the process of study selection. A total of 115 studies were identified. Study abstracts were examined and a total of 95 studies were excluded for the following reasons; abstract only = 2, Not English = 10, rehab only/not EL=64, long-term intervention=13, Not MCI/dementia =3, Conference abstract only=2. A total of 21 studies remained. Of those 21 full text studies, 9 were included in the meta-analysis. Those studies not included in the meta-analysis were excluded for the following reasons: they utilised a between-subjects design, the outcome data were not obtained immediately following the learning task, the outcome data were not purely derived from participants with

MCI/dementia, or they did not include a within-subjects control/EF condition. A total of 12 studies were excluded for these reasons, which are detailed in Table 1. The 12 excluded studies were: Clare, Wilson, Breen and Hodges (1999); Winter and Hunkin (1999); Clare, Wilson, Carter, Breen, Gosses and Hodges (2000); Tailby and Haslam (2003); Dunn and Clare (2007); Jean, Simard, Reekum and Bergeron (2007); Provencher, Bier, Audet and Gagnon (2008); Kessels and Olde Hensken (2009); Lubinsky, Rich and Anderson (2009); Rothi et al. (2009); Tilborg, Kessels and Hulstijn (2011); Noonan, Pryer, Jones, Burns and Lambon Ralph (2012).

(((Please insert table 1 here)))

(((Please insert Figure 1 here)))

Outcome Measure

For the purposes of this review, the outcome measure was the difference between EL and EF scores on the immediate (with brief delay) memory test in which the participant was asked for recall or recognition of the material presented. Three test modalities were identified: free recall, cued recall and recognition. Free recall involved the participant attempting to recall the taught information without cues. Cued recall involved the use of cues (the first and/or the second letter of the target word/object name) to elicit recall of the taught information. The recognition task involved showing the original stimuli from the teaching phase in addition to distractor items, with the participant being asked to identify the target word/object.

Statistical Analysis

Mean difference scores between EL and EF methods were converted into an effect size (ES) by dividing the mean difference by group variance (Cohen's *d*). This method was considered preferable to correlation coefficient *r* as it was the group difference rather than the relationship between groups which was of interest. If a study reported the *t* or *F* statistic, the relevant statistical formula for converting this to an effect size was applied. The precise formulae for these calculations can be found in Kontopantelis and Reeves (2009), and their statistical software 'MetaEasy' was used to calculate the results.

Results

Sample

Table 1 provides an overview of the 9 studies included in this review (Akhtar, Moulin & Bowie, 2006; Bier et al., 2008; Dechamps et al., 2011; Haslam, Gilroy, Black & Beesley, 2006; Haslam, Moss & Hodder, 2010; Haslam, Hodder & Yates, 2011; Jokel & Anderson, 2012; Metzler-Baddeley & Snowden, 2005; Ruis & Kessels, 2005). Taken together, these comprised data from one hundred and ten participants comparing EL and EF methods. Participant ages ranged from 67-87 years with a mean age across studies of 77 years. Gender was generally equally distributed with 2 studies not reporting this information (Akhtar, Moulin & Bowie, 2006; Haslam, Gilroy, Black & Beesley, 2006). Only one study included participants with MCI (n=16; Akhtar, Moulin & Bowie, 2006), with the remaining studies including participants with a range of dementia diagnoses: AD (n=74), VD (n=10), Mix (n=3) and SD (n=7). Two studies did not report the Mini Mental State Examination (MMSE; Folstein & Folstein, 1975) score (Haslam, Gilroy, Black & Beesley, 2006; Metzler-Baddeley & Snowden, 2005). The average MMSE score across the remaining 7 studies was 21.25 which would be considered to reflect mild dementia.

Methodology

The reviewed studies used a variety of learning tasks to compare EL and EF methods. Face-name association tasks were most popular (Bier et al., 2008; Haslam, Gilroy, Black & Beesley, 2006; Haslam, Moss & Hodder, 2010; Haslam, Hodder & Yates, 2011; Metzler-Baddeley & Snowden, 2005; Ruis & Kessels, 2005) ; difficulty with recalling names of friends or acquaintances is a common occurrence in MCI and dementia, particularly AD. Metzler-Baddeley and Snowden (2005) added object-picture naming alongside their face-name association task, whereas Haslam, Gilroy, Black and Beesley (2006) included details of the person's occupation as a measure of higher level knowledge with their face-name association task. Word list learning (Akhtar, Moulin & Bowie, 2006) and object-picture naming (Jokel & Anderson, 2012) were also used. Dechamps et al. (2011) used a more ecologically valid method through focussing learning on the acquisition of instrumental activities of daily living, in which participants were presented with three tailored tasks based on their particular areas of need.

In studies using face-name association tasks, faces were either novel (Bier et al. 2008) or a combination of novel and previously-known items (Metzler-Baddeley & Snowden, 2005). Number of faces to be learnt also differed (e.g. Bier et al., 2008 - face-name pairs = 5 across 2 learning trials; Haslam, Moss & Hodder, 2010 - face-name pairs = 40 across 4 learning trials). EF methods were similar in the number of errors that the participants were allowed to make. A total of 3 guesses and/or a specific time limit (e.g. 25s for Akhtar et al, 2006) were allowed before the target word was shown/spoken (Akhtar et al, 2006; Dechamps et al, 2011; Haslam, Gilroy, Black & Beesley, 2006).

Across the reviewed studies, EL was described as a method where taught stimuli were presented to the participant in an errorless environment and in a similar format to that adopted by Baddeley and Wilson (1994). A principal aim of EL is the reduction of errors at the encoding stage and various methods adopt this principle such as MVC and SR. There is therefore a clear distinction between EL as a method in itself and EL as a methodological principle, such as MVC and SR. Some studies compared other learning methods in addition to EL and EF (counterbalanced across participants). Haslam, Moss and Hodder (2010) also used vanishing cues (VC) in isolation and in addition to EL. Haslam, Hodder and Yates (2011) used spaced retrieval (SR) in isolation and in addition to EL. Jokel and Anderson (2012) compared active and passive methods of both EL and EF, resulting in 4 learning conditions. Passive conditions mapped on to the traditional EL and EF methods whereas the addition of questions (either in an EL or EF environment) was used to create the active conditions. As noted earlier, the results of other learning conditions such as MVC and SR were not analysed for the purposes for this review.

(((Insert Figure 2 here)))

Statistical results

Figure 2 shows a forest plot of the ES for each study with corresponding CI (95%). All individual ESs were above zero which suggests that EL resulted in better learning than EF for people with MCI and dementia. Six of the ten reported ESs had CIs which crossed zero indicating a non-significant ES (Bier et al., 2008; Dechamps et al., 2011; Haslam, Moss & Hodder, 2010; Haslam, Hodder & Yates, 2011; Metzler-Baddeley & Snowden, 2005). Therefore, while results for EL learning were better than for EF learning, the majority of the results did not reach significance.

AD, VD & Mix

Free Recall

Four studies used free recall as an outcome measure for people with AD,VD and Mix (Bier et al., 2008; Dechamps et al., 2011; Metzler-Baddeley & Snowden, 2005; Ruis & Kessels, 2005). Ruis and Kessels (2005) was the only study that had a significant ES (1.2121, CI 0.34-2.09). Participants had to learn 10 novel face-name associations over two learning trials. Average MMSE score across 10 participants was 16 (no SD) which could suggest that EL is more beneficial for participants with greater cognitive decline. However, for Dechamps et al. (2011) who explored the benefits of EL for re-acquisition of individually tailored activities of daily living found that for their 14 participants with an average MMSE of 15.2 (no SD) a non-significant ES of 0.02 (CI -0.72-0.77) was achieved. Free recall relies heavily on explicit memory processes and Dechamps and colleagues measured outcome through assessing implicit knowledge of the daily living tasks. The assessed outcome however was based on asking participants to provide an explicit account. The explicit free recall of the taught task may therefore have been too difficult for the participants resulting in a low ES and non-significant result. Bier et al. (2008) used a face-name association task with 19 participants (MMSE 23.7 SD 3.2). Five face-name associations were taught over ten 45 minute sessions for each learning condition. The authors did not achieve a statistically significant difference between the scores for EL and EF, and the ES (0.25 CI -0.39-0.89) was not significant. Given the relatively high mean MMSE score and the amount of time spent on learning each task, it would be logical that the small difference between EL and EF scores could be attributable to task ceiling effects rather then there being no benefits of EL over EF learning. Metzler-Baddeley & Snowden had the smallest number of participants (n=4) for their face-name/object association task. Although a large ES was achieved (1.21, CI -0.18-2.59) the CI crosses zero and is large which suggests that the ES cannot be relied upon. This may be as a result of low participant numbers. Factors which therefore confound the overall calculated ES of these studies are participant numbers, task methodology and outcome measure.

Cued Recall

Three studies used cued recall as an outcome measure (Haslam, Gilroy, Black & Beesley, 2006; Haslam, Moss & Hodder, 2010; Haslam, Hodder & Yates, 2011). Only one study (Haslam, Moss & Hodder, 2010) achieved a significant ES (0.99 CI 0.40-1.58) for 22 participants with an average MMSE of 24 (SD 4). Ten face-name associations were taught over a 45 minute session for each learning method. Cued recall consisted of participants being shown a photograph with the first letter of the name as a cue. The authors obtained a statistically significant result which is reflected in the ES. Haslam, Hodder & Yates (2011) demonstrated a non-significant ES (0.55 CI -0.17-1.27) for 15 participants with an average MMSE of 21.27 (SD 1.52) for a face-name association task. The task consisted of 12 face-name associations for each learning trial, each face-name association was presented for 3 seconds, and a delay of 8min 30 occurred before the cued recall task. Three experiments were conducted with different populations in the study, with the third experiment reported being relevant to this review. The study authors ensured that the first and second experiments avoided ceiling and floor effects, yet this was not done with the third experiment. Crucially, the final recall task was changed from free recall to cued recall for the third experiment which may have made the task too easy resulting in a non-significant difference between EL and EF performance. Haslam, Gilroy, Black & Beesley (2006) also used a face-name association task but with a focus on levels of knowledge i.e. occupation and questions such as "Is this person a primary or high/secondary school teacher?" The teaching phase consisted of two sessions of one-to-one memory training with a two week break between sessions. There were 7 participants in total and the MMSE score was not provided. The authors noted however that the 7 participants had evidence of general cognitive decline and severe memory impairments. The authors also noted that there was a great deal of variability in participant scores, with 3 participants performing better with EF teaching methods. The non-significant ES of 0.34 (CI -0.71-1.39) could therefore reflect the small number of participants and/or the variability in participant scores.

Recognition

Only one study used a recognition task (Bier et al. 2008) in addition to a cued recall task. As already discussed, the study methodology which allowed ten 45 minute teaching session for 5 face-name associations may have resulted in ceiling effects which could account for the lack of significant difference between the EL and EF learning conditions. The ES of 0.43 (CI -0.21-1.07) for the recognition task was greater than that for the cued recall task (0.25, CI -0.39-0.89) which would reflect the outcome measure rather than study methodology (as both ESs were calculated from the same study). For the recognition task, the participants were shown the correct face-name associations in amongst distractor face-name associations. This would naturally be easier than being shown the photograph with a one-letter cue.

SD

Free Recall

Jokel and Anderson (2012) used a picture-naming task for a sample of 7 participants with semantic dementia. Average MMSE score was 26 (SD 1.83). The treatment programme consisted of 96 half-hour sessions over 24 non-consecutive days covering 8-12 weeks. Stimuli consisted of 15 pictures with the aim of learning object names. Semantic dementia is characterised by impairments in object recognition and word comprehension. Although there is loss of semantic knowledge, episodic memory is relatively spared (Hodges, Patterson, Oxbury & Funnell, 1992) which may account for the high MMSE score. A large ES (1.65 CI 0.60-2.70) was achieved. Semantic impairments limit the efficacy of verbal encoding and efficiency; therefore although episodic memory is spared in semantic dementia, distinguishing previously erroneous stimuli from target information which is semantic in nature may prove challenging. This may account for the large ES and overall effectiveness of eliminating errors at encoding.

