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The benefits of errorless learning for people with amnestic 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 learning in people with amnestic mild cognitive impairment (MCI), and to examine whether accuracy in error recognition relates to any observed benefit of errorless over errorful learning.

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

Results: Errorless learning was significantly superior to errorful learning for both free recall and cued recall. The benefits of errorless learning were less marked in participants with better error recognition ability.

Conclusions: Errorless learning methods are likely to prove more effective than errorful methods learning for those people with MCI whose ability to monitor and detect their own errors is impaired.

Keywords: errorless learning, neuropsychology, implicit memory, error-recognition, executive function

With increasing focus on early identification of cognitive problems associated with neurodegenerative disorders, there is growing need to develop relevant interventions for people with mild cognitive impairment (MCI), particularly those with amnestic MCI who experience significant memory impairment (Petersen & Negash, 2008; Petersen, Smith, Waring, Ivnik, Tangalos & Kokeman, 1999), which can lead to anxiety and depression (Apostolova & Cummings, 2008). It is therefore worthwhile to explore cognitive rehabilitation methods for people with amnestic MCI which could improve their memory ability and help maintain quality of life.

One approach often used to facilitate learning or relearning in people with memory impairments is errorless learning (EL). EL is a method wherein errors during learning are avoided, in contrast to trial-and-error or errorful learning (EF) where learners are required to guess at the answer before receiving feedback, which may result in errors. The EL approach encompasses a range of techniques in which errors are prevented or reduced during learning, many of which have been used among people with dementia (De Werd, Boelen, Olde Rikkert, & Kessels, 2013). The EL method described by Baddeley and Wilson (1994) has been the most influential, and in contrast to other EL methods such as the method of vanishing cues (Glisky, Schacter & Tulving, 1986) or spaced retrieval (Camp, Foss, O'Hanlon & Stevents, 1996), does not allow for error production during learning. Baddeley and Wilson's EL condition involved the experimenter showing a word stem and immediately telling the participant the word that completes it e.g., AR_____ - ARTIST. In the EF condition, the participant was shown a word stem and encouraged to guess what the word might be before being given the correct answer, ensuring that errors were made. This EL method has been shown to produce better learning than EF for people with brain injury (Wilson et al., 1994; Squires et al., 1997; Hunkin et al., 1998; Page et al., 2006). The evidence for an errorless advantage among people with neurodegenerative conditions,

however, is less clear. A systematic review and meta-analysis by Roberts, Jones and Clare (2015) suggests that EL may be more beneficial than EF for people with Alzheimer's disease, other dementias or MCI, but that further research is warranted given the small number of studies and the small number of participants in those studies. Research on EL with people who have amnestic MCI, in particular, has been limited. Of the three studies identified, findings suggest that EL is more beneficial than EF for some people with MCI, but not all (Akhtar, Moulin & Bowie, 2006; Jean, Simard, Reekum & Bergeron, 2007; Jean et al., 2010; Lubinsky, Rich & Anderson, 2009).

Theoretical explanations as to why EL affords greater benefits than EF for people with memory impairment have primarily focused on the role of implicit memory. It has been argued that people with explicit memory impairments learn new information by relying on largely preserved implicit memory rather than explicit memory (Baddeley & Wilson, 1994; Glisky, Schacter & Tulving, 1986). Implicit memory does not allow for conscious discrimination between errors or correct answers, and hence any errors made during the learning phase are committed to memory and are indistinguishable from the target stimuli presented for learning. Therefore, where there are impairments in explicit memory, EL will produce better results than EF as it capitalizes on implicit processes that are intact. Others have argued, however, that the benefit of EL over EF is greater in those with residual explicit memory (Tailby & Haslam, 2003; Hunkin, Squires, Parkin & Tidy, 1998).

Both the implicit and explicit theories focus on memory processes, yet the role of other neurocognitive domains may be of relevance (Anderson, Guild, Cyr, Roberts & Clare, 2012). The success of EF learning is dependent on error-recognition abilities which are associated with attention and executive functions (Clare & Jones, 2008), domains which are affected among some people with amnestic MCI (Belleville, Chertkow & Gauthier, 2007) and thought to interfere with memory and recall (Stuss & Alexander, 2000). This may offer a

possible explanation as to why EL is beneficial for some people with MCI but not others. For an individual with intact executive functions and thus good error-recognition, the benefit of EL over EF learning may be less beneficial relative to an individual with compromised executive functions and poorer error-recognition (Cyr & Anderson, 2014).

