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A Comparison of Automatic and Intentional Instructions when Using the Method of Vanishing Cues in Acquired Brain Injury

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Abstract

Thirty-four participants with acquired brain injury learned word lists under two forms of Vanishing Cues – one in which the learning trial instructions encouraged intentional retrieval (i.e. explicit memory) and one in which they encouraged automatic retrieval (which encompasses implicit memory). The automatic instructions represented a novel approach in which the cooperation of participants was actively sought to avoid intentional retrieval. Intentional instructions resulted in fewer errors during the learning trials and better performance on immediate and delayed retrieval tests. The advantage of intentional over automatic instructions was generally less for those who had more severe memory and/or executive impairments. Most participants performed better under intentional instructions on both the immediate and the delayed tests. Although those who were more severely impaired in both memory and executive function also did better with intentional instructions on the immediate retrieval test, they were significantly more likely to show an advantage for automatic instructions on the delayed test. It is suggested that this pattern of results may reflect impairments in the consolidation of intentional memories in this group. When using vanishing cues, automatic instructions may be better for those with severe consolidation impairments, but otherwise intentional instructions may be better.

Key words

Cognitive rehabilitation, method of vanishing cues, implicit memory, explicit memory, acquired brain injury

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Introduction

Much of the research into teaching methods for those with acquired memory impairments has focused on the avoidance of learning trial errors and the errorless learning procedure. This focus has been at the expense of other factors that can also enhance learning (such as effortful processing) and there is increasing recognition of the need to ensure that teaching procedures also promote these other factors (Clare & Jones, 2008; Middleton & Schwartz, 2012). As a result, there has been renewed interest in teaching procedures that involve more effortful processing, particularly those that involve retrieval practice, such as the method of vanishing cues (VC) and spaced retrieval (Middleton & Schwarz, 2012). The effectiveness of VC has been questioned at times. Kessels and de Haan (2003) reported a meta-analysis of errorless learning and VC, and found that, whereas errorless learning had a large and significant effect size, VC had a small non-significant effect. However, the result for VC was based on only three studies and 24 participants in total. Moreover, these three studies included comparisons using a form of VC in which the first trial begins with a minimal prompt and additional prompts are gradually added until the learner gives the correct response. This procedure can lead to many errors and a modified version is now more commonly used in which the first trial provides the full response, thereby reducing error rates (Hunkin & Parkin, 1995; Bier et al., 2008). Haslam, Moss and Hodder (2010) reported that this modified version (labelled the ‘combined’ method in their study) was more effective than the original version, and was of equivalent effectiveness to errorless learning. Other studies using this modified version have also reported that it can be as effective as errorless learning (Bier et al., 2008; Dunn & Clare, 2007) or even more effective (Laffan, Metzler-Baddeley, Walker, & Jones, 2010 (labelled ‘self-generated EL’ in the study); Riley, Sotirou, & Jaspal, 2004).

Another variation in the delivery of VC relates to the instructions used on the learning trials. In some applications, the instructions make clear reference to previous presentations of the material and encourage the learner to try to remember that material (e.g. Glisky, Schacter, & Tulving, 1986; Riley, Sotiriou, & Jaspal, 2004), whilst in other applications participants are encouraged to give the first answer that comes to mind, even if it seems like a guess, and no reference is made to the previous learning trials (e.g. Bier et al., 2008).

Automatic vs. intentional instructions. The difference between these instructions has usually been described using the terminology of implicit and explicit memory (e.g. Bier et al., 2008; Page, Wilson, Shiel, Carter, & Norris, 2006). Explicit memory refers to the intentional recollection of information; whereas implicit memory has been defined in terms of the influence of past experience in the absence of any intention to recall that experience and of any conscious recollection of this past experience (Schacter, Chiu, & Osner, 1993). So the instructions used by Riley et al. (2004) would be classified as explicit because they encourage the intentional recall of the information, whereas those used by Bier et al. (2008) would be classified as implicit because they aim to elicit the information in the absence of any intention to retrieve it and any awareness of recollecting information from previous trials.

A problem with the instructions used by Bier et al. (2008) is that they may not be a particularly effective way of ensuring that the individual uses implicit memory. Within the research on priming effects, the problem of ‘explicit contamination’ when using instructions of this type is well documented (Jacoby, 1991; McKone & Slee, 1997; Schacter, Bowers, & Booker, 1989). If the instructions simply make no reference to the fact that memory is being tested, it is possible that some learners may realise that their answers correspond to the material previously presented, suspect their memory is being tested, and then use their explicit memory to aid performance. Within the context of using VC, this type of instruction may be effective in ensuring the use of implicit memory when the participants have severe amnesia, but otherwise may result in participants using their explicit memory.