MCI

Free Recall

Only one study included in the meta-analysis involved participants with MCI. Akhtar, Moulin & Bowie (2006) used a word learning task with 16 participants. The average MMSE score was 27.31 (1.14). The ES was significant (0.74 CI 0.05-1.44) with a respectable CI range which suggests that this is a meaningful result. There were three learning trials and each lasted from 40-60 minutes. Following each presentation of the word list in either the EL or EF condition, the participants were immediately tested by cued recall where the first two letters of the word was provided and an instruction for the participant to write down all the words they could remember. Participants were encouraged not to guess during the cued recall task. Each stimulus word was therefore tested on three occasions before the final free recall task (following a five minute conversation break). The learning phase in this study was thorough and this may demonstrate that for EL to be beneficial, the time spent during learning is crucial. There would also be greater effort involved in the EF condition, which may have had a greater priming effect on errors. It would therefore appear that the length of training in both EL and EF conditions may influence the mean difference and subsequent ES.

Summary Effect Size

The summary ES for all studies included in the meta-analysis is 0.65 (CI 0.41-0.89). This would be considered a moderate effect size (Cohen, 1998) and a significant result, with a respectable CI range. Despite the six non-significant ESs for individual studies, the combination of participants from all studies would have increased the power and therefore the reliability of the summary ES. The CI of the summary ES is not a large range which suggests that overall the studies included in this review are homogeneous in nature, thus supporting the use of a fixed effects model for analysis. This is supported by the heterogeneity measure Q which did not reach significance (p>0.05) and a low I^2 percentage of 25.32% which suggests homogeneity.

Table 2 shows the overall ESs and CIs for the whole sample of studies, as well as showing group ESs according to participant type (AD/VD/Mix, SD or MCI). For AD/VD/Mix studies, the summary ES for free and cued recall is also shown. For free recall, the overall ES was 0.47 (CI 0.06-0.87) which is a moderate and significant ES. For cued recall the ES increased to 0.73 (CI 0.32-1.16) which is again significant.

(((Insert Table 2 here)))

Discussion

This systematic review and meta-analysis aimed to synthesise the evidence on the benefits of EL as a memory rehabilitation method for people with MCI or dementia through identifying studies directly comparing EL and EF methods within an experimental design. The summary ES of 0.65 (CI0.41-0.89) is a moderate effect size (Cohen, 1988) with a respectable CI range which would be considered significant. This shows that when combining the 9 reviewed studies, EL methods result in better learning than EF methods for people with MCI and dementia. These results support the outcomes of other reviews such as Kessels and Haan (2003) who demonstrated the effectiveness of EL over EF methods for memory rehabilitation in people who had experienced memory problems following a range of conditions such as Traumatic Brain Injury (TBI), schizophrenia or stroke. However, this meta-analysis is the first to focus on MCI and dementia.

Some caution is recommended given the individual number of non-significant ESs. A CI range that crosses zero does not mean that EL is no more beneficial than EF learning, only that this may be true should the study be replicated. From a clinical perspective, EL did produce better recall than EF methods, but this difference did not reach statistical significance in all cases (Bier et al., 2008; Haslam, Hodder & Yates, 2011) and resulted in a total of six non-significant ESs. This may indicate that for some people, EL does not lead to better recall than EF. There are, however, other factors which should be considered. Although the nature of EL and EF instruction were similar across studies, the length of the teaching phase and the number of stimuli used differed, which may account for the lack of individual significant mean differences. If the learning tasks were too easy, ceiling effects could account for the lack of significant difference between EL and EF. Similarly, if the task should prove too difficult, the level of difference in recall between EL and EF methods may also be less than what could be expected. Additionally, participant numbers were low across studies (range 4-22) which may account for the lack of significance in some cases.

The nature of the recall task will also influence study outcome. The results for this meta-analysis show that for people with AD, VD and mixed dementia, cued recall results in better recall than free recall. This suggests that cueing aids recall, although this is only shown in a purely experimental design and may not lend itself to therapeutic cognitive rehabilitation; if autonomy is the goal, cues in everyday life may be difficult to arrange. Cueing may also be a far more pleasurable experience as the requirement for free recall may be very challenging for participants with memory difficulties. Following EF conditions where the participant makes at least one mistake for each target word, the experience of having made errors during training could make the participant less inclined to guess during recall. Clearly, the methods used to elicit recall impact on the results of each study. The use of free recall, cued recall and recognition in combination may produce a clearer and more inclusive range of outcomes when exploring learning methods such as EL and EF.

The implications for practice derived from the results of this review can only be tentative given that the included studies only explored immediate learning. The long-term utility of EL for memory rehabilitation in MCI and dementia is of greater interest if such methods are to be adopted in clinical practice. Dunn and Clare (2007) explored the benefits of EL over EF learning for novel and previously-known face-name associations and demonstrated that both learning and re-learning is possible in early-stage AD, VD and Mix. No statistical difference was found between the methods used, and similar mean scores were achieved, which suggests that EL methods were no more advantageous than EF learning for some individuals. The Dechamps et al., (2011) study also showed that not all AD participants were able to master the individualised tasks fully, which suggests that even with EL methods full autonomy may not be achieved. It is clear from this review that no clear guidelines for clinicians with regard to the benefits of EL over EF learning can be developed until the evidence-base for these methods gives a stronger indication as to why EL learning can be advantageous for some people with memory impairment and not others. What can be recommended is that when engaging in cognitive rehabilitation, there has to be an individualised approach where the rehabilitation goals are person-centred and based on personal and social factors (Kitwood, 1997). This is of particular relevance for individuals with a neurodegenerative condition where continued monitoring is recommended so that rehabilitation is adapted to accommodate further cognitive decline.

In considering recommendations for future research, the number of studies included in this review was low, particularly for conditions other than AD. Further experimental research is therefore recommended so that the current limited evidence-base is expanded. It is also recommended that there be further development of EL approaches in real-life settings which will have practical and clinical relevance and offer direct benefit to participants (Clare et al., 1999, 2000, 2001 & 2002). Dechamps et al. (2011) was the only study in this review that utilised instrumental activities of daily living as learning material. These included using an umbrella, making a cup of tea or using a mobile phone. Each task differed in complexity depending on the ability of the participant. This is the first study to show the benefits of EL relative to EF for everyday activities although the addition of a control condition for such personally relevant tasks may be questionable. Each task was split into a number of steps in a sequence. The EL condition involved a therapist giving a verbal instruction at the beginning of each step whereas for the EF condition, three guesses or 25s were allowed before the therapist gave a cue. Each learning condition involved a different task. There has to be some ethical consideration of the impact of teaching personally-relevant tasks across different methods which are expected to differ in their success.

There are limitations to this meta-analysis which should be considered. For all the reviewed studies, participant numbers were low, which influenced the significance of individual study effect sizes. Including varying neurodegenerative conditions (MCI, AD/VD/Mix & SD) may have influenced the overall outcome of this review. The nature of the learning task also differed across the reviewed studies, which influenced subsequent performance on recall and study outcome in addition to heterogeneity across recall methods. Inferences from the data are therefore tentative. However, this is the first systematic review and meta-analysis of EL in MCI and dementia and there is evidence to suggest the superiority of EL methods over EF in supporting cognitive rehabilitation for this population.

Conclusion

This systematic review and meta-analysis found that across the 9 reviewed studies there was a moderate effect size for the benefit of EL over EF learning for memory rehabilitation for people with MCI and dementia. Results are tentative as six of the reviewed studies had non-significant ESs which may reflect small sample sizes or methodological issues, or indicate that EL may not be any more advantageous than EF for some individuals. There is therefore a need for further experimental studies in this area so that the precise mechanism and process of EL learning can be defined.

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Figure 1. Flow diagram showing the process of study selection.

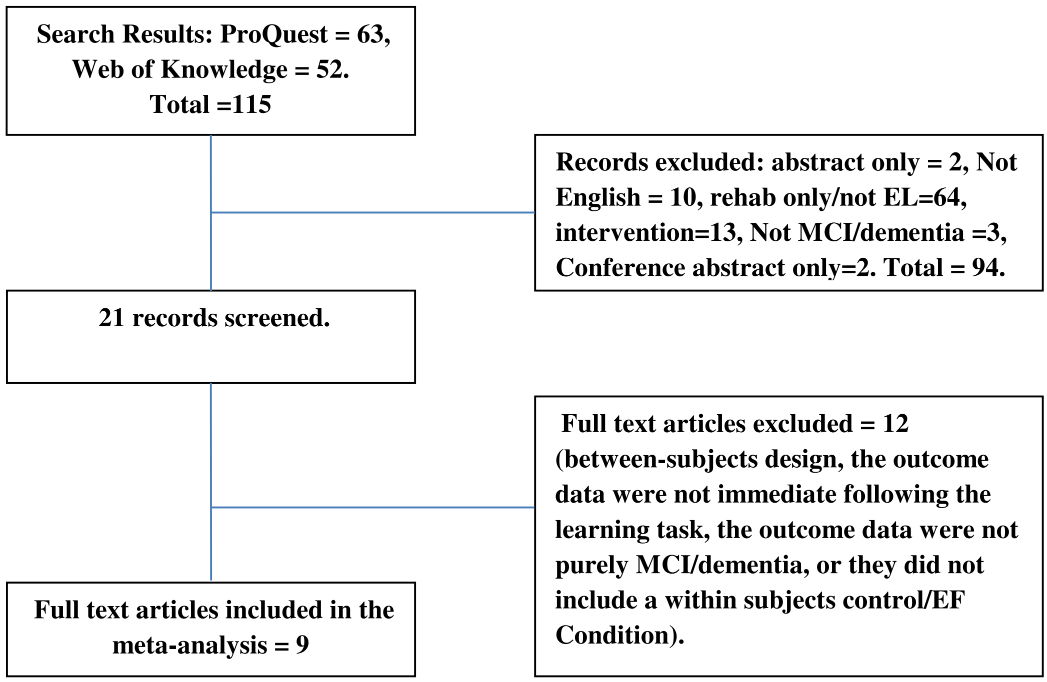

Table 1. Table of reviewed studies

Authors & Year	Participants					EL/EF task	Study design
	N	Gender (Female)	Age (years;Mean/ SD)	Diagnosis (MCI vs. mild/ early AD)	MMSE (SD)		
*Akhatar et al (2006)	16	Gender not stated	78.19 (5.67)	MCI Comp with HOA	27.31 (1.14)	Word learning task. ***Free Recall***	Within Subjects
*Bier et al. (2008)	19	9	73.3 (7.9)	AD	23.7 (3.2)	Face-name association task ***Free Recall & Recognition***	Within Subjects
Clare, Wilson, Breen & Hodges (1999)	1	0	72	AD	27	Face-name association task ***Free Recall***	Single-case study
Clare, Wilson, Carter, Breen, Gosses & Hodges (2000)	6	3	69.33 (3.93)	AD	24 (2.1)	Individually tailored tasks (face-naming, recall of personal information & use of a calendar) ***Free Recall***	Multiple singe-case study
*Dechamps et al. (2011)	14	12	86 (5.7)	AD	15.2 (no SD)	Acquisition of Instrumental Activities of Daily Living ***Free Recall***	Within Subjects
Dunn & Clare (2007)	10	5	80.9 (range 76-86)	AD/VD/Mxd	24.8 (range 18-28)	Face-name associations ***Free Recall/Cued Recall/Recognition***	Within Subjects Comparison of vanishing cues, paired associates, target selection and forward cueing.
*Haslam, Gilroy, Black & Beesley (2006)	7	Gender not stated	67-87	2 x AD 5 x VD	No MMSE score	Face-name-occupation association task. *Experiment 3.* ***Cued Recall***	Within Subjects