The aims of this study is to examine whether EL produces better learning outcomes than EF in people with amnestic MCI using the learning protocol employed by Baddeley and Wilson (1994), and to consider whether the observed benefits of EL vary depending on error-recognition (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 utilised a within-subjects design to examine the effects of EL and EF learning in a group of people with amnestic MCI 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

Nineteen participants were recruited from four National Health Service memory clinics in North Wales, UK. Memory Clinic staff identified potential participants who would be willing to take part in the research and who had received a diagnosis of MCI based on the

Petersen (2001) criteria. Diagnoses were made by a multi-disciplinary clinical team based on neuropsychological assessments, functional assessments and clinical histories. Inclusion was dependent on a diagnosis of amnestic MCI (single or 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 were the presence of major depressive disorder, current or past history of psychosis, other neurological disorders, stroke or brain injury. This information was confirmed by the clinicians involved with the participant and by consulting medical records.

Measures

Neuropsychological measures were used to explore whether cognitive abilities associated with error-monitoring and episodic memory were related to any observed benefit of EL over EF. A measure for anxiety and depression was included in order to screen participants for clinical levels of anxiety and depression that might influence their performance in this study (Apostolova & Cummings, 2008).

- *D-KEFS (Delis, Kaplan, & Kramer, 2001):* Three components of the D-KEFS Verbal Fluency Test were used: Letter Fluency, Category Fluency and Category Switching. Scores reflected the number of correct items. Repetitions were not counted. Analysis was based on raw scores.
- *WMS-III (Word list sub-test; Wechsler, 1997):* The word list subtest used in this study consists of a list of 12 words which are read out over 4 trials, with the participant being required to repeat all remembered words in any order on each trial. This task evaluates immediate episodic recall. Analysis was based on the total raw scores added across the 4 trials.
- *HADS (Zigmond & Snaith, 1983):* The HADS is a screening tool which yields separate scores for anxiety and depression on two subscales (scores 0-21). A score of

11 or higher indicates the probable presence of a clinically significant level of either anxiety or depression.

Procedure

Participants were visited at home on two occasions. The neuropsychological assessment was carried out during the first visit and the learning task was administered during the second visit.

Word learning task

Two word lists were prepared, each comprising 12 unique two-letter word stems with four possible 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, two at the beginning and two at the end of each list, to control for primacy and recency effects. Word stems and target words were presented on a computer screen using E-Prime (1.1 SP3 Psychology Software Tools, Pittsburgh, PA). Participants were instructed that they should try to remember the words for a later memory test. List assignment to either the EL or EF condition was counterbalanced. One list was learned under an EF procedure, and the other under an EL procedure, in counterbalanced order. In the EL procedure, a word stem appeared on the screen for 1 second, during which 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 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". If the participant guessed the correct word,

the target word was replaced with an alternative word beginning with the same word stem. 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 cued recall test. In the free recall task, participants were asked to recall as many words from the study list as they could in any order. For the cued recall task, they were shown the word stems of the 12 words, one at a time and 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 they needed to respond. Accuracy was defined in both tests as the number of target words correctly recalled. Error scores were also calculated, reflecting the number of novel, previously unseen words generated for both EL and EF. In addition to calculating the number of novel, previously unseen words for EF, the number of prior guesses incorrectly recalled was recorded.

After the second list had been studied and recalled, the participant was given a 30-minute break, with the materials from the learning phase removed to avoid rehearsal. During this time the examiner modified the recognition test list so that it contained 72 words, comprising the 12 target words from both lists (24 words), 24 new words from the EL list that started with the same word stem as the target words (24 words), 12 new words from the EF list that started with the same word stems as the target words but had not been generated as errors (12 words), and the first error provided to each word stem by the participant in the EF condition (12 words). The words were randomly presented on a computer screen, one at a time, and participants were asked to indicate by pressing a number on the computer keyboard, for each word, whether it was a target word, a prior error (incorrect guess) or a newly-introduced (novel) word. The recognition task was self-paced.