An approach to developing an alternative to explicit instructions is suggested by Jacoby's distinction between automatic and intentional memory. Jacoby (1991) argued that the dissociations that gave rise to the distinction between explicit and implicit memory are best considered within a broader process-oriented framework that distinguishes between controlled and automatic processes. Automatic processes are those that occur passively; may, or may not, be accompanied by conscious awareness; and do not require intention, effort or make demands on the limited capacity central processor that controls mental processing. Controlled processes, by contrast, do depend on this processor, and are associated with intention and effort. Jacoby used the term "intentional memory" to refer to controlled memory processes, and this is equivalent to explicit memory. By contrast, automatic memory covers both the traditional conceptualization of implicit memory (no intention to retrieve and no awareness of having retrieved) and memory in which there is no intention to retrieve, but the person is aware that the material has been retrieved from memory (cf. Roediger, Weldon, & Challis, 1989). The latter type of memory (sometimes referred to as "involuntary") is often triggered by environmental cues, and includes both episodic autobiographical memories (Berntsen, 2010) and semantic memories ("mind-popping" – Mandler, 1994). Jacoby's intentional-automatic distinction has subsequently been applied to the study of age-related memory decline (Jennings & Jacoby, 1997; Jennings & Jacoby, 2003).

Within the process-oriented approach, processes, rather than structures or products, are considered the key determinants of memory performance (Jacoby, 1991; Roediger et al., 1989). Applying this to the present context, what is important is not whether the person is aware that they are remembering information from a previous experience, but whether or not they are making intentional efforts to remember. From this perspective, the important distinction to make between different kinds of VC instructions is whether the learner intentionally tries to remember the material. It is less important whether or not they are aware that their response involves recollection from a previous learning trial. This emphasis on intentionality as the key determinant of performance suggests an alternative to the type of instructions used by Bier et al. (2008). The current study used “automatic” instructions that focused on avoiding the intention to retrieve, regardless of whether or not the participant was aware that their response corresponded to material presented on previous learning trials. Specifically, the participants were made aware that the cues on the learning trial were intended to assist them in remembering previously presented words, but were told to avoid making any intentional effort to try to recall those words and to say the first thing that came to mind. In addition, they were instructed to try to relax and clear their minds – because research on involuntary memories suggests that they are more likely to occur when the central processing unit that guides mental processing is less active (Berntsen, 1998; Berntsen & Jacobsen, 2008; Kvavilashvili & Mandler, 2004; Mandler, 1994). Gaining the participant’s collaboration in using the method of retrieval (albeit different to the one which they are used to) may prove a more effective way of ensuring the use of automatic retrieval processes (which encompass both involuntary and implicit memories) than one which aims to facilitate implicit memory by simply not mentioning that memory is being tested and hoping that the learner does not notice this.

The relative effectiveness of automatic and intentional instructions. In the original rationale for VC (Glisky, 1992; Glisky, Schacter, & Butters, 1994; Glisky, Schacter, & Tulving, 1986), it was noted that, despite severe deficits in explicit memory, people with amnesia respond at normal levels to word-stem cues in priming studies that require the participant to say the first word that comes to mind rather than trying to remember the word; and that this often occurs despite the lack of any explicit recollection of having seen the word previously (e.g. Graf, Squire, & Mandler, 1984). This indicates an intact implicit priming system. It was suggested that repeated priming using these kinds of cues (as in VC) might enable a more durable form of learning to be established that can be accessed in the absence of the cues. The aim of VC is therefore to facilitate initial reliance on this implicit priming system. A clear implication of this is that implicit (automatic) instructions are preferable so that learning occurs by means of this intact priming system, rather than the damaged explicit (intentional) system.

A number of objections can be raised against this argument. First, although it may apply to people with more severe intentional memory deficits, its validity is less clear in relation to those with moderate problems who retain some degree of intentional memory abilities. It may be that, for such individuals, a reliance on automatic memory may not lead to better learning than reliance on a damaged, but nevertheless still functioning, intentional system. Second, it assumes that the operations of intentional and automatic memory are mutually exclusive; specifically, that an act of intentional memory cannot involve the operation of automatic memory. This is an assumption that has been challenged. Jacoby (1991) put forward a model that proposes that automatic processes are always involved in any act of memory; that intentional processes are sometimes involved; and that the effects of these two processes on any particular act of memory are additive and not interactive. The implication of this model for using VC is that intentional instructions will always be preferable – because automatic memory will be operating anyway, and encouraging intentional processes will cue any additive contribution that intentional memory can make. Consequently, intentional instructions will be more effective when intentional memory does make a contribution, and just as effective as automatic instructions when intentional memory does not make a contribution. Put another way, there will be no circumstances in which automatic instructions will be more effective.

How, and in what circumstances, might intentional instructions boost performance? The aim of the present study was to test the hypothesis that intentional instructions are sometimes more effective, and always at least as effective, as automatic instructions. It also aimed to investigate the mechanisms whereby they might be more effective, and the circumstances that might enhance their effectiveness relative to automatic instructions.

There are a number of mechanisms whereby intentional instructions might boost performance. The first concerns the negative impact that errors made during the learning trials may have on memory. It has been noted that a significant number of errors can occur during learning trials using VC (Middleton & Schwartz, 2012). These are potentially problematic because errors may be learnt alongside the correct response and interfere with the learning of the correct response. Baddeley and Wilson (1994) argued that error detection and elimination are dependent on explicit (intentional) memory. Intentional instructions thus have the potential to reduce errors on VC learning trials more effectively than automatic instructions because they cue the learner to use their intentional memory to check whether they are giving the correct response – whereas the automatic instructions (as well as the implicit instructions used by Bier et al., 2008) require the learner to say whatever comes into their head without checking its accuracy.