*Haslam, Moss & Hodder (2010)	22	12	75.3 (7.3)	Probable AD	24 (4)	Face-name association task *Experiment 2.* ***Cued Recall***	Within Subjects
*Haslam, Hodder & Yates (2011)	15	10	77 (8.15)	*N*=7 AD *N*=5 VD *N*=3 Mxd	21.27 (1.52)	Face-name association task. *Experiment 3.* ***Cued Recall***	Within Subjects
*Jokel & Anderson (2012)	7	3	68.29 (10.77)	Semantic Dementia	26 (1.83)	Picture-naming task ***Free Recall***	Within Subjects
Jean, Simard, Reekum & Bergeron (2007)	1	1	68	Amnesic MCI	29	Face-name associations ***Free Recall***	Single-case study
Kessels & Olde Hensken (2009)	20	13	76.5 (7.9)	20 mild to moderate AD	22 (2.6)	Procedural problem solving task ***Free Recall***	Between Subjects
Lubinsky, Rich & Anderson (2009)	19	9	76.95 (7.33)	MCI & HOA	No MMSE score	Word learning task ***Free Recall, Cued Recall & Recognition***	Within Subjects (Reported data is the sum of the results for both MCI and HOA participants)
*Metzler-Baddeley & Snowden (2005)	4	1	68.5 (4.04)	AD	No MMSE score	Face/Object picture-name association task. ***Free Recall***	Within Subjects
Noonan, Pryer, Jones, Burns & Lambon Ralph (2012)	8	No gender	No age	AD & Profound anomia	17.88 (4.97) Range 9-24	Picture-naming task ***Free Recall***	Within Subjects (Reported results were for 1 week and 5 week post learning phase)

Provencher, Bier, Audet & Gagnon (2008)	1	1	77	Probable AD	24	Acquisition of Instrumental Activities of Daily Living ***Free Recall***	Single-case study
Rothi et al., (2009)	6	1	72.9->90	Probable AD	Range 10-30	Picture-naming task	Single-case studies
*Ruis & Kessels (2005)	10	5	81.8	AD	16	Face-name association task. ***Free Recall***	Within Subjects
Tailby & Haslam (2003)	1	No gender	No age	AD	No MMSE	Word learning task ***Cued Recall***	Single-case study
Tilborg, Kessels & Hulstijn (2011)	10	6	82.8 (5.2)	Mild to moderate dementia	20.6 (4.7)	Pattern learning task ***Free Recall***	Within Subjects Explicit tasks-observational learning and learning by guidance
Winter & Hunkin (1999)	1	1	66	AD	20	Face-naming task ***Cued Recall***	Single-case study

**=Studies included in the meta-analysis.*
Abbreviations: AD-Alzheimer's dementia; MCI-Mild Cognitive Impairment; Mix-Mixed dementia; VD-Vascular dementia.

Figure 2. Forest plot with effect sizes and 95% confidence intervals parenthesis.

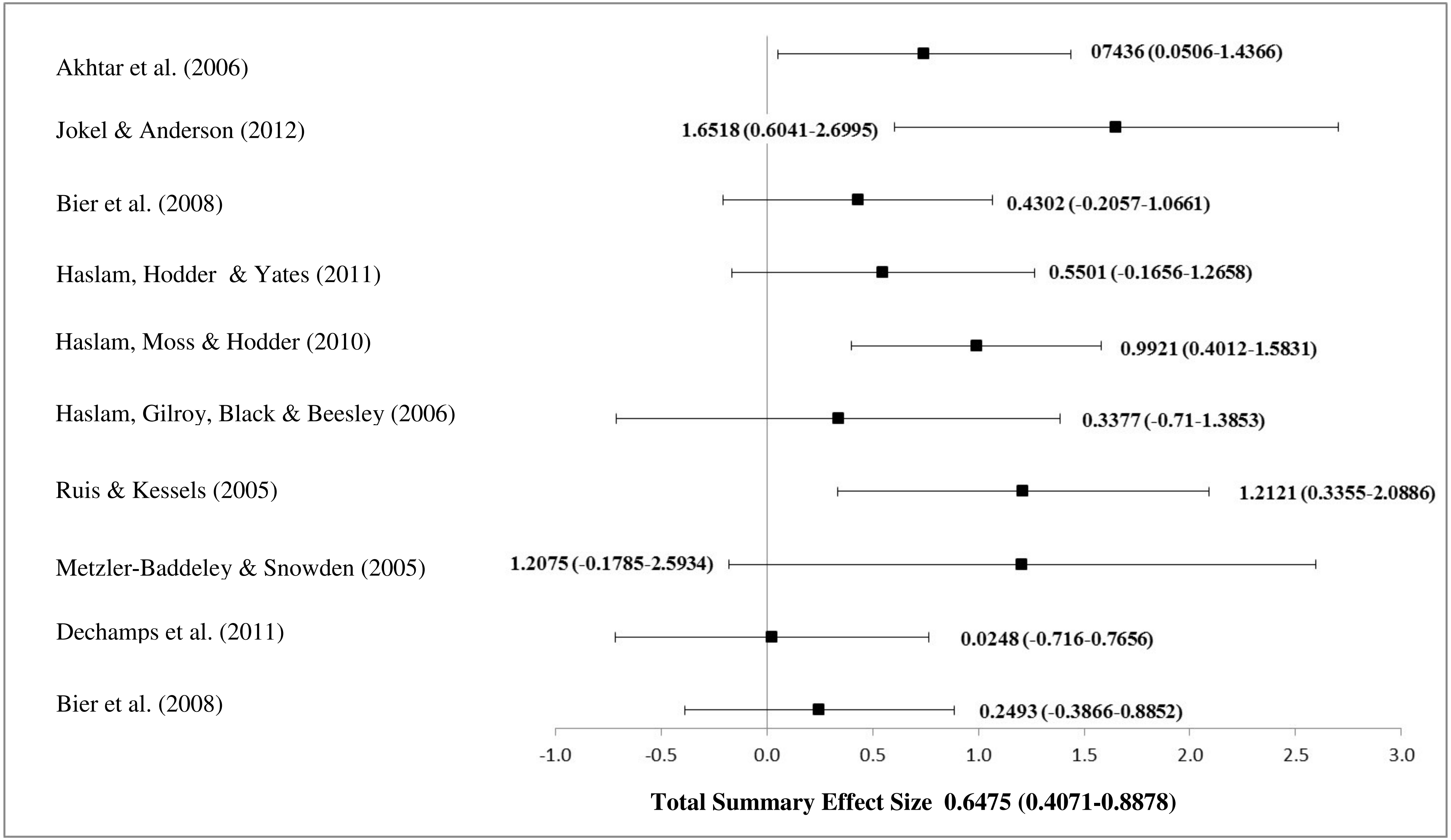

Table 2. Summary Effect Sizes, CI's and heterogeneity across outcome measures.

	Outcome measure	n	K	Effect	lower 95%CI	upper 95%CI	Heterogeneity Q(*p*)	I^2 (%)
MCI								
Akhtar et al. (2006)	Free recall	16	**1**	0.7436	0.0506	1.4366		
SD								
Jokel & Anderson (2012)	Free recall	7	**1**	1.6518	0.6041	2.6995		
AD/VD/Mix								
Bier et al. (2008)	Recognition	15	**1**	*0.3398*	-0.2961	0.9757		
Haslam, Hodder & Yates (2011)	Cued recall	15		*0.5501*	-0.1656	1.2658		
Haslam, Moss & Hodder (2010)	Cued recall	22		0.9921	0.4012	1.5831		
Haslam, Gilroy, Black & Beesley (2006)	Cued recall	7		*0.3377*	-0.71	1.3853		
Effect size for cued recall		**44**	**3**	**0.7373**	**0.3195**	**1.1552**	**1.54 (0.4639)**	**0**
Ruis & Kessels (2005)	Free recall	10		1.2121	0.3355	2.0886		
Metzler-Baddeley & Snowden (2005)	Free recall	4		*1.2075*	-0.1785	2.5934		
Dechamps et al. (2011)	Free recall	14		*0.0248*	-0.716	0.7656		
Bier et al. (2008)	Free recall	15		*0.3398*	-0.2961	0.9757		
Effect size for free recall		**43**	**4**	**0.4688**	**0.0645**	**0.8731**	**5.69 (0.1276)**	**47.29**
OVERALL EFFECT SIZE		**110**	**10**	**0.6475**	**0.4071**	**0.8878**	**12.05 (0.2104)**	**25.32**

Abbreviations: MCI-Mild Cognitive Impairment; SD-Semantic Dementia; AD-Alzheimer's Dementia; VD-Vascular Dementia; Mix-Mixed Dementia (AD&VD).

The benefits of errorless learning for people with mild cognitive impairment

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Abstract

Objective: The aim of this study was to explore whether errorless learning leads to better outcomes than errorful methods in people with mild cognitive impairment in addition to whether accuracy in error recognition relates to any observed benefit of errorless over errorful learning.

Method: Eleven participants with a clinical diagnosis of mild cognitive impairment were recruited. A word-list learning task was used and learning was assessed by free recall, cued recall and recognition tasks.

Results: Errorless learning did not prove to be a significantly superior method to errorful learning across free recall, cued recall and recognition tasks. There was a significant relationship between errorless and errorful difference scores for target words and the number of correctly recognised errors, which suggests that for people with better error recognition ability, the benefit of errorless learning over errorful learning diminishes.

Conclusion: It is therefore proposed that error-monitoring ability and the effectiveness of errorless learning methods should be the focus of future experimental research. A review of current errorless and errorful task methodologies is also recommended.

Keywords: errorless learning, neuropsychology, implicit memory, error-monitoring, frontal lobe

Mild cognitive impairment (MCI) is cognitive decline which is greater than would be expected with age, yet does not meet the criteria for dementia. The most prominent classification system for MCI is that of Petersen (1999, 2001) who set out the diagnostic criteria for MCI as follows: (a) memory complaint, (b) intact activities of daily living, (c) intact general cognitive function, (d) memory impairment beyond that which would be expected for age, and (e) no dementia. Evidence suggests (Petersen, 1999) that people who meet the criteria for MCI are at greater risk of developing Alzheimer's disease (AD; 10-15% annually) as opposed to healthy older people (1-2% annually). Further classification of the criteria for MCI led to the identification of two subtypes, amnestic and non-amnestic MCI. Both subtypes can be further classified into 'single cognitive domain' or 'multiple cognitive domains'. Amnestic MCI would therefore encompass either memory decline in isolation or memory decline with at least one other affected cognitive domain (Petersen & Negash, 2008). A decline in memory ability for this population can also impact on independence and wellbeing potentially leading to anxiety and depression (Apostolova & Cummings, 2008). The increased risk of developing AD and associated neuropsychiatric conditions provides a strong argument for the development of specific intervention methods aimed at minimising the impact of increasing memory difficulties for people with MCI (PwMCI).

One such intervention designed to facilitate memory capacity for people with memory impairment is errorless learning (EL). EL is in contrast to trial-and-error or errorful (EF) learning where 'guessing' and subsequent errors are encouraged. It was hypothesised that people with amnesia would rely on their intact implicit memory rather than their diminished explicit memory when learning (Baddeley & Wilson, 1994). Implicit memory does not allow for conscious recollection of errors; therefore any errors made during the learning phase would be committed to memory and indistinguishable from target stimuli. Impairments in explicit episodic memory, and to a lesser extent semantic memory, are core features of MCI and early-stage AD, while implicit memory is thought to be spared (Grundman et al., 2004; Knopman & Nissen, 1987; Petersen, Smith, Waring, Ivnick, Tangalos & Kokmen, 1999). We can therefore predict that PwMCI should benefit from EL methods.