Statistical Analysis

Data analyses were conducted using IBM SPSS statistics for Windows (v. 20). Accuracy on free recall, cued recall and recognition tests under EL and EF conditions were compared using paired samples t-tests. Difference scores for free recall, cued recall and recognition were calculated by subtracting EF from EL scores in order to measure the magnitude of any EL benefit, and correlational analyses examined the relationship of these difference scores with neuropsychological test scores and with the number of errors correctly identified during the recognition task in order to explore error-monitoring ability. Correlation analyses used Pearson's product-moment correlation coefficient. An alpha level of 0.05 was used throughout.

Results

Nineteen participants (11 women, 8 men) with a clinical diagnosis of single domain amnestic MCI participated in the study. The mean age was 76.79 (S.D. 8.14, range 58-90). MMSE scores ranged from 24-30 with a mean of 26.74 (S.D. 2.26). Table 1 shows the scores on neuropsychological tests and self-report questionnaires. Mean HADS anxiety score was 5.11 (S.D. 3.38) and mean HADS depression score was 3.84 (S.D. 3.02). Although five participants scored within the mild to moderate range for anxiety and depression, no participant was being treated clinically for either anxiety or depression at the time of testing.

(((Table 1 about here)))

Experimental Task

Free Recall performance

The total number of correct target words (max = 12) correctly recalled for each participant in the free recall task is shown in Figure 1. Free recall performance was

significantly better following EL (M 1.00; S.D. 1.25) than EF learning (M = 0.37; S.D. = 0.88), t (18) = 2.59, p = .019). Eleven participants were able to recall some target words following the EL condition whereas only four participants were able to recall some target words following the EF condition. Of the four participants who were able to recall target words following both the EL and EF condition, three participants showed better recall following the EL condition.

(((Figure 1 about here)))

Cued Recall performance

The total number of correct target words (max = 12) correctly recalled for each participant in the cued recall task is shown in Figure 2. Cued recall performance was significantly better following the EL (M = 3.42; S.D. = 2.04) than the EF condition (M 1.79; S.D. 1.55), t (18) = 3.45, p = .003. Individual participant data shows that 18 participants were able to recall target words following the EL condition and 16 of these also recalled words following the EF condition. Of the 16 participants who were able to recall target words following both the EL and EF conditions, 12 participants showed better recall following the EL condition. Participant 9 showed greater recall following the EF condition and participants 3, 10 and 11 did equally well following both the EL and EF condition.

(((Figure 2 about here)))

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

For both EL and EF conditions, cued recall resulted in significantly better performance than free recall, t (18) = -5.85, p < .001, and t (18) = -4.60, p = .000, < .001, respectively (see Table 2). More novel errors (previously unseen words) were made during

free and cued recall for EL lists than for EF lists (t (18) = 1.35, p = .202 and t (18) =. 4.11, p = .001 respectively) with the difference for cued recall reaching significance. The difference between the total number of errors (for EL this is novel errors only; for EF this included novel errors and previous guesses) during free recall for EL and EF lists did not reach significance, t (18) = 1.13, p = .274, although comparatively more errors were produced in the EL condition. The difference in total errors during cued recall for EL and EF lists was not significant, t (18) = -.824, p = .420.

(((Insert Table 2 about here)))

(((Insert Table 3 about here)))

Recognition

Participants were asked to classify 72 words according to whether they were targets (words that were identified as target words from both the EL and EF learning conditions), novel (previously unseen alternate words) or error words (the first incorrect guess from the EF condition). 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. Of the 19 participants, 12 showed better recognition of target words learned during the EL relative to the EF condition, four participants showed better recognition of target words learned during the EF relative to the EL condition, and three participants performed equally well for the recognition of target words learned during both the EL and EF conditions. Participants were better able to correctly identify new words (previously unseen) than previous errors (incorrect guesses). At the group level, there was no significant difference in the number of target words correctly identified in the EL and EF learning conditions, t (18) = 1.79, p = .091 The difference

between EL and EF learning conditions for accurate identification of previously unseen words did reach significance (t (18) = 8.78, $p < .000$). For recognition of previous errors (guesses) in the EF condition only, 30.89% of the maximum score was achieved.