Another potential contribution of intentional instructions is that they may encourage the learner to encode the material in a way that increases the probability of its retrieval. Intentional instructions (which emphasize the need to learn the material) may cue the person to use their own mnemonic strategies (e.g. visual imagery or categorizing the information in a memorable way) whereas automatic instructions (which tell the person not to try to remember the material) do not; and the use of such strategies may enhance the probability of subsequent retrieval. The elaborateness and distinctiveness of the encodings are also features that enhance subsequent retrieval (Jacoby & Craik, 1979). It has been suggested that requiring effortful retrieval of the information on the learning trials encourages more elaborate and distinctive encoding (Middleton & Schwartz, 2012; Riley & Heaton, 2000; Riley, Sotiriou, & Jaspal, 2004). Intentional instructions, with their emphasis on trying to remember the material, may serve to cue such effortful retrieval. By contrast, automatic instructions ("say the first word that comes into your head") presumably elicit less effort, and less elaborate encoding.

These additional contributions of intentional memory are likely to be moderated by the abilities of the learner. If error detection and elimination are dependent on intentional memory (Baddeley & Wilson, 1994), then those with less severe intentional memory deficits may be more able to detect and eliminate errors than those with more severe deficits. So we might expect that the advantage for intentional over automatic instructions in terms of reducing learning trial errors will be greater for those with less severe intentional memory impairments. The monitoring, detection and elimination of response errors are also a recognised aspect of executive functioning (Clare & Jones, 2008; Shallice, 1988). Thus, any advantage to intentional instructions in terms of cueing the learner to detect and eliminate errors, may also be less likely to materialize for those with more impaired executive abilities.

Similarly, the benefits of being cued to make an effort to remember the material being learnt, and to use mnemonic strategies, are likely to depend on the intentional memory and executive abilities of the learner. Both mechanisms involve intentional memory, and so those with greater impairments to their intentional memory are clearly going to benefit less from being cued to employ them, relative to those with lesser impairments. The executive system also appears to play an important role in generating and implementing mnemonic strategies. For example, Cannellopoulou and Richardson (1998) found an association between the level of executive impairment and the degree of benefit derived from the use of an imagery mnemonic. Those with more severe executive dysfunction may be less likely to generate mnemonic strategies and less likely to implement them effectively.

The present study. In summary, the implication of Jacoby's additive model of intentional and automatic memory is that intentional instructions will produce performance that is better than, or at least as good as, automatic instructions. It has been argued that the benefits of intentional instructions will occur by means of reducing the number of training trial errors, and eliciting more elaborate encoding and the use of mnemonic strategies; and that the advantage of intentional over automatic instructions is likely to be greater for those with less impaired memory and executive abilities.

The present study tested these predictions. A sample of 34 people with acquired brain injury, and a range of memory and executive impairments, learnt word lists using VC, and their memory for the words was subsequently tested on a number of retention tests. Each participant learnt one set of words under intentional instructions and another under automatic instructions. Assuming Jacoby's additive model, the following hypotheses were tested:

- Compared to automatic instructions, intentional instructions will lead to a lower rate of errors on the learning trials; but this advantage will be less for those with more severe memory and executive impairments.
- Compared to automatic instructions, intentional instructions will lead to better performance on the retention tests; but this advantage will be less for those with more severe memory and executive impairments.

- There will be no circumstances in which automatic instructions lead to better retention test performance.

Method

Participants. Participants were recruited via Headway, a non-governmental organization that provides services for adults in the community with acquired brain injury. Participants were required to be between 18 and 65 years; to be capable of giving informed consent; and to have sustained their brain injury at least 12 months prior to the study. Those with severe language impairments (as judged by Headway staff) were excluded from the study. English was the first language for all participants.

Forty-two participants were recruited, 34 of whom were included in the analysis. Of the eight not included, two were excluded because they stated that they had used intentional memory strategies during the automatic teaching condition (see below), and the remaining six were not able to attend all three sessions for various reasons and thus did not provide full data sets. Demographic details of the 34 participants who did provide a full data set are contained in Table 1.

[Table 1 about here]

Materials. Participants learnt two word lists using VC. Each list contained 10 five-letter words. The words were selected from a list used in a study by Jacoby (1998) which provides information about a range of factors likely to influence the ease with which words can be learnt using word-stems (specifically, the frequency with which the targeted word was given by participants in response to word stems without any prior exposure, word frequency in common usage, and the number of alternative words that participants gave in response to the word-stem). To try to match the two lists in terms of ease of learning, words were selected so that the mean value of the two lists in respect of these factors was approximately equivalent. Words were also selected to ensure wide variability on these factors within each list to try to ensure that each list contained words that varied significantly in terms of how easy they were to learn. All 20 words started with a different letter to minimise the opportunity for confusion between items.

For each word, a set of five cue cards was constructed. The first card contained the whole word (e.g. BLACK), whilst the subsequent cards contained one or more letters followed by a number of dashes to indicate the missing letters (e.g. BLAC_, BLA_ _, BL_ _ _, B_ _ _ _). The cue card with three letters missing was also used for the cued recall retention tests.