A range of techniques in which errors are prevented during learning can be termed EL. These include the method of vanishing cues (VC; Glisky, Schacter & Tulving, 1986) and spaced retrieval (SR; Camp, Foss, O'Hanlon & Stevens, 1996). Vanishing cues involves gradually removing cues following successful recall of target information or the introduction of cues until the correct response is achieved. Glisky et al. (1986) applied VC to four memory-impaired patients who had experienced a closed-head injury or viral encephalitis. This group were able to learn novel computer-related vocabulary, and demonstrated retention of this information after a 6-week interval, although only three of the participants showed greater benefits as a result of VC when compared to a control condition. Spaced retrieval involves the participant being asked to recall taught information over increasing time intervals. The time intervals are closer together at the beginning and thereafter spaced at increasing intervals according to the participant's performance. If an error occurs, it is corrected immediately and the last successful interval is repeated. There have been critiques of both VC and SR in that they are not strictly 'errorless' as the production of errors during learning is not controlled (Hochhalter et al, 2005; Page, Wilson, Shiel, Carter & Norris, 2006).

The method described by Baddeley and Wilson (1994) has been the most influential in the brain injury literature and in contrast to VC and SR, does not allow for error production during learning. Baddeley and Wilson's EL condition involved the experimenter showing a word cue (verbally and visually) such as AR____ and immediately telling the participant what the word was e.g. ARTIST. In the EF condition the participant was encouraged to guess what the full word might be following a cue before being given the correct answer. Baddeley and Wilson compared memory performance following EL and EF methods in people with severe memory impairment resulting from different forms of brain injury, healthy older controls and healthy younger controls. The study found that people with memory impairment and healthy older participants recalled more words in the EL condition than the healthy younger participants. If the presence of errors at the encoding stage results in greater interference at recall, the standard EL method should demonstrate greater benefits than EF learning for people with memory impairment, which is supported by the brain injury literature (Wilson et al., 1994; Squires et al., 1997; Hunkin et al., 1998; Page et al., 2006).

The evidence for neurodegenerative conditions such as Alzheimer's disease is less clear. Haslam, Moss and Hodder (2010) found that EL and VC produced significantly better results than EF for their sample of AD participants (n=22) when undertaking a face-name association task. Metzler-Baddeley and Snowden (2005) also found a significant advantage for a standard EL method over EF when they compared these methods for participants with AD (n=4) for a face/object picture-name association task. In comparison, Noonan, Pryer, Jones, Burns & Lambon Ralph (2012) found their EL and EF methods to be equally effective for a picture-naming task (n=8) as did Bier et al. (2008) who compared the efficacy of five learning methods with AD participants (n=15). Three of these methods were EL (VC, SP, standard EL method) with two being EF (trial-and-error). Bier and colleagues found that all EL and EF methods were successful in promoting learning when teaching a face-name association task. It is of interest, therefore, given the divergent results from the brain injury and AD literature whether EL is beneficial for PwMCI.

For PwMCI, only three studies were identified where the benefits of EL were explored and again results were mixed, with some participants showing better recall following EL learning and others not (Akhtar, Moulin & Bowie, 2006; Jean, Simard, Reekum, Bergeron, 2007; Lubinsky, Rich & Anderson, 2009). Akhtar et al. (2006) reported that 12 of their 16 MCI participants benefited from EL in comparison to EF learning. Lubinsky et al. (2009) demonstrated that a combination of EL and elaborate self-generation showed some benefits over EF learning for their MCI participants in a word-learning task (n=19). A case report describing two MCI participants by Jean et al. (2007) demonstrated that immediate and long term recognition of face-name associations could be supported by EL on an individual basis. EL seems to work for some PwMCI but not all, which is consistent with the literature on AD and is an area that is worthy of further exploration. Although Baddeley and Wilson (1994) proposed the role of intact implicit memory as being responsible for the benefit of EL for people with memory impairments resulting from brain injury, others have argued that it is the role of residual explicit memory which determines the relative benefitsof EL over EF learning methods (Tailby & Haslam, 2003; Hunkin, Squires, Parkin & Tidy, 1998). Both the implicit and explicit theories focus on memory alone, yet the role of other neurocognitive domains which impact on memory may be of relevance.

What is central to the success of trial-and-error or EF learning is the ability to detect errors, and such error-monitoring ability would be associated with attention and executive functions (Clare & Jones, 2008). Executive functions are located in the frontal lobes whereas episodic memory which is associated with new learning is mediated by the hippocampus and medial temporal lobes (McClelland & McNaughton, 1995). Thinning in dorsolateral prefrontal and posterior cingulate cortices have been linked to poorer executive function ability for PwMCI and found to modulate some aspects of memory ability (Chang et al., 2010). Cortical thinning of this nature is supported by earlier studies which also highlighted the role of prefrontal regions in executive functions (for a review, see Stuss & Alexander, 2000). Mateer (1999) developed a clinical model of executive functions which have been described as a supervisory system for other cognitive processes, particularly those involved with novel or non-routine activities (Norman & Shallice, 1986). Mateer describes several domains of executive function which include; 1) Initiation and drive; 2) Response inhibition; 3) Task persistence; 4) Organizing; 5) Generative thinking; 6) and Awareness (self-monitoring). These areas, particularly self-monitoring, support the function of comparing incoming stimuli with stored internal representations in order to detect mismatches and errors. It is logical to assume that if an individual has good error-monitoring ability as a result of intact executive functions, the benefit of EL over EF learning would diminish relative to an individual who had poorer error-monitoring ability where the reduction of errors at encoding may be beneficial.

In conclusion EL has been found to be beneficial for some people with memory impairment resulting from brain injury, dementia and MCI, but without a rationale as to why it is of benefit to some and not others, it is difficult to make any clear therapeutic recommendations. The literature base for PwMCI is small and further investigation is warranted given the potential benefits of EL as a rehabilitative approach for this population. Of all the EL methods considered, that described by Baddeley and Wilson (1994) eliminates error production at the encoding stage and is therefore considered the most useful experimental method in exploring the benefits of EL. In addition, the ability to detect errors during recall is also of interest as this may determine the relative contribution of error reduction at encoding. The aim of this study is therefore to explore whether EL methods produce better learning outcomes than EF learning methods in people with the amnestic form of MCI using the standard EL method and to consider the contribution of error-monitoring ability. The research questions are:

1) Does EL produce better performance than EF on a word-list learning task in people with the amnestic form of MCI?
2) Does the accuracy of error recognition at recall relate to any observed benefit of EL over EF learning?

Method

Design

This study utilises a within-subjects design to explore the benefits of EL learning in comparison to EF learning in a group of PwMCI (amnestic-single or multiple domain) in a word-list learning task with learning assessed by free recall, cued recall and recognition. The relevant NHS and University ethics committees granted approval for this study.

Participants

Thirteen participants were recruited across 4 NHS memory clinics in North Wales, UK. Inclusion was dependent on a diagnosis of amnestic MCI (single and multiple domain), a score of 24 or above on the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975), and the ability to communicate verbally in English. Exclusion criteria for the PwMCI were the presence of major depressive disorder or a current or past history of psychosis or other neurological disorder, stroke or brain injury. This information was confirmed by medical records and discussion with the clinicians involved with the participant. Only 11 participants met the inclusion criteria, with one participant scoring below 24 on the MMSE and one disclosing a prior history of stroke.

Measures

In order to explore the research aims, the following measures were administered to participants so that their memory function and executive function could be profiled. The Hospital Anxiety and Depression Scale (HADS) was included so that participants could be screened for clinical levels of anxiety and depression which might influence their performance in this study (Apostolova & Cummings, 2008).

- *Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001):* A set of 9 tests which explore different areas of executive function. The tests used in this study were those assessing verbal fluency, category fluency and category switching. Scores on these tests represent several executive function abilities which include verbal knowledge, processing and monitoring abilities.

- *Wechsler Memory Scale (Word list sub-test; WMW-III; Wechsler, 1997):* The WMS-III is a battery of memory measures which evaluate working memory, learning and immediate and delayed recall. The word list subtest used in this study evaluated immediate recall which was representative of episodic memory and consisted of a list of 12 words. These words are read out and the participant is asked to repeat all remembered words in any order.
- *Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983):* The HADS is a screening tool for anxiety and depression. There are two subscales, for anxiety (scores 0-21) and depression (scores 0-21). Higher scores suggest the presence or absence of clinically meaningful degrees of mood disorders.

Learning tasks

Two lists were administered, each comprising 12 unique word stems with four endings assigned to each (e.g., cha______: chair, charm, chain, chapel). The order of the words for each word stem was arranged so that there were no simple or interactive effects of list or word position on word frequency (Kucera & Francis, 1967). Four additional word stems with four unique endings were added to the beginning (2 stems) and the end (2 stems) of each list to control for primacy and recency effects. Word stems and complete target words were presented on a computer screen using E-Prime (1.1 SP3 Psychology Software Tools, Pittsburgh, PA).

Participants studied two lists of 12 words. Participants were instructed that they should try to remember the words for a later memory test. One list was learned under an EF procedure, and the other under an EL procedure. The order of EF and EL presentation was counterbalanced across participants. In the EL procedure, a word stem appeared on the screen for 1 second, during which time the examiner said “I am thinking of a word beginning with [word stem]”, followed by presentation of the complete word for 3 sec during which time the examiner said “And the word is [word], please write that down”. In the EF procedure, a word stem appeared on the screen, and the examiner said “I am thinking of a word beginning with [word stem]. Can you guess what it is?” The word stem remained on the screen until after the participant had made two responses, to each of which the examiner responded “No, good guess, but that is not the word I am thinking of”. Then the examiner presented the full word on the screen for 3 sec and said “The word is [word], please write that down”. After each list of 12 words was presented, participants completed a free recall and a word stem cued recall test. Immediately after list presentation, participants were asked for free recall of the 12 words. Next they were shown the word stems (consisting of the first two letters) of the 12 words, one at a time in a random order, and were instructed to complete each stem with a target word from the study list. Participants had as much time as needed to respond.

After the second list was studied and recalled, the participant was offered a break, during which time the examiner modified the recognition test list so that it contained 72 words, comprising 12 target words from both lists (24 words), 12 new words from each list that started with the same word stems as the target words (24 words), the first error provided to each word stem in the EF condition (12 words), and 12 additional new words from the EL conditions that started with the same word stem as the target words (12 words). Following the break, which provided a 30 minute delay, participants completed the recognition test. The recognition test consisted of the 72 words described above, presented one at a time in a random order. Each word remained on the screen until the participant responded. Participants were instructed to press one button for target words, one button for prior error words, and a third button for new words. See figure 1 for a flow chart of the experimental procedure.

(((Figure 1 about here)))

Procedure

Participants were visited at home on two occasions. The first visit comprised a neuropsychological assessment with the second visit dedicated to administering the learning task.

Statistical Analysis

Data analyses were conducted using IBM SPSS statistics for Windows (v. 20). Scores for EL and EF conditions on free recall, cued recall and recognition scores were compared using paired samples t-tests. Difference scores were calculated by subtracting EF from EL scores on the tasks of free recall, cued recall and recognition, and correlational analyses examined the relationship of these with neuropsychological test scores. The number of correctly identified errors during the recognition task was also correlated with the difference scores for free recall, cued recall and recognition. All correlation analyses were conducted using Pearson's product-moment correlation coefficient.

Results

Eleven participants (5 women, 6 men) with a clinical diagnosis of single domain amnestic MCI participated in the study. The mean age was 77.27 (S.D. 9.11, range 58-90). MMSE scores ranged from 24-30 with a mean of 26.55 (S.D. 2.25). Table 1 shows the scores on individual neuropsychological tests and self-report questionnaire scores. Mean HADS anxiety score was 4.64 (S.D. 3.78) and mean HADS depression score was 3.82 (S.D. 3.43). No participant was being treated clinically for either anxiety or depression at the time of testing.