(((Insert Figure 3 about here)))

(((Insert Table 4 around here)))

Correlation analyses - Relationship between EL benefit and memory for errors

In order to explore whether the magnitude of benefit for EL over EF was related to cognitive ability, a Pearson product-moment correlation analysis was conducted to identify any significant relationships between neuropsychological measures and difference scores for EL and EF conditions, the results of which are shown in Table 4. No significant relationships were found.

Correlation analyses - Relationship between EL benefit and error-monitoring

Scores for the correct identification of errors during the recognition task (previous guesses made during EF learning) were also compared to difference scores between EL and EF conditions for free recall, cued recall and recognition to explore whether error-monitoring ability was related to the benefit of EL over EF. For free recall, the ability to correctly identify errors was significantly correlated with the difference between EL and EF scores, $r = -.506$, $p < 0.05$. Greater ability to correctly identify errors was associated with smaller difference scores and hence with smaller benefits of EL over EF. For cued recall and recognition, there was no significant correlation between the ability to correctly identify prior errors and EL and EF difference scores, although the direction of the relationship suggests that the ability to correctly identify errors is associated with smaller difference scores between the EL and EF conditions ($r = -.181$, $p = .459$ and $r = -.245$, $p = .312$ respectively).

Discussion

The aims of this study were to determine whether EL produces better performance on a word-list learning task compared to EF in people with the amnestic form of MCI, and to examine whether the ability to recognize self-generated errors relates to any observed benefit. For memory for target words, we found a benefit of EL relative to EF learning in free and cued recall; however, this EL advantage was not found in recognition. The ability to correctly identify previous errors (error-monitoring) was associated with smaller benefits of EL over EF, although this only yielded a significant correlation for the free recall task.

Free recall was particularly difficult for the people with MCI who participated in this study, as evidenced by the fact that only four participants recalled any target words following EF. Of those four, three participants demonstrated greater recall following EL. The cued recall task resulted in better performance from participants than the free recall task, with 16 participants recalling target words following EF. Recall was greater following the EL condition than for the EF condition for 12 participants. Not all participants benefited from EL following free or cued recall, with EF showing greater benefits for at least one participant in each test modality. Such mixed results are consistent with previous research (Akhtar, Moulin & Bowie, 2006; Jean, Simard, Reekum & Bergeron, 2007; Lubinsky, Rich & Anderson, 2009), but overall, free recall and cued recall demonstrated a clear advantage for the EL condition, which is of clinical relevance for memory rehabilitation.

The apparent advantage of EL over EF learning could be a result of the errors participants made during the EF condition, which may have made them less inclined to guess during recall after EF, although this was not observed when cues were offered during the cued recall task. It is also notable that the degree of effort during EF learning was greater due to participants being asked to guess what the target word was on two occasions. The

generated ‘errors’ may have been better retained than the more passively received target words (Jacoby, 1978). However, the pattern of errors (novel and previous guesses) for the free recall task shows that participants made more errors following EL, which does not support the view that advantage of EL over EF learning shown is a result of a generation effect in the EF condition.

For the recognition task, EL resulted in better recognition of target words for 12 participants. Three participants demonstrated better recognition following EF. The recognition task was less effortful for participants, with all participants showing some recognition and with higher scores achieved for the recognition task than for the free and cued recall tasks. Although more participants showed better recognition of target words learnt during the EL condition, this did not reach significance. It has been argued that recognition involves less self-initiated cognitive processing than recall (Craik & Tulving, 1975) which may suggest that the benefit of EL over EF learning diminishes when memory tasks require less cognitive processing. Generating learning material during the EL condition has been shown to be more effective than a simple repetition EL condition with Alzheimer’s disease patients in learning face-name associations (Laffan, Metzler-Baddeley, Walker & Jones, 2010). A more effortful EL learning method involving more self-initiated, elaborative processes may well have yielded greater benefits (Anderson & Craik, 2006). This also supports the role of error-recognition as mediating the apparent advantage of EL over EF learning; memory tasks that do not utilise internal cognitive processes such as error-recognition will not demonstrate any advantage of EL over EF learning. If it is error recognition which explains the benefit of EL over EF learning, an EL task that does not allow for this cognitive process, will not demonstrate its benefits.