To assess the degree of memory impairment, the Word Lists subtest of the Wechsler Memory Scale - Third Edition (Wechsler, 1997) was used. This test involves four successive learning trials of a list of 12 words and was chosen because of its close resemblance to the experimental task. Raw scores from this test were used in the analysis to categorise participants into a high- and a low-memory group. As a measure of executive functioning, participants completed the Tower Test of the Delis Kaplan Executive Functioning System (Delis, Kaplan, & Kramer, 2001). The raw total achievement score was used in the analysis to categorise participants into a high- and a low-executive group. This test was chosen because it purports to assess a fairly broad range of executive functions and because many people find it a reasonably enjoyable task to complete. The Wechsler Test of Adult Reading (Wechsler, 2001) was used to provide a measure of pre-morbid cognitive functioning. The neuropsychological assessment was kept brief to avoid making excessive demands on participants' time. Scores on the tests are summarised in Table 1. All participants bar two scored below the mean for their age group on the Word Lists subtest. Performance on the Tower Test was generally higher, with 41% obtaining a score at or above the mean for their age group. It was decided not to administer the Wechsler reading test to three participants who stated that they had reading difficulties. The relatively low mean for the estimate of pre-morbid IQ (90) should be noted.

At the end of each series of learning trials, participants were administered a brief questionnaire that asked about how they had retrieved the words on the learning trials. The purpose of this was to monitor whether participants were following the instructions. Two participants reported that they had used intentional strategies during the automatic learning trials, and so their results were excluded from the analysis.

General procedure. The general procedure is summarised in Table 2. Participants took part in three sessions, each one separated by a week. Each participant learnt two words lists (A and B) using VC. One list was learnt under intentional instructions and the other under automatic instructions. One list was learnt in the first session and the other was learnt in the second session. The pairing of word list with instructions, and the order of the instructions, were counterbalanced across the four possible combinations to minimise possible order and list effects (see Table 2).

[Table 2 about here]

Memory for the lists was tested using four retention tests – an immediate free recall, an immediate cued recall test, a delayed free recall and a delayed cued recall test. It was difficult to predict beforehand the extent to which results would be affected by floor and ceiling effects. The inclusion of a range of retention tests was intended to ensure that there would be at least one test relatively unaffected by such effects. Having free and cued recall, and immediate and delayed tests, also provided the opportunity for a more thorough investigation of the differential effects of automatic and intentional instructions. For example, in some previous studies, different teaching procedures have had different effects in the immediate term, but these differences have not been sustained over time (e.g. Bier et al., 2008).

Learning trials in automatic condition. As noted earlier, in some previous studies in which implicit instructions have been used, participants have been told to give the first answer that comes to mind, and no reference is made to the previous learning trials (e.g. Bier et al., 2008). The present study took a different approach. In the automatic instruction condition, the participants were told immediately before the first block of learning trials that they were required to learn a list of words, and that the aim of the study was to see how well they could learn the words using a novel method that would involve them staying relaxed and not trying to remember the words. To illustrate the memory process they were being encouraged to emulate, they were given the example of seeing someone, trying to remember their name and failing, and then the name coming to them later when they were not even trying to remember it. Once they had received this information, participants were asked to summarize the nature of the task to ensure it had been understood. The information was repeated if the participant did not give a satisfactory answer.

Participants were then given six blocks of learning trials, each block involving one trial for each word of the list that was being learnt. In the first block, the participant was shown the complete words one at a time, each word being presented on its own card for five seconds. They were asked to read out each word to make sure they were paying attention. On the second block of trials, the cue cards on which the final letter had been removed (e.g. PLAT_) were presented. If the participant gave the correct answer, then, on the subsequent trial, the cue card had one less letter (e.g. PLA_ _) than the cue card presented on the previous trial. If the participant gave no response or an incorrect response on the previous trial, the cue card gave one more letter than the cue card used on the previous trial. This process continued for the remaining blocks. If no errors were made on a particular word, then trials five and six involved the card with a one-letter cue only (e.g. P _ _ _ _).

For blocks 2-6, the following instructions were used at the beginning of each block: “Now I’m now going to show you the same words but with some letters missing. The number of letters missing is indicated by the number of dashes after the letters. Please add the appropriate number of letters to make a complete word. As I show them to you, clear your mind and stay as relaxed as you can. And just say the first word that comes into your head when I show you the card. Don’t try to remember what you saw before or what words were on the list. Don’t make any effort. Just say the first thing that comes into your head. If nothing comes into your head, just tell me and we’ll move on to the next word. Remember, it’s most important to follow my instructions not to try to remember the word but to see if it comes to you without trying”.

If the correct word was given on a learning trial, the participant was told that it was a word they had seen before. If the participant gave an incorrect word, they were told “that word was not one that I showed you; the word I showed you was [relevant word].” If they failed to give a response within 10 seconds, they were told ‘the word I showed you was [relevant word].”