(((Table 1 about here)))

Experimental Task

Free Recall

The total number of correct target words (max = 12) correctly recalled for each participant immediately following the learning phase is shown in Figure 1. Group data were analysed using a paired samples t-test. Free recall performance was better (M 1.36; S.D. 1.43) following EL learning than EF learning (M 0.64; S.D. 1.03) but this did not reach significance (t (10) = 1.90, p = .087). When looking at individual participant data (see Figure 1), 4 participants were able to remember target words following both the EF and EL condition (3, 4, 5 & 10) with participant no 10 showing greater recall following the EF condition. Three participants were only able to recall target words following the EL condition and not following the EF condition. Three participants (6, 9 & 11) did not recall any items in either the EL or EF condition.

(((Figure 2 about here)))

Cued Recall

The total number of correct target words (max = 12) correctly recalled for each participant immediately following the cued recall task is shown in Figure 2. Group data were analysed using a paired samples t-test. Cued recall performance was better (M 3.55; S.D. 1.81) following the EL condition than the EF condition (M 2.27; S.D. 1.68) but this did not reach significance (t (10) = 1.88, p = .089). Individual participant data shows that all participants were able to recall target words following both EL and EF conditions, with 7 participants showing better recall following the EL condition, 3 participants (6, 10 & 11) showing equal scores for both EL and EF conditions and 1 participant (9) showing greater recall following the EF condition in comparison to the EL condition.

(((Figure 3 about here)))

Comparison of Free and Cued Recall (target scores and error intrusions)

For both EL and EF conditions, cued recall resulted in better recall than free recall (see table 2) which reached significance in both cases (EL t (10) = -5.787, p = .000; and EF t (10) = -3.614, p = .005). More novel errors were made during EL free and cued recall tasks than during EF free and cued recall tasks (EL t (10) = .886, p = .397; EF t (10) =. 3.492, p = .006) with the difference for cued recall reaching significance at the .01 level. The difference between the number of free recall total errors for EL and EF did not reach significance, t (10) = .607, p = .557, although comparatively more errors were produced in the EL condition. The difference between cued recall total errors for EL and EF was not significant, t (10) = -2.020, p = .071, with more errors produced in the EF condition.

(((Insert Table 2 about here)))

(((Insert Table 3 about here)))

Recognition

Participants were asked to classify a total of 72 target (words that were identified as target words from both the EL and EF learning condition), new (previously unseen) and error words (first incorrect guess from the EF condition) which were presented one at a time. Figure 3 shows how each participant scored on the correct identification of target words for EL learning and on the correct identification of target words and error words for the EF condition. Mean scores are shown in Table 3. When looking at individual participant performance on the recognition task, 7 of the 11 participants demonstrated better recognition of target words taught in the EL condition than in the EF condition. However, of the 4 participants who did not show an EL advantage, 2 participants (7 & 10) achieved equal scores following both the EL and EF condition and 2 participants (1 & 9) showed better recall following the EF condition. At group level, here was no significant difference in the number of target words correctly identified in the EL and EF learning conditions (t (10) = 1.72, p = .117). The difference between EL and EF learning conditions for accurate identification of previously unseen words did reach significance (t (10) = 7.56, p = .000). For recognition of previous errors (guesses) in the EF condition only, 36.91% of the maximum score was achieved.

(((Insert Figure 4 about here)))

(((Insert Table 4 around here)))

Order of presentation

Across free recall, cued recall and recognition the order of task condition (i.e. EL or EF) did not relate to greater recall in the task condition that was presented first. For free recall, participant 10 scored higher in the EF than EL condition, with the EF condition being presented first. However, for cued recall, participant 9 who scored higher in the EF than EL condition was presented with the EL condition first. Similarly for the recognition task, both participants 1 and 9 scored higher in the EF than EL condition, both of which were presented with the EL condition first. This does not suggest that the pattern of results obtained were influenced by order of task condition.

Correlation analyses

In order to explore whether any significant relationships could be identified between neuropsychological measures and difference scores between EL and EF conditions across all learning modalities, a Pearson product-moment correlation analysis was undertaken, the results of which are shown in Table 4. No significant relationships were found for these variables.

Scores for the correct identification of prior errors were also compared to difference scores for free recall, cued recall and recognition. For free recall and recognition, the ability to correctly identify errors was correlated significantly with the difference between EL and EF scores (r = -.709, p <.05; r = -.619, p <.05 respectively). Greater ability to correctly identify prior errors was associated with smaller difference scores and hence with smaller benefits of EL over EF. For cued recall, there was no significant correlation between the ability to correctly identify prior errors EL and EF difference scores (r = -.398, p =.226).

Discussion

The aims of this study were to determine whether EL produces better performance on a word-list learning task compared to EF learning in people with the amnestic form of MCI and whether accuracy in error recognition relates to any observed benefit of EL over EF learning. Participants undertook a learning task under both EL and EF conditions using a traditional list-learning paradigm. Immediately following each condition, a free recall and cued recall test was administered. A subsequent recognition test incorporating studied words, participant-generated errors and novel words followed a 30 minute break.

This study shows that for this group of PwMCI, EL did not prove to be a significantly superior method to EF across free recall, cued recall and recognition for a word-list learning task, with only some of the participants showing better learning following EL. This is consistent with prior research for PwMCI (Akhtar, Moulin & Bowie, 2006; Lubinsky, Rich & Anderson, 2009). Order of presentation between the EL and EF conditions did not relate to performance across free recall, cued recall and recognition task. Errors which occurred during free recall and cued recall showed an interesting pattern. For the EL condition, only novel errors (new words previously unseen) could be generated whereas for the EF condition errors could be either novel words or previous incorrect guesses. Following the free recall task, there were more errors following EL learning than EF learning in contrast to the cued recall task where there were more errors following EF learning than EL learning. Free recall is difficult for people with MCI, which is demonstrated by the very low scores on this task. Free recall following the EF condition may be inhibited by the participants having made errors in the learning phase which would make them less inclined to guess, an effect that was not observed when cues were provided during cued recall. The free recall task was also administered before the cued recall task, and successful recall has been found to improve following more testing during the study phase (Hogan & Kintsch, 1971). Cued recall did result in better performance than free recall for both the EL and EF conditions. Cues are therefore useful in promoting recall and should, wherever possible, be incorporated into rehabilitative support.

In considering the results of this study, it is of interest whether individual participant data reflects the neurocognitive capabilities of PwMCI or the nature of the learning task undertaken or, indeed, a combination of both. A great deal has been written about how to best support memory when learning (Baddeley, 2000). Cognitive models of memory emphasise the need to consider the stages of encoding, storage and retrieval (Sohlberg & Mateer, 2001). An encoding technique which has been used in the EL literature involves levels of processing theory (Craik & Lockhart, 1972) where deeper processing such as semantic meaning, chunking and categorising of target stimuli is thought to be better recalled than target stimuli which is shallowly processed (e.g. repeating target information). Self-generated information (generation effect) is better retained than information that is passively received (Jacoby, 1978). The level of effort at the time of encoding is also believed to impact on retrieval, with more effort at encoding leading to greater recall than less effort, such as SR techniques where there is repeated practice but with an absence of errors (Bjork, 1994). This is supported by the

AD literature where effort at the encoding stage led to better recall of novel associations (Dunn & Clare, 2007). Based on these theoretical observations, it has to be noted that there is a degree of effort in the EF task where participants were asked to 'guess' what the word was on two occasions before being given the correct word. Errors may therefore be easier to recall than target words in the EF condition which may be responsible for the apparent advantage of EL over EF.

Neurocognitive theories which account for the benefits of EL for people with memory impairment include aspects of memory which are associated with the medial and temporal lobes (McClelland & McNaughton, 1995). These include the intact nature of implicit memory in spite of explicit memory deterioration, which is unable to distinguish between errors (e.g. Baddeley & Wilson, 1994), and residual explicit memory which can distinguish between errors but which is negatively influenced by the interference of errors during EF learning in comparison to EL which would be less effortful (e.g. Hunkin et al., 1998). There is also an emerging literature which suggests that error-monitoring ability is crucial in determining the success of either EL or EF methods, an area associated with the frontal lobes, specifically executive functions (Clare & Jones, 2008; Anderson, Guild, Cyr, Roberts & Clare, 2012). Clearly, a consensus from a neurocognitive perspective has yet to be reached. Although the results of this study do not contribute to the debate about implicit and explicit theories of the mechanism of EL, the pattern of error recognition in this study is certainly of interest.

There was a significant relationship between EL and EF difference scores for target words and the number of correctly recognised errors (previous guesses), which suggests that for people with better error recognition ability, the benefit of EL over EF diminishes. Although executive function ability was tested for the purposes of this study (DKEFS; Delis, Kaplan, & Kramer, 2001), there was no significant relationship between these measures and the difference scores between EL and EF across all learning modalities. Executive functioning is a broad concept which includes different components such as initiation and drive, response inhibition, organising and self-monitoring (Mateer, 1999). The particular DKEFS measures used in this study focussed on verbal knowledge, processing and monitoring abilities, which may not have been sensitive enough to capture the relevant facets of error-monitoring. This study also had a small pool of participants which may have masked any potential significant result. It is recommended that future research focus on the role of executive functions, particularly error-monitoring abilities when considering the potential benefit of EL.

This research is limited as a result of the small number of participants. The recruitment of MCI participants is challenging as the rates of PwMCI in the community can range from 3-36% (Busse, Bischkopf, Riedel-Heller & Angermeyer, 2003). Not all identified participants wished to take part in this study as it can be uncomfortable to undertake a memory task when experiencing memory difficulties in everyday life. Clearly the experimental task used does not map easily onto the use of EL in clinical contexts; however, studies of this kind are needed to provide evidence on which to base clinical practice. The artificial introduction of errors in clinical practice would not be ethical and therefore experimental studies such as this offer a clear advantage.

This study has shown that EL is not significantly superior to EF when undertaking a word-list task for PwMCI. These equivocal results may result from the level of effort applied to error production during the EF condition, leading to deeper encoding of these words which then impacts on subsequent recall. Alternatively, contrary to the current debate around implicit and explicit theories, error-monitoring ability may well be the crucial factor; if error-monitoring is good, EL does not offer any benefit over EF as a learning method. Cued recall resulted in better recollection than free recall of target information; therefore the use of cues in rehabilitative support should be emphasised. It is therefore proposed that error-monitoring and EL may offer a fruitful area for future experimental research, with a review of current methodologies a priority.

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Table 1. Individual neuropsychological test and self-report questionnaire scores.

	Max. Score	P.1	P.2	P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10	P.11	Mean (SD)	Range
MMSE	30	25	24	27	29	28	24	27	25	30	29	24	26.55 (2.25)	24-30
WMS-III	48	12	16	18	19	17	19	20	13	21	18	16	17.18 (2.79)	12-21
DKEFS verbal fluency	N/A	29	26	20	34	35	41	48	45	47	16	20	32.82 (11.51)	16-48
DKEFS category fluency	N/A	23	22	24	41	30	17	41	27	34	21	30	28.18 (7.93)	17-41
DKEFS category switching	N/A	9	10	8	14	8	8	16	8	11	10	14	10.55 (2.88)	8-16
DKEFS category switching accuracy	N/A	8	9	9	13	7	7	16	7	10	9	13	9.82 (2.96)	7-16
HADS Anxiety	21	3	1	13	3	4	5	0	4	3	5	10	4.64 (3.78)	0-13
HADS Depression	21	2	2	12	1	5	7	1	6	3	2	1	3.82 (3.43)	1-12

Abbreviations. Neuropsychological tests: MMSE-Mini mental status examination; WMS-III-Wechsler memory scale III word list learning; DKEFS-Delis-Kaplan Executive Function System. Self-report questionnaires: HADS-Hospital Anxiety and Depression Scale.

Higher scores = better performance on neuropsychological tests and higher levels of anxiety or depression (HADS).