There was a negative correlation between the difference score for EL and EF in the free recall modality and the number of correctly recognised errors (previous guesses) during

the recognition task, which suggests that the benefits of EL over EF emerge as error-recognition ability diminishes. The fact that this correlation was not present during cued recall or recognition suggests that error-recognition has less influence on memory tasks that provide greater environmental support, such as cued recall and recognition (Craik & Tulving, 1975). Although executive function ability was tested for the purposes of this study (DKEFS; Delis, Kaplan, & Kramer, 2001), there was no significant correlation between scores on these measures and the difference scores for EL and EF across all test modalities. Executive functioning is a broad concept which includes different components such as initiation and drive, response inhibition, organising and self-monitoring (Mateer, 1999). It is well documented that verbal fluency tasks (such as the DKEFS sub-tests) are valid measures of executive function ability in addition to indicators of verbal ability (Shao, Janse, Vissert & Meyer, 2014). However, as the findings of this study suggest that error-monitoring ability is a key factor in the benefits of EL over EF the inclusion of a wider battery of executive function measures in future studies could further explore the role of executive function in error recognition.

The small number of study participants is consistent with other studies of this type. The recruitment of MCI participants is challenging as the prevalence of MCI in the community can range from 3-36% (Busse, Bischkopf, Riedel-Heller & Angermeyer, 2003) with fewer numbers attending memory clinics. Additionally, 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. Although this study did demonstrate the overall benefits of EL, a larger sample of study participants would allow group comparisons according to a detailed neuropsychological profile and increase the magnitude of correlations between variables of interest, thus allowing a more detailed exploration of error-recognition and EL.

This study has shown that EL is significantly superior to EF when undertaking a word-list learning task for people with MCI under free recall and cued recall conditions. Additionally, this study found that error-recognition may well be a crucial factor; if error-recognition is good, EL offers limited benefits over EF as a learning method. Further investigation of the role of error-recognition may therefore be useful in enhancing understanding of the mechanisms underlying the relative benefits of EL and EF for people with MCI and other neurodegenerative disorders.

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Table 1. Neuropsychological test and self-report questionnaire scores.

	Max. Score	Mean	SD	Range
MMSE	30	26.74	2.26	24-30
WMS-III word list learning	48	17.67	5.72	10-37
DKEFS verbal fluency	N/A	34.63	12.62	16-57
DKEFS verbal fluency SS	N/A	10.44	3.79	4-17
DKEFS category fluency	N/A	28.84	9.03	14-47
DKEFS category fluency SS	N/A	8.44	3.75	4-16
DKEFS category switching	N/A	10.68	3.45	5-18
DKEFS category switching SS	N/A	8.50	4.15	3-17
DKEFS category switching accuracy	N/A	9.84	4.03	0-18
DKEFS category switching accuracy SS	N/A	9.17	3.87	1-17
HADS Anxiety	21	5.11	3.38	0-13
HADS Depression	21	3.84	3.02	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. SS = Scaled Scores.

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)

	EL condition	EF condition	Paired sample t-test
Free Recall Targets (Correctly recalled; Max = 12)	1 (1.25)	0.37 (.83)	t(18) = 2.59, p = .019*
Free Recall Errors (novel)	.47 (1.12)	.11 (.32)	t(18) = 1.35, p = .202
Free Recall Errors (previous guesses)	N/A	.05 (.23)	
Free Recall Errors TOTAL	.53 (1.26)	.16 (.50)	t(18) = 1.13, p = .274
Cued Recall Targets (Correctly recalled; Max = 12)	3.42 (2.04)	1.79 (1.55)	t(18) = 3.45, p = .003**
Cued Recall Errors (novel)	4.84 (3.52)	2.16 (2.01)	t(18) = 4.11, p = .001**
Cued Recall Errors (previous guesses)	N/A	3.26 (2.75)	
Cued Recall Errors TOTAL	4.84 (3.52)	5.42 (3.91)	t(18) = -.824, p = .420

** = significant at the .05 level; ** = significant at the .01 level*

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

	EL condition	EF condition	Paired sample t-test
Target words correctly identified (Max 12)	6.05 (2.48; 50.37%)	5.37 (2.81; 44.58%)	t (18) = 1.79, p = .091
New words correctly identified (EL-Max 24; EF-Max 12)	15.26 (6.52; 63.68%)	7.26 (3.62; 60.16%)	t (18) = 8.78, p = .000*
Previous errors (guesses-correctly identified) (EF only-max 12)	N/A	3.74 (2.66; 30.89%)	N/A