Retention tests in automatic condition. Performance on a retention test depends on the degree of overlap between the processes performed during encoding and those performed during the retention test (Bransford, Franks, Morris, & Stein, 1979; Tulving & Thomson, 1973). There is evidence that this principle of ‘transfer appropriate processing’ plays an important role in the context of the application of errorless learning and VC (Guild & Anderson, 2012; Riley et al., 2004). For those words learnt under the automatic instructions, it was therefore decided to use instructions for the retention test that matched those used on the learning trials in an attempt to maximize the overlap. Thus, the retention test instructions also encouraged the use of automatic memory. This eliminated the possibility that any differences in performance between the automatic and intentional conditions were due to a mismatch between learning trial and retention test processing. The instructions for the immediate free recall task in the automatic condition were as follows: "Now we're going to spend some time to see if any of the ten words shown to you at the beginning of the session come back to you. Once again, don't try hard to remember the words, just stay relaxed and see if any come into your mind. Remember, it's most important to follow my instructions not to try hard to remember the word but to see if it comes to you without trying. I'm going to give you 90 seconds, and remember stay as relaxed as you can." The instructions for the delayed free recall test in the automatic condition were the same, with appropriate changes being made to the time frame reference. The immediate cued recall and delayed cued recall tests used similar instructions, but involved presenting the participant with the cue cards which provided the first two letters (e.g. PL _ _ _) and asking them to say what word came to mind.

Participants were not given immediate feedback about whether their responses were correct on the retention tests. However, once both the cued and free recall tests within a session were completed, the cards with the complete words were shown and read out to the participant one at a time.

Learning trials in intentional condition. The instructions given at the beginning of the intentional learning blocks were as follows:

"I am going to show you some words one at a time. Please try and remember each word. If you have ways of trying to remember things that work for you, please try to use these to remember the words. For example some people find it helpful to repeat the word over and over to themselves; others imagine a picture related to the word, but you should do whatever works best for you. I'll just give you a few seconds to think about how you want to learn the words ... Do you have any questions about what you're being asked?" Once they had received the information, participants were asked to summarize the nature of the task to ensure it had been understood. The information was repeated if the participant did not give a satisfactory answer.

The procedure for the intentional learning trials was the same as for the automatic learning trials, with two exceptions. First, the following instructions were used prior to learning blocks 2-6: "Now I'm now going to show you the same words again but with some letters missing. Please think back to the list you learned before and try to remember what the word is, using any ways of trying to remember that work for you. Please try as hard as you can to remember the word". Second, if the correct word was given on a learning trial, the participant was told that it was 'correct'. If the participant gave an incorrect word, they were told "no, that's wrong; the correct word is [relevant word]." If they failed to give a response within 10 seconds, they were told 'the correct word is [relevant word]."

Retention tests in intentional condition. Instructions for the immediate free and immediate cued recall tests for words learnt under intentional instructions referred back to the list learnt earlier and encouraged the participant to try as hard as they could to remember the words, using whatever way of remembering that worked best for them. Instructions for the delayed intentional retention tests were the same, with appropriate changes being made to the time frame reference.

Pilot study. Because the automatic instructions used in this study are a novel form of teaching, it is unclear how effective they are as a means of encouraging automatic memory (i.e. implicit and involuntary memory). To obtain some preliminary evidence relating to this, a pilot study was conducted (Finlayson, 2010). The automatic instructions used in the present study were compared with a standard form of errorless learning in which participants were presented with the whole word on each learning trial and asked to read the word out loud. These errorless learning instructions similarly aspire to encourage the use of implicit memory (Baddeley & Wilson, 1994; Clare & Jones, 2008). The design of the pilot study was otherwise identical to the design of the present study. Seven participants took part. Although the results were not statistically significant, mean performance under the automatic instructions was higher than under the errorless learning instructions for both immediate free recall (3.57 vs. 3.00) and delayed cued recall (4.00 vs. 3.00).

Results

Preparation of the data. Data for the immediate cued recall test showed a severe ceiling effect (i.e. many participants obtained maximum scores) and data for the delayed free recall test showed a severe floor effect (i.e. many scored zero). These data were therefore excluded and analysis focused on the immediate free recall and delayed cued tests.

Analysis involved the use of repeated-measures ANCOVA. Included data were therefore checked for outliers and to ensure that the distributions were suitable for parametric analysis. Although there was a high scorer on the Word Lists subtest, this did not present a difficulty because raw scores were not entered into the analysis and were only used as the basis for categorizing the participants into high- and low-memory groups. All distributions were reasonable approximations of the normal distribution, and all ANCOVA analyses met the assumptions of sphericity and homogeneity of variance.

For the purpose of the analyses relating to the first two hypotheses, participants were divided equally into high- and low-memory groups and high- and low-executive groups on the basis of their raw scores on the Word Lists subtest and the Tower Test respectively[1]. For additional analyses, participants were further divided into executive-memory groups: Those who were in both the high-executive and high-memory groups (N=10); those in the high-executive and low-memory groups (N=7); those in the low executive and high-memory groups (N=6); and those in the low-executive and low-memory groups (N=11) (see Table 1). Because of the small numbers involved in the second and third groups, these were combined into one group for the analysis (N=13).