Table 2. Free and cued recall target and error scores following EL and EF learning conditions (mean, SD; range)

	EL condition	EF condition	Paired sample t-test
Free Recall Targets (Max = 12)	1.36 (1.43; 0-4)	0.64 (1.03; 0-3)	t(10) = 1.90, p = .087
Free Recall Errors (novel)	.55 (1.21; 0-4)	.18 (.40; 0-1)	t(10) = .886, p = .397
Free Recall Errors (previous guesses)	N/A	.09 (.30; 0-1)	
Free Recall Errors TOTAL	.55 (1.21; 0-4)	.27 (.65; 0-2)	t(10) = .607, p = .557
Cued Recall (Max = 12)	3.55 (1.81; 1-7)	2.27 (1.68; 1-5)	t(10) = 1.88, p = .089
Cued Recall Errors (novel)	5.45 (3.39; 0-9)	2.64 (2.16; 0-6)	t(10) = 3.492, p = .006
Cued Recall Errors (previous guesses)	N/A	4.00 (2.65; 1-8)	
Cued Recall Errors TOTAL	5.45 (3.39; 0-9)	6.64 (3.44; 1-11)	t(10) = -2.020, p = .071

Table 3. Performance on the recognition task following EL and EF learning conditions (mean, SD; range; % of maximum possible score)

	EL condition	EF condition	*Paired sample t-test
Target words correctly identified (Max 12)	6.27 (2.49; 2-10; 52.09%)	5.36 (2.87; 2-11; 50.36%)	t (10) = 1.72, p = .117
New words correctly identified (EL-Max 24; EF-Max 12)	15.55 (5.79; 5-24; 64.82%)	7.18 (3.09; 1-11; 59.45%)	t (10) = 7.56, p = .000
Previous errors (guesses) (EF only-max 12)	N/A	4.45 (2.62; 0-9; 36.91%)	N/A

**Note: Paired sample t-tests were conducted on percentage scores.*

Table 4. Correlations between EL/EF difference scores and neuropsychological test scores.

	Free recall-difference between scores on EL and EF Correlation (sig)	Cued recall-difference between scores on EL and EF Correlation (sig)	Recognition- difference between scores on EL and EF-target words correctly identified. Correlation (sig)
WMS-III word list learning	-.097 (.776)	-.345 (.298)	.208 (.540)
DKEFS-Verbal fluency total	.112 (.742)	-.075 (.826)	.429 (.188)
DKEFS-Category fluency total	.293 (.382)	.081 (.812)	-.099 (.772)
DKEFS-Category switching total	-.037 (.913)	-.103 (.763)	-.424 (.193)
DKEFS-Switching accuracy total	.092 (.789)	-.022 (.949)	-.426 (.191)

Abbreviations; WMS-III-Wechsler memory scale III word list learning; DKEFS-Delis-Kaplan Executive Function System.

Note. Positive correlations; better/lower neuropsychological functioning=greater/lower difference between EL and EF scores. Negative correlations; better/lower neuropsychological functioning=lower/greater difference between EL and EF scores.

Figure 1. Flow chart of the experimental task procedure.

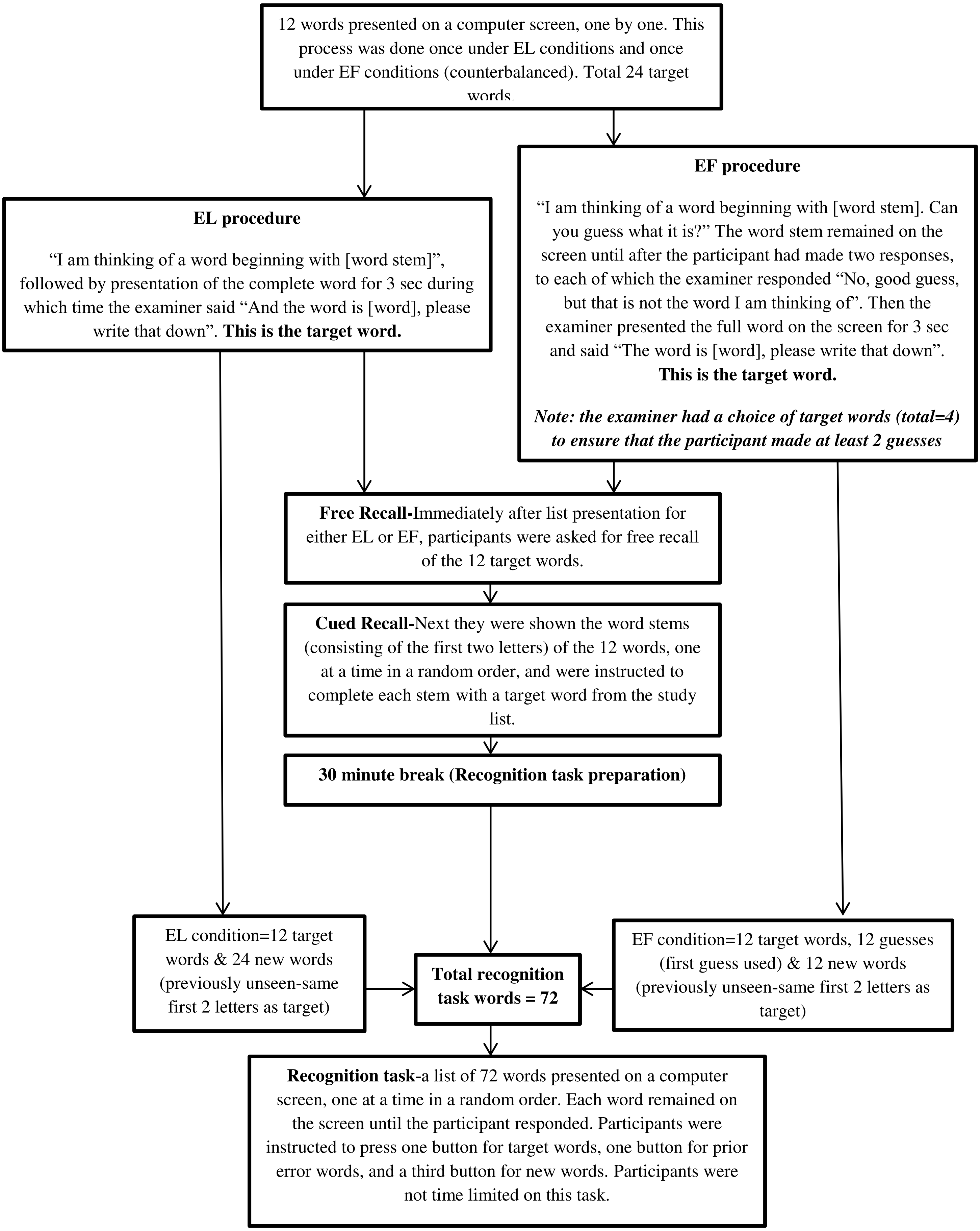


Figure 2. Individual scores for EL and EF learning conditions-free recall.

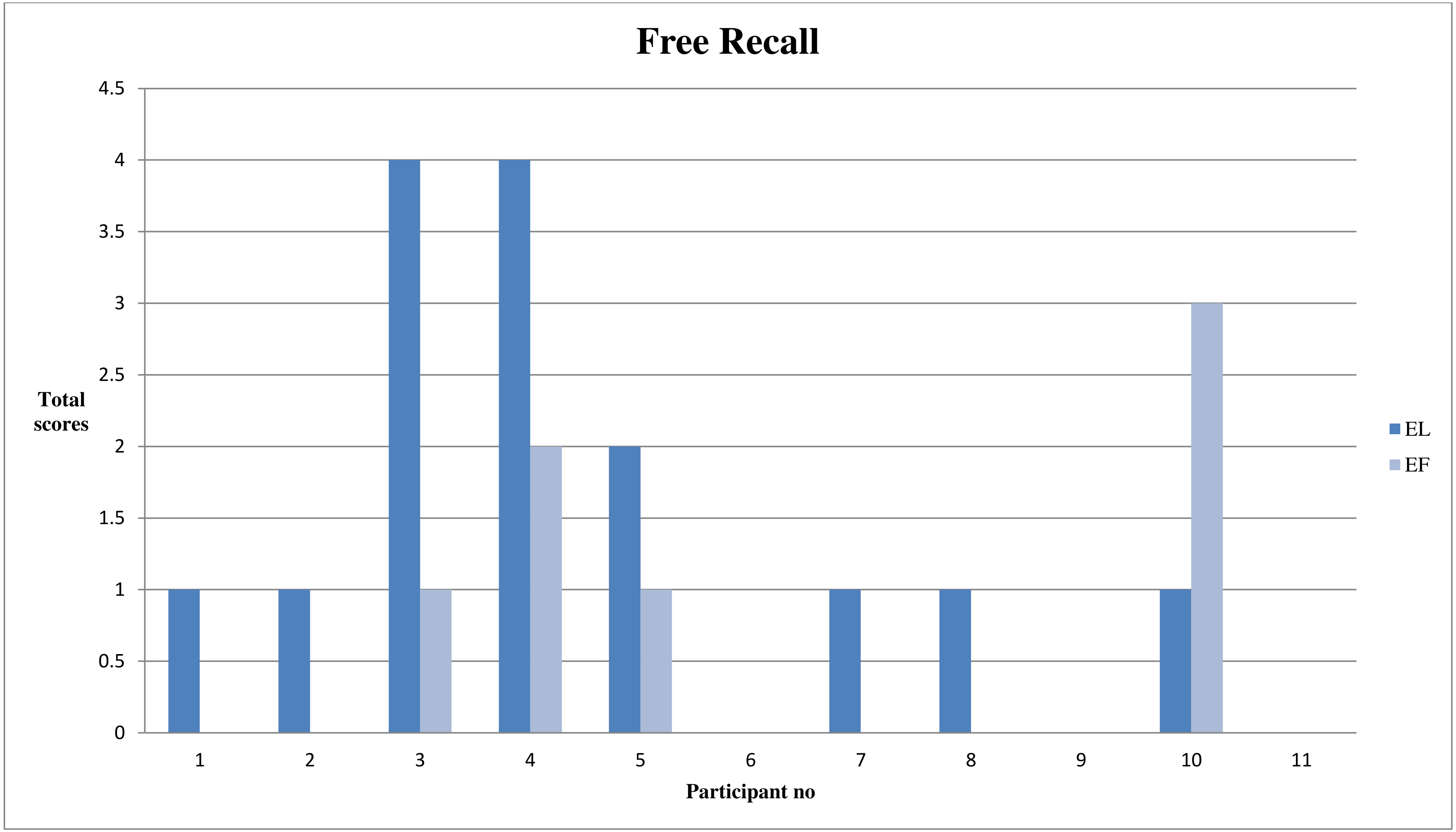


Figure 3. Individual scores for EL and EF learning conditions-cued recall.