* *= significant at the .05 level*

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	-.022 (.931)	.343 (.163)	.016 (.949)
DKEFS-Verbal fluency total	.167 (.494)	.168 (.493)	-.030 (.904)
DKEFS-Category fluency total	.202 (.408)	.316 (.187)	-.221 (.363)
DKEFS-Category switching total	.133 (.587)	.264 (.274)	-.376 (.113)
DKEFS-Switching accuracy total	.180 (.461)	.260 (.282)	-.404 (.086)

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

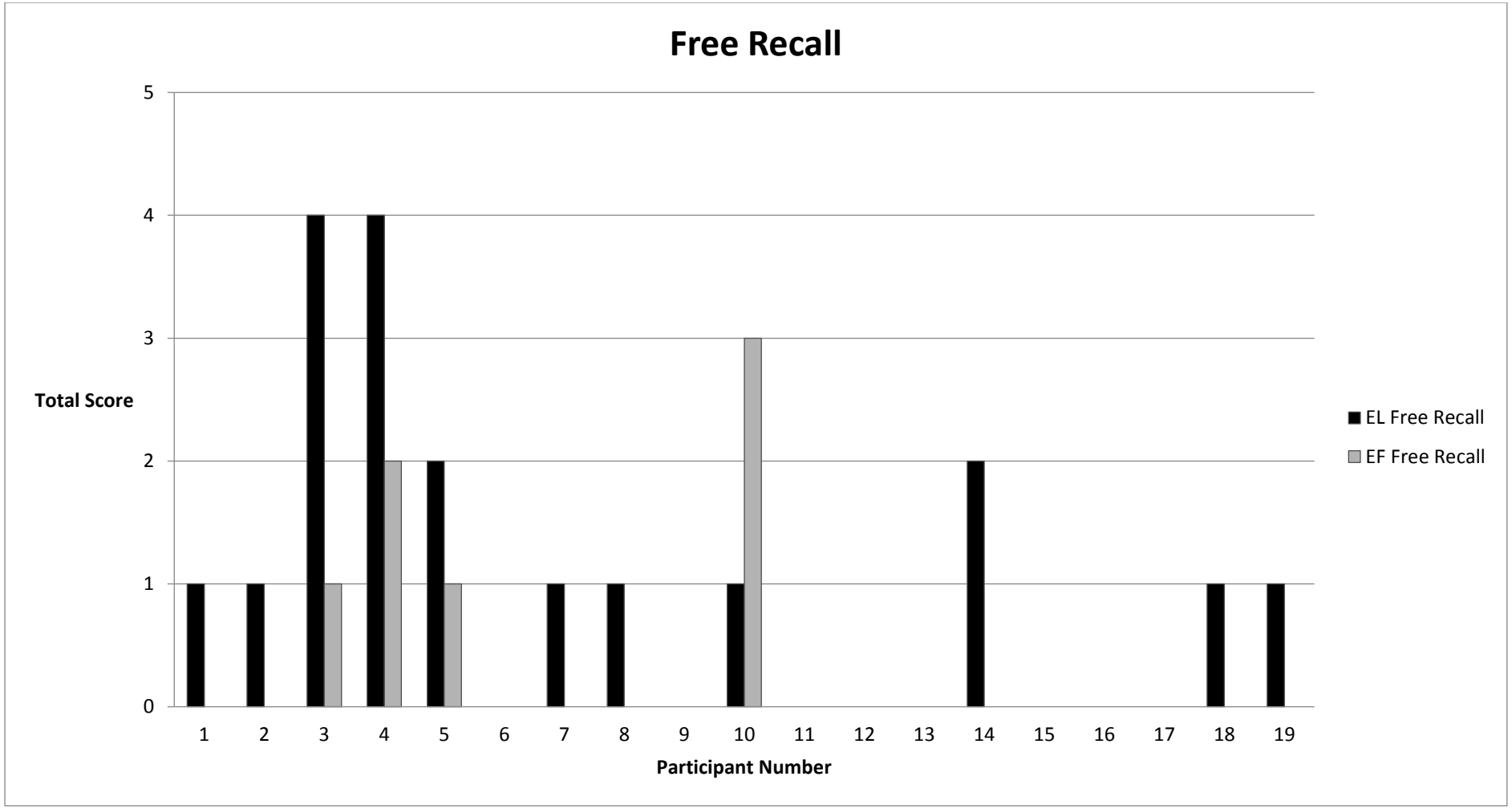

Figure 2. Individual scores for EL and EF learning conditions-cued recall.