Hypothesis 1. *(a) Compared to automatic instructions, intentional instructions will lead to a lower rate of errors on the learning trials; but this advantage will be less for (b) those with more severe memory impairments and (c) those with more severe executive impairments.* In the initial ANCOVA to test this hypothesis, the dependent variable was the total number of learning trial errors made by each participant; the within-groups variable was instructional condition (intentional vs. automatic); and the between-groups variables were memory group (high vs. low) and executive group (high vs. low). The list-instruction combination (Table 2) was entered as a covariate because there was evidence that this variable had an effect on performance (e.g. mean performance on the list learnt first was better than on the list learnt second) and because the counterbalancing was incomplete due to the exclusion of several participants. Hypothesis 1a was tested by the main effect of instruction type, and hypotheses 1b and 1c were tested by the interaction terms of instruction-x-memory group and instruction-x-executive group respectively.

Hypothesis 1a was supported. Participants made a significantly greater number of errors on the automatic learning trials; mean for automatic=6.15, mean for intentional=4.09; $F(1, 29) = 9.49$, $p<.01$. Hypotheses 1b and 1c were not supported by the analysis. There was no significant interaction between instruction type and either memory group, $F(1, 29) = 0.36$, or executive group, $F(1, 29) = 0.97$. However, closer inspection of the data generated by the three executive-memory groups indicated that those in the high-memory-high executive group made very few mistakes in the automatic (mean=2.8) and the intentional (mean=0.9) conditions, and the scope for them to show a significant advantage for intentional instructions was therefore limited. Accordingly, an ANCOVA was run that excluded the 10 participants in this group. It compared those in the low-executive-low-memory group (N=11) with those who fell either into the high-executive-low-memory or the low-executive-high-memory groups (N=13). This analysis provided some support for hypotheses 1b and 1c: There was a significant interaction between instructional condition and group membership, $F(1, 21) = 4.85$, $p<.05$. Those in the low-executive-low-memory group showed little difference in error rate between the two conditions (automatic mean = 6.9; intentional mean = 6.4), but those in the other group showed a large advantage for the intentional condition (automatic mean = 8.1; intentional mean = 4.6) (see Figure 1).

[Figure 1 about here]

Hypothesis 2. *(a) Compared to automatic instructions, intentional instructions will lead to better performance on the retention tests; but this advantage will be less for (b) those with more severe memory impairments and (c) those more severe executive impairments.* In the ANCOVA to test these hypotheses, the dependent variable was the total number of words correctly recalled by each participant; the within-groups variable was instructional condition (intentional vs. automatic); and the between-groups variables were memory group (high vs. low) and executive group (high vs. low). List-instruction combination and the total number of learning trial errors (across both instructional conditions) were entered as covariates. The reason for including error rate as a covariate was that, as noted earlier, the intentional condition was associated with fewer errors, and, given that errors may interfere with performance, an advantage for the intentional condition in terms of retention test performance could occur because of this reduced error rate. Of more interest was the question whether, with the level of errors controlled, the intentional condition still resulted in better test performance. If it did, this would support the idea that this was due to differences in the way in which the word lists were encoded (e.g. the use of mnemonic strategies and/or more elaborate encoding), rather than differences in learning trial error rates. Moreover, those with poorer memories and poorer executive systems tended, unsurprisingly, to make more learning trial errors. Again, controlling for errors in the analysis would allow any interaction effect (i.e. evidence that the test performance of these participants was not boosted by intentional instructions to the same degree as the other participants) to be attributed to differences in encoding processes rather than error rates.

The results of the main ANCOVA for the immediate free recall data are shown in Table 3. The main effect of instruction type was significant, supporting hypothesis 2a (automatic mean = 4.18; intentional mean = 5.44). However, there was no significant interaction between instruction type and either memory group or executive group; and so there was no evidence that the advantage for intentional instructions was dependent on the executive or memory abilities of the participant (hypotheses 2b and 2c).

[Table 3 about here]

Hypotheses 2a, 2b and 2c were all supported by the analysis of the delayed cued recall data (Table 3). Intentional instructions led to significantly better performance than automatic instructions, and this intentional boost was significantly greater for those with better memory and for those with better executive functioning (shown by the significant instruction-x-memory group and instruction-x-executive group interactions).

Hypothesis 3. *There will be no circumstances in which automatic instructions lead to better retention test performance.* To explore the possibility that there are circumstances in which automatic instructions lead to better performance, two ANCOVAs were conducted with instruction type as the within-groups variable, the three executive-memory groups as the between-groups variable, and total errors and list-instruction combination as the covariates. In one analysis, the dependent variable was the number of words correctly recalled on the immediate free recall test, and in the second analysis it was the number correctly recalled on the delayed cued recall test. The scores predicted by these models (i.e. scores adjusted to remove the effects of the covariates) were then used in a series of paired-samples t-tests comparing the performance under each instruction condition for each of the three memory-executive groups. The means and the t-tests are shown in Table 4 and Figure 2. The intentional mean was significantly higher than the automatic mean in all comparisons except in the case of the low-executive-low-memory group. Although they scored significantly better under intentional instructions on the immediate free recall test, on the delayed test their mean score was higher under automatic instructions, though not significantly so.