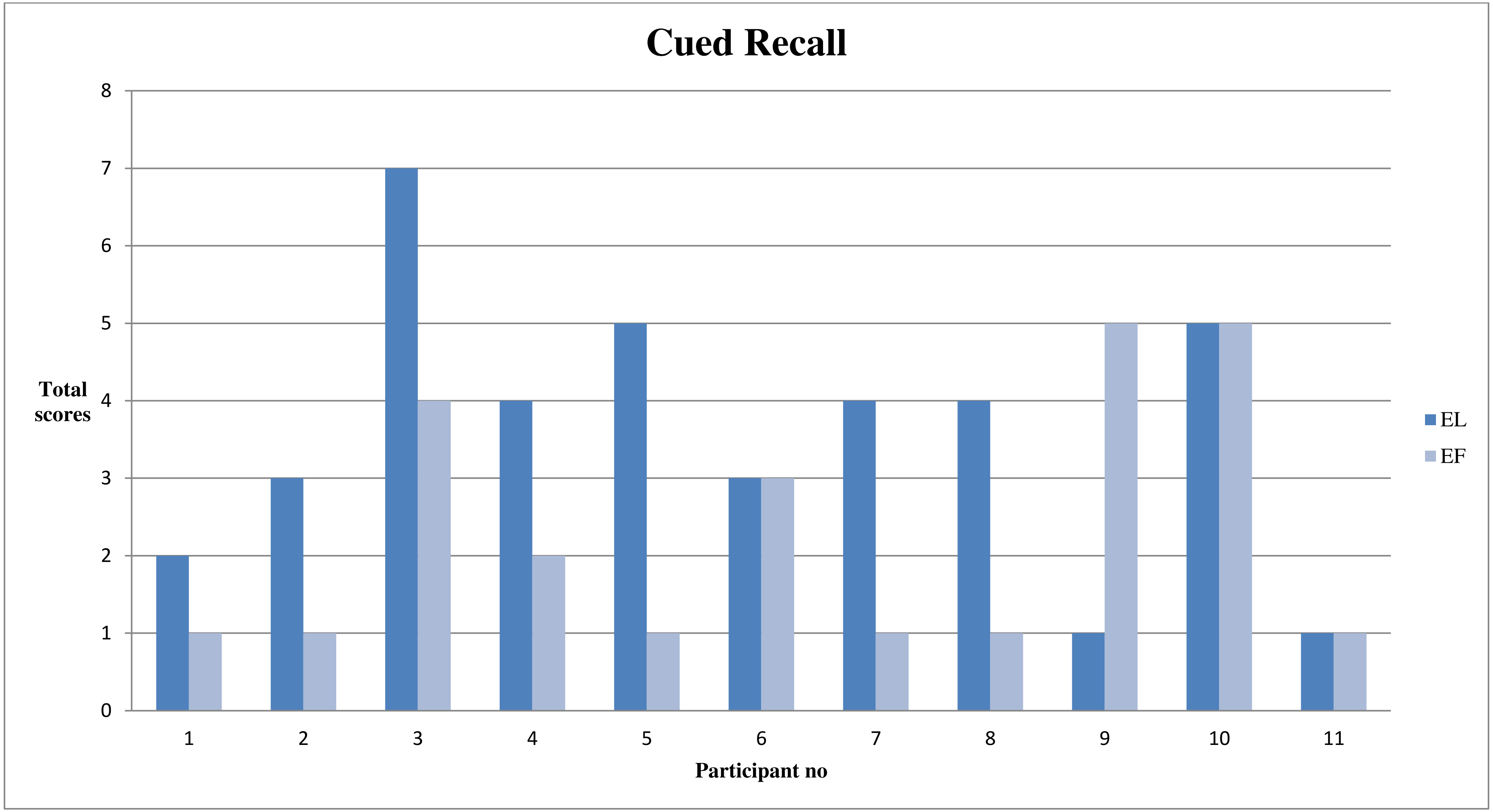
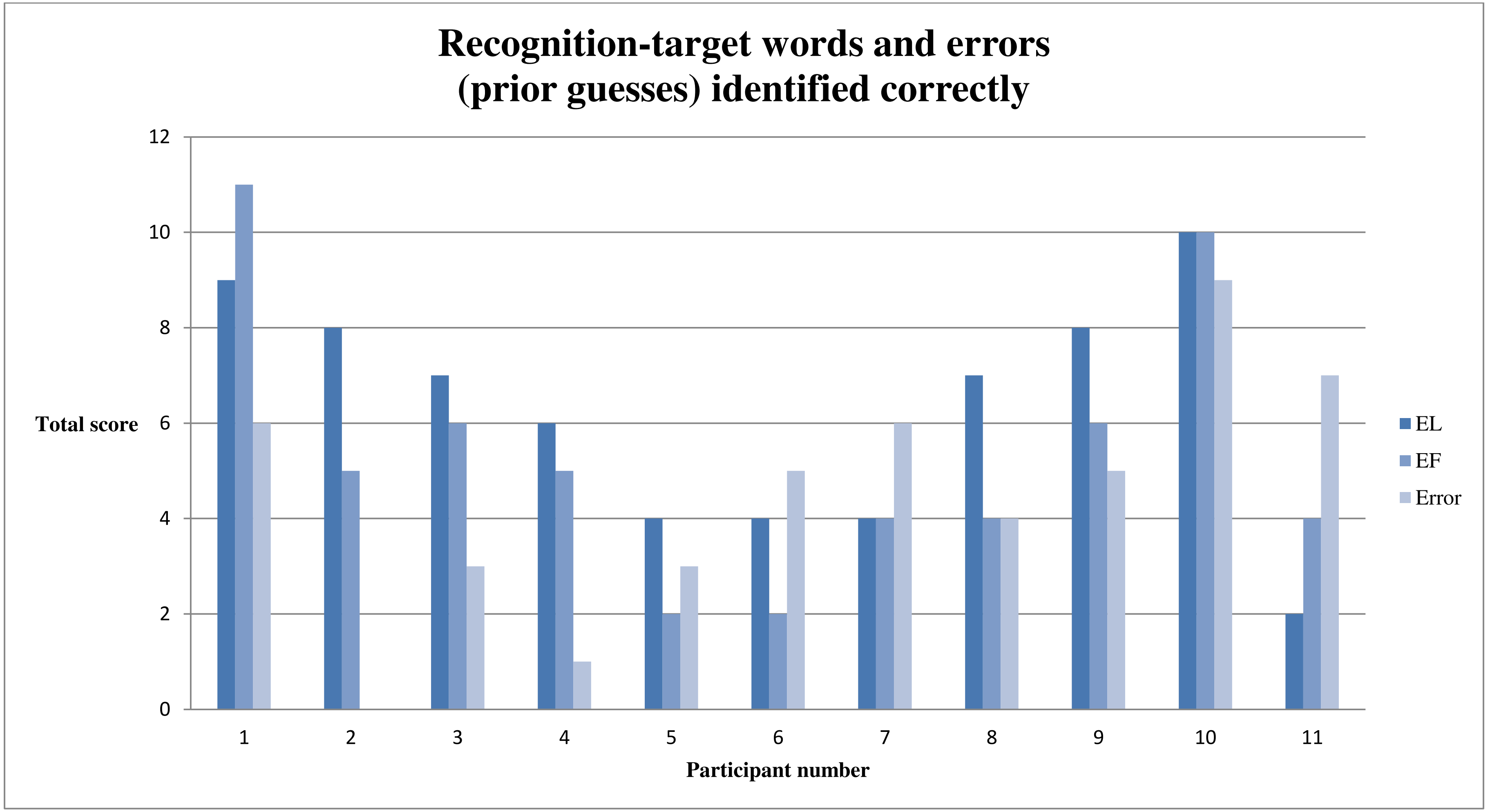


Figure 4. Individual scores for EL and EF learning conditions-recognition.



Contributions to theory and clinical practice

The preceding two papers of this thesis aimed to explore the benefits of errorless learning (EL) in comparison to learning by trial-and-error or errorful (EF) learning for neurodegenerative conditions, namely dementia and mild cognitive impairment (MCI). The literature review found that across the 10 reviewed studies there was a moderate effect size for the benefit of EL over EF learning for people with MCI and dementia. Results were tentative as six of the reviewed studies had non-significant ESs which may have reflected small sample sizes or methodological issues, or indicate that EL may not be any more advantageous than EF for some individuals. Given that only three studies were identified in the review which explored EL with MCI participants, it seemed appropriate to explore the benefit of EL further with this population. The findings of the empirical study showed that EL was not significantly superior to EF when undertaking a word-list task for people with MCI (PwMCI). It was suggested that the equivocal results across individual participant data may have been influenced by the level of effort applied to error production during the EF condition, leading to deeper encoding of these words which then impacted on subsequent recall. A review of current EL and EF methodology was recommended. It was also proposed that contrary to the continuing debate around implicit and explicit theories, error-monitoring ability may well prove to be the crucial factor in determining whether EL is a superior learning method in comparison to EF. The following discussion will focus on the implications of these findings for future research and theory development as well as implications for clinical practice. Limitations of the thesis will be considered and a concluding paragraph will offer a personal reflection on the process of conducting this research.

Implications for future research and theory development

When considering future research and theory development, it is necessary to review the current theories available, which have influenced this research project. For this section an overview of the theoretical background of memory will be provided with a discussion of the implications on cognitive rehabilitation which will lead to a focus on the EL task. A concluding paragraph will offer recommendations for theory development and future research.

Theoretical background of multiple memory systems

Memory is not a unitary construct, and the beginning of the experimental discourse of how memory consists of different systems can arguably be attributed to the work of Milner (1962). Milner showed that a severely amnesic patient H.M. could learn a hand-eye coordination skill over a period of days in the absence of any recollection of having practiced the skill. From this early work a theoretical distinction was drawn between declarative and procedural knowledge (Cohen & Squire, 1980) and explicit and implicit memory (Graf & Schacter, 1985). It was, however, disputed whether the broad phenomena of memory could be divided into such a dichotomy (Tulving, Schacter, & Stark, 1982). With further work in the 1980's showing the implication of a number of different brain structures associated with a variety of learning and memory tasks, a multiple systems approach to memory evolved (Tulving, 1985).

The placing of memory into a biological framework meant that a more accurate view of memory classifications could be reached (for a review see Squire, 2004). According to Squire, memory could be classed as either declarative (explicit) or non-declarative memory (implicit). Implicit memory can be termed procedural, priming and perceptual learning, simple classical conditioning or non-associative learning, areas which are associated with various brain structures such as the striatum, neocortex, amygdala, cerebellum and reflex pathways. Explicit memory includes semantic and episodic memory, areas which are associated with the medial temporal lobe. Semantic memory is composed of knowledge about the world, facts, ideas and word meanings. This knowledge is what someone knows but where there may be no recollection of when or where it was learnt (Tulving, 1983). Episodic memory relates to personal experiences which are tagged in time or place and which are representational of the external world (Squire, 2004). Such theoretical work is crucial when considering the nature and impact of memory impairment in conditions such as dementia and MCI. Indeed, research shows that implicit memory is relatively spared in MCI and Alzheimer's disease whereas impairments in episodic memory and to a lesser extent semantic memory are present (Grundman et al., 2004; Knopman & Nissen, 1987; Petersen, Smith, Waring, Ivnik, Tangalos & Kokmen, 1999). It is therefore possible to consider rehabilitation methods which supplement impaired memory by utilising the remaining intact memory systems.

Implications of memory theory for cognitive rehabilitation

The research on memory systems has led to the development of a variety of techniques that can aid memory for people with impairments in this domain. These can be split between restorative memory intervention approaches (aim to improve memory ability across a variety of tasks and context) and domain-specific memory intervention approaches (aim to teach a particular skill of body of information) Sohlberg & Mateer (2001).

Glisky & Schacter (1989) provide three characteristics of domain-specific training

- Rather than restore memory processes or improve general memory functioning, the goal is to alleviate a specific problem associated with memory impairment.
- Instructional techniques will have practical value for the individual.

- The aim is to teach certain techniques or procedures which the individual can carry out independently.

EL is one such method of domain-specific training which meets all three of the criteria proposed by Glisky and Schacter and which has become a popular rehabilitation approach. The literature on EL shows that specific problems associated with memory impairment can be alleviated, for example Clare (1999, 2001) who successfully applied EL techniques to the re-learning face-name associations. It is also regarded in principle as a method of instruction which alleviates error-intrusion on recall and a method which allows memory-impaired individuals to re-learn previously known skills (e.g. Dechamps et al., 2011). EL is in contrast to trial-and-error or errorful (EF) learning where 'guessing' and subsequent errors are encouraged. An influential study on the use of EL for people with profound amnesia as a result of brain injury showed that EL promoted better recall than EF in a word-list task (Baddeley & Wilson, 1994). Baddeley and Wilson hypothesised that people with memory impairment would rely on their intact implicit memory rather than their diminished explicit memory when learning. It was proposed that implicit memory does not allow for conscious recollection of errors; therefore any errors made during the learning phase would be committed to memory and indistinguishable from target stimuli.