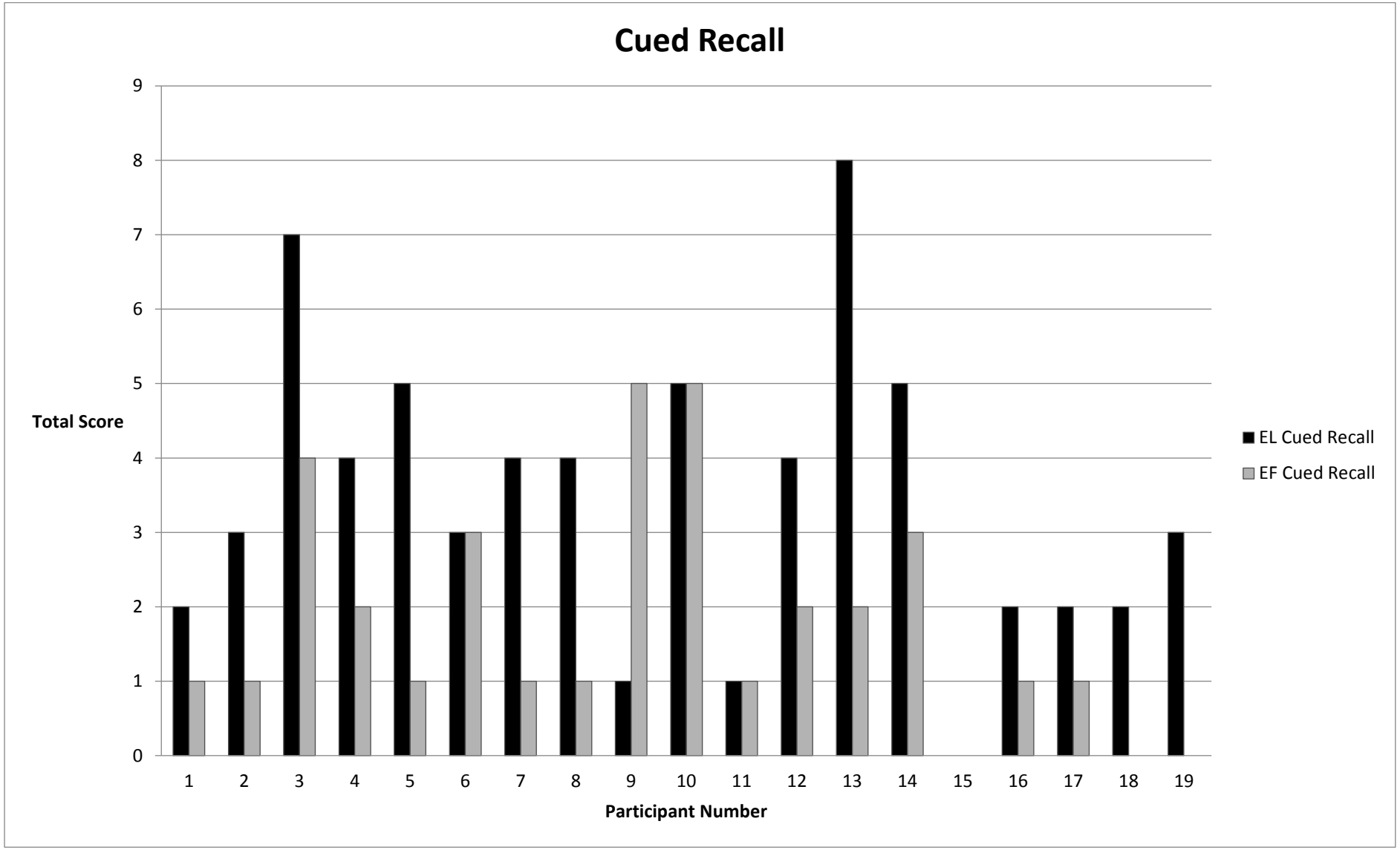

Figure 3. Individual scores for EL and EF learning conditions-recognition.