[Figure 2 about here]

[Table 4 about here]

To explore further this result for the low-executive -low-memory group on the delayed test, a second analysis was conducted that focused on the number of participants in each group who showed an advantage for automatic instructions on the delayed test. Six out of 11 (55%) in the low-executive-low-memory group obtained higher scores on the delayed cued recall test in the automatic condition (with 3 (27%) showing no difference and 2 (18%) showing an advantage for the intentional condition), whereas only 5 out of 23 (22%) in the other two groups showed an advantage for the automatic condition (with 2 (8%) showing no difference and16 (70%) showing an advantage for the intentional condition). A chi-square test on these frequencies indicated a significant interaction between group membership and which instructional condition showed an advantage (chi-square (2*df*) = 7.93; p =.019): Those in the low-executive-low-memory group were significantly more likely to show an advantage for the automatic instructions on the delayed test. This result suggests there are circumstances in which automatic instructions lead to better performance, and is therefore inconsistent with the hypothesis.

Discussion

The results were broadly supportive of the first two hypotheses. As predicted, intentional instructions led to a lower rate of errors on the learning trials and better performance on both the immediate free recall and delayed cued recall tests. When those in the low-memory-low-executive group were compared with the rest of the sample (excluding those in the high-memory-high-executive group), the advantage for intentional instructions in terms of error rate reduction was significantly greater for the rest of the sample. The advantage for intentional instructions in terms of retention test performance was significantly greater for the group with less impaired memories and the group with less impaired executive abilities on the delayed cued recall test, but not on the immediate free recall test. The fact that intentional instructions led to these increments in test performance when the number of learning trial errors was entered as a covariate suggests an explanation of their superiority in terms of promoting the quality of encoding, rather than decreasing errors. Specifically, it supported the idea that intentional instructions led to better learning because they were more effective in ensuring more elaborate encoding and more effective use of other mnemonic coding strategies, at least for those with less impaired memory and executive systems.

Jacoby's additive model of automatic and intentional memory processes (Jacoby, 1991) implies that there will be no circumstances in which automatic instructions will be more effective (the third hypothesis). The results contradicted this hypothesis. Even though they performed better under intentional instructions on the immediate test, a chi-square analysis showed that those in the low-executive-low-memory group were significantly more likely to show an advantage for the automatic instructions on the delayed test.

Delayed advantage for automatic instructions may relate to impairments in the consolidation of intentional memories. Jacoby's additive model has been challenged by others and evidence suggests the two systems may interact (Curran & Hintzman, 1995; Hirshman, 2004). Specifically, there is evidence that the operation of intentional memory may interfere with the operation of automatic memory (Mandler, 1994). For example, Galea, Albert, Ditye and Miall (2010) investigated performance on a serial reaction time task which involves learning a random sequence of button presses. The task engages both automatic and intentional processes: Automatic learning is evidenced by an increase in the speed with which the correct sequence is executed, and intentional learning by the participant correctly stating what the sequence is[2]. Transcranial magnetic stimulation was used to disrupt the functioning of the dorsolateral prefrontal cortex, an area which appears to be involved in the intentional declarative learning of sequences (Murray & Ranganath, 2007). Participants learnt the sequence; their memory for it was tested (in terms of the speed of execution and ability to state what the sequence was); they received the TMS; and then, after an interval of eight hours, their memory was retested. Compared to a control group who received occipital TMS, the group receiving prefrontal TMS showed a greater increase in speed of performance after an interval of eight hours (i.e. better automatic retention), but their ability to state the sequence was worse (i.e. worse intentional retention). Galea et al. suggested that their results were consistent with a 'competition suppression model' in which both intentional and automatic memory compete with each other for brain resources required for the consolidation of specific memories. TMS of the prefrontal area disrupted the intentional memory processes (impairing the ability to state the sequence), but freed up resources for a more effective consolidation of the automatic memory (leading to an increase in speed of performance).

The suggestion that intentional memory processing can interfere with the consolidation of automatic memories may shed some light on results in the current study. The low-executive-low-memory group performed significantly better under intentional instructions on the immediate test, but were more likely to show a benefit from automatic instructions on the delayed test. It may be that intentional instructions led to the enhancement of some process (e.g. more elaborate encoding) which resulted in better intentional memory for the material, but that this benefit was only temporary in this group because of deficits in their consolidation of the intentional component of specific memory traces. However, the process of consolidating these intentional components may also have had the effect of interfering with the consolidation of the automatic components of the memory traces. As a result, the contribution of the automatic components to memory performance following intentional instructions was diminished in comparison to the automatic instructions condition. In the absence of any lasting benefit from the intentional components, this would result in better performance on the delayed test after automatic instructions. Those with fewer problems in the consolidation of intentional memories may obtain more durable benefits from intentional instructions that outweigh any disadvantage resulting from the interfering effects of intentional consolidation on automatic consolidation, and hence they would continue to show an advantage for intentional instructions on the delayed test.