Errorless learning as a cognitive rehabilitation technique

The application of EL for memory rehabilitation was reviewed by Clare and Jones (2008) who suggested that EL was a valuable method for some people on some types of task but that the evidence showed certain limitations. Clare and Jones recommended further research in determining for whom this approach would be most beneficial and how the efficacy of both EL and EF could be maximised. This provided the rationale for reviewing the literature on EL and EF approaches for PwMCI and dementia. The results of the review and meta-analysis supported the outcomes of other meta-analyses such as Kessels and Haan

(2003) who demonstrated the effectiveness of EL over EF methods for memory rehabilitation in people who had experienced memory problems following a range of conditions such as traumatic brain injury (TBI), schizophrenia or stroke. Although a moderate effect size for EL in comparison to EF methods was shown, a number of theoretical issues were identified. The EL and EF methods adopted across the reviewed studies were consistent with that used by Baddeley and Wilson yet there were variations in the number and nature of stimuli as well as the length of training schedules. Such variations were shown to impact on floor and ceiling effects which may have masked the true nature of EL in some studies. The review also found that the number of studies which explored EL in conditions other than Alzheimer's disease (AD) was low and it was recommended that further experimental research focus on other dementias or PwMCI. This became the rationale for the empirical study which utilised the experimental method of Baddeley and Wilson with PwMCI on a word-list learning task. A further reason for focussing on a potential cognitive rehabilitation method for PwMCI was the increased threat of future dementia for this population (Petersen, 1999) and the potential for neuropsychiatric conditions as a result of memory-impairment (Apostolova & Cummings, 2008).

Equivocal results across individual participant data for PwMCI showed that EL did not always benefit participants in comparison to EF methods. The absence of a significant result when comparing the results for EL and EF is in itself interesting and of particular note is the significant relationship between error-monitoring ability and difference scores between EL and EF. Theoretically, the empirical study demonstrated that previous hypotheses concerning the role of implicit and explicit memory systems in EL may not tell the whole story. There have already been attempts at explaining why the implicit memory theory (Baddeley and Wilson, 1994) alone cannot account for the benefits of EL. Hunkin, Squires, Parkin and Tidy (1998) first suggested a role for residual explicit memory in the relative success of EL techniques for people with memory impairments resulting from various types of brain injury. Hunkin et al. conducted two word-list experiments; the first replicated the Baddeley and Wilson (1994) study and the second was an attempt to assess whether the benefits of EL are due to the implicit learning theory. The second study utilised a fragment completion task, which the authors suggest relied on implicit memory, immediately following either the EL or EF presentation of target words. Immediately following the fragment completion task, participants completed a cued recall task using two letter stems from the target words, which was termed an explicit memory task by the authors. Hunkin and colleagues found EL only benefitted performance in their explicit memory task and not their implicit memory task, which led them to conclude that benefits of EL were based on residual explicit memory rather than on implicit memory alone.

A critique is offered by Page et al. (2006) of the retrieval methods used by Hunkin et al. (1998). Page and colleagues argue that the implicit task (fragment completion) used was not a sufficient measure of implicit memory for prior errors. Following the EF learning condition, none of the error responses of the previous encoding phase would fit; therefore it was more likely that the primed correct response would be used. It could therefore be argued that the implicit memory task would not distinguish between the EL and EF condition which would account for the finding that EL and EF methods were equivalent in the implicit learning task. It was also noted by Page and colleagues that the nature of the fragment completion task could act as an EF condition, as potential fragment completions could be made in error. Clearly the methodology adopted by researchers in this field is a crucial factor when exploring EL, particularly when considering the roles of implicit and explicit memory systems.

The empirical study highlighted the relationship between error-monitoring and EL. This supports an emerging literature which suggests that error-monitoring ability is crucial in determining the success of either EL or EF methods (Clare & Jones, 2008; Anderson, Guild, Cyr, Roberts & Clare, 2012). In considering memory systems as part of a biological framework, it would be logical to consider other systems which influence memory, such as executive functions. Retrieval is linked to frontal lobe contributions to memory, specifically executive functions which are associated with strategy formation, memory for temporal order, self-monitoring and initiating retrieval. Those with frontal lobe damage show poor source memory where facts are recalled yet the context in which that information was acquired is missing (Janowsky, Shimamura, & Squire 1989). Poor source memory would therefore lead to poor error-monitoring which may account for the benefits of EL when compared to EF.

Issues of research methodology

The outcome of the aforementioned studies in determining whether the benefit of EL is as a result of implicit memory systems or residual explicit memory systems appears, in part, dependent on the retrieval task used. The nature of the retrieval task influences whether implicit or explicit memory resources are utilised. A purely implicit test of memory would measure recollection of previously-studied stimuli through an unrelated task (Ward, Berry & Shanks, 2013). If a participant is asked to recall previously studied material, his/her response will invoke residual explicit memory whereas an implicit task instruction would ask the participant to complete a word-stem cue with the first word that comes to mind (Fleischman et al., 1999). Even if the task instruction is implicit, at the point of retrieval, the participant is free to utilise explicit processing to improve their performance which is referred in the literature as explicit contamination (Fleischman, 2007). Page et al. (2006) used both implicit and explicit task instructions in their sample of 23 people with stable organic memory impairment. Regardless of the nature of the task instruction, EL was shown to be more beneficial than EF which led the authors to question whether the participants explicitly attributed the implicit task instruction to the prior learning phase, leading to the use of explicit memory strategies regardless of task instruction. It is therefore difficult in practice to design a memory task which will target and show implicit memory functioning, which leaves the debate surrounding implicit and explicit memory systems and their role in EL a somewhat moot point.

A further methodological limitation is that some EF methods encourage errors through guessing. The 'levels of processing theory' (Craik & Lockhart, 1972) which states that stimuli which involves deeper processing or effort is thought to be better recalled than stimuli which is shallowly processed and the 'generation effect' which posits that self-generated information is better retained than information that is passively received (Jacoby, 1978) both apply to the degree of effort in an EF task where participants are asked to 'guess'. If errors produced during the EF condition are better recalled as a result of the above theoretical observations, in comparison to either EL or EF target stimuli, more errors will be elicited in the EF condition than target stimuli which may account for the apparent superiority of EL in some instances.

Future research directions

The following research recommendations are therefore suggested;

- Future experimental research should explore error-monitoring and how this influences EL or EF methods, with a focus on the role of executive functioning.
- A review of current methodology is required with a focus on potential methods which elicit implicit memory and a consideration of the impact of artificially introducing errors.
- Research on the utility of EL as a long-term form of memory rehabilitation in MCI is of greater interest if such methods are to be adopted in clinical practice, yet there are

no clinically relevant studies at this time. It is noted however, that given the lack of consensus as to how EL may be more beneficial than EF, further experimental research is required.

Implications for clinical practice

It is clear from both this thesis that no clear guidelines for clinicians with regard to the benefits of EL over EF learning for PwMCI can be given with such a divergent evidence-base, particularly following the equivocal results of the empirical study. However, the usefulness of such an approach should not be underestimated. Methods of memory rehabilitation are certainly a focus of clinical practice where memory-impairment causes problems in day-to-day life. The principle of EL (the reduction of the potential for errors during encoding) applied to a functional task in a step-by-step manner may be of great benefit to the individual. Rehabilitation is goal-directed and serves to empower the individual, which is of particular utility for PwMCI, where there may be a concern about future dementia. The absence of errors should be a less aversive experience for PwMCI as there would be no experience of failure, which is inherent in EF approaches. Additionally, such an approach would not have any adverse effects, so its use should not be avoided. It is also recommended though that EL not be applied without a thorough assessment of the individual and consideration of other approaches which may be more suitable.

If memory rehabilitation is to be successful, all aspects of an individual's life will need to be considered to ensure that rehabilitative methods are given the best chance of success. Should the individual have a co-morbid illness or disability, this should be taken into account when adopting a suitable rehabilitation method. The severity and nature of memory impairments should be assessed through neuropsychological assessment with careful monitoring and review over time for PwMCI where further decline is possible. If a person-centred approach is adopted (Kitwood, 1997) in addition to the outcomes of a neuropsychological assessment, this can inform the method of memory rehabilitation used.

The clinical psychologist has a key role in a multi-disciplinary setting and can provide consultation to staff groups who offer memory-rehabilitation for PwMCI. This could involve various disciplines such as occupational therapists, physiotherapists and speech and language therapists who are working with the individual as well as having direct input to the carer/family. Knowledge of evidence-based rehabilitation techniques is therefore necessary so that the best method is chosen for each individual.

Clinical recommendations

The following clinical recommendations are therefore suggested;

- That the goals of any form of memory rehabilitation for PwMCI are person-centred and guided by a thorough neuropsychological assessment.
- There should be periodical review of PwMCI, in order to monitor any further cognitive decline which may impact the success of the rehabilitation technique adopted.
- That the psychologist be able to inform and offer consultation for other disciplines in a multi-disciplinary team setting of evidence-based rehabilitation techniques.
- EL should not be avoided as a memory rehabilitation technique as a result of a lack of clear supporting evidence; the absence of the potential for errors during learning may prove to be a less aversive experience for the individual who may be anxious about their memory problems.

Limitations

The small number of participants with MCI in the empirical study is a limitation. Rates of PwMCI in the community can range from 3-36% (Busse, Bischkopf, Riedel-Heller & Angermeyer, 2003) with numbers of clinically identified PwMCI being lower. Low participant numbers were a feature of the studies focussing on MCI and dementia included in the literature review with numbers ranging from 4-22. This may have influenced individual study effect sizes and the non-significant outcome for the empirical study. The original aim was to recruit 20 participants for the empirical study. In order to have sufficient statistical power, and avoid the possibility of missing an effect which is in fact present, a 0.80 standard level of power would be required (Cohen, 1992). As the thesis was essentially exploratory in nature, the application of a more lenient alpha level of 0.10 would require 20 participants for a large effect size (Table 2; Cohen, 1992) within the 0.80 standard level of power. As the number of participants achieved was 11, it is possible that the statistical analysis conducted missed an effect that was indeed present i.e. that EL is of greater benefit for people with MCI than EF. It is therefore not possible to conclude that EL is no more beneficial than EF. It is also of note that participant performance on free and cued recall was poor, in particular for free recall where the mean score (out of a potential 12) for both EL and EF was low (1.36; 0.64 respectively). Floor effects may therefore mask any real differences in these scores.

Due to the inherent power issues and floor effects, ESs were not included in the empirical paper for the following reasons. The total summary ES when combining the mean difference ESs between free recall, cued recall and recognition was 0.58 (CI 0.10-1.06) which would be considered a moderate and significant ES. In comparison to the literature review, this result is similar to the total summary ES achieved. However, individually each outcome measure achieved a non-significant ES; free recall ES 0.58 (CI -0.26-1.41); cued recall ES 0.73 (CI -0.10-1.57); and recognition ES 0.34 (CI -0.50-1.17). In combining the three outcome measures, the summary figure does not take into account the nature of the recall task or whether this is influenced by ‘floor’ or ‘ceiling’ effects. Although the ES is a useful statistic when considering the effectiveness of a particular treatment or condition, it is recommended that a summary ES only be calculated across homogenous recall tasks and participant groups.

Undertaking such an experimental task where memory problems are explored may be considered an aversive experience for potential participants. Such a study also offers little motivation for participants to take part whereas a therapeutic study may focus on participant goals which would be of real-life relevance. The experimental nature of the empirical study does not map easily onto clinical practice although the ethical implications of introducing an EF control condition for clinically relevant issues is questionable. There is still a lack of clarity as to who would benefit from EL therefore experimental research is still a priority in this field.

Personal reflection

Conducting research with PwMCI offers the possibility to gain an understanding of the qualitative experience of living with memory problems in addition to the collection of study data. In this privileged position, the real life impact of the research becomes clear and the motivation to make a difference served to motivate the writing of this thesis. At times frustrating, the literature on EL covers many aspects, from learning theories to memory systems and their biological counterparts. It took a great deal of reading, then thinking, and a great deal more thinking before the many aspects which inform the research on EL became somewhat clearer. It was only in the final throes of writing that a cohesive idea of the thesis as a whole became apparent and it is hoped that this is reflected in the preceding studies and this, the final chapter.

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