If the problem lies in the consolidation of intentional memories, why did only those showing more severe deficits in both memory and executive function showed this pattern of results (i.e. more benefit from intentional instructions on immediate test, but more likely to show benefit from automatic instructions on delayed test)? Given that the consolidation of intentional memories involves pre-frontal areas and temporal and sub-cortical areas involved in memory (Insel & Takehara-Nishiuchi, 2013), why did those in the high-executive-low-memory and low-executive-high memory groups not show the same pattern of results? This could be an artefact arising from the use of broad measures of memory and executive functioning that are not sufficiently specific to deficits in the consolidation of intentional memories. Those who performed poorly on both the memory and executive assessments were likely to have sustained more widespread brain damage, and were therefore more likely to have sustained damage to the systems sub-serving the consolidation of intentional memories. The high-executive-low-memory group may have contained a higher number of those whose memory difficulties related to encoding and retrieval difficulties, rather than consolidation difficulties; and those in the low-executive-high-memory group may have contained a higher number of those whose executive difficulties were not associated with the pre-frontal areas sub-serving memory consolidation. Further exploration of these ideas would require use of a measure that is more specific and sensitive to difficulties in the consolidation of intentional memories. The prediction is that people with these consolidation difficulties would be most likely to show more benefit on delayed retrieval from automatic instructions relative to intentional ones.

Limitations of the study. Some limitations of the study need to be considered. The study used a new form of automatic instructions. It was argued that they may have an advantage over the more traditional form of implicit instruction used in VC (making no reference to previous trials and asking the person to say the first word that comes into their head) because, unless the participant has severe amnesia, these instructions may be ineffective in ensuring that the learner uses their automatic memory. However, apart from the pilot study described earlier (Finlayson, 2010), there is no empirical evidence that the automatic instructions used here are an effective means of facilitating automatic memory. Clearly, further investigation is required into their effectiveness.

The retention tests differed across the automatic and intentional conditions: Those in the automatic condition matched the instructions given during the automatic learning trials, and those in the intentional matched the instructions given during the intentional learning trials. It could therefore be argued that the difference in outcome for the two conditions was due to the difference in the retention tests, rather than in the learning trials. However, had the same set of instructions been used for both conditions (e.g. intentional for both), then it could equally have been argued that the difference in retention test performance was due to the fact that, in one condition, the test instructions provided more overlap with the teaching instructions (which, according to the transfer appropriate processing principle (Bransford et al., 1979), would lead to better performance) but in the other there was less overlap (which would lead to worse performance). In any case, if the superiority in test performance in the intentional condition was due to a difference in the retention tests, then, given the close match between the learning trials and the test trials, it would be difficult to argue that the benefit associated with the intentional condition applied to the test trials but not to the learning trials. So even if the difference between automatic and intentional test performance was partly due to differences in the retention test instructions, it would seem likely that it was also partly due to differences in the learning trial instructions.

It is possible that the order of the retention tests (free and then cued, for both immediate and delayed tests) may have influenced the outcome. The data entered into the analysis were from the immediate free recall and delayed cued recall tests. The immediate free recall test would have been unaffected by the immediate cued recall test, since it preceded the latter test. The delayed cued recall test did come after the delayed free recall test, and performance on the former may have been affected by performance on the latter.

However, it is not clear how large the effect would have been. Over 40% of participants failed to recall any item on the delayed free recall test. In any case, the hypotheses were not specific to the type of retention test. If performance on the delayed free recall test benefited delayed cued recall performance, any benefit would be likely to have accrued from the benefit that free recall performance gained from the intentional instructions.

The experimental tasks were not particularly engaging. They were repetitive and involved learning an arbitrary list of words of no practical relevance. This may have contributed to the number of drop-outs from the study, and to the order effects (performance on lists learnt first was better than on lists learnt second). The findings need to be replicated using a more engaging learning task of practical relevance.

Participants were classified into high and low memory and executive groups on the basis of one standardized neuropsychological test of memory and one of executive function. The validity of these classifications is therefore somewhat limited. However, the aim of keeping the neuropsychological assessment to a minimum was to avoid an excessive burden on participants.

A control condition would have been useful to establish the probability of the words used in the study being given, in the absence of any prior learning, in response to the two-letter cues used in the cued recall test. A comparison between performance in this condition and in the two instructional conditions would have given an indication of the size of the learning effect in the delayed cued recall test.

In neither instructional condition was there any strict control over what the participant was actually doing during the learning trial. Although two participants who reported using intentional memory during the automatic trials were excluded, there may have been others retained in the study who did likewise but did not report it. Also, it is not clear whether the intentional instructions were effective in ensuring that participants used any kind of mnemonic strategy or made an effort to retrieve the words.

Implications. The present study has a number of implications for the general direction of research into teaching methods for those with acquire memory impairment. It provides support to those who have called into question the emphasis on errorless learning and the avoidance of errors (Middleton & Schwartz, 2012). Even when the rate of errors was controlled for in the analysis for the second hypothesis, there were differential effects of instruction type and neuropsychological profile which indicated that processes other than the commission of errors were contributing significantly to the effectiveness of memory performance. We need to focus more on what those other processes are, and how they can be facilitated within teaching procedures (Clare & Jones, 2008; Middleton & Schwartz, 2012; Riley & Heaton, 2000). This seems particularly relevant given that the majority of those who receive memory rehabilitation in practical settings are not profoundly amnesic, and retain a significant degree of intentional memory abilities. We need to know how best to make use of these residual abilities.

The present study also highlights the importance of investigating how the neuropsychological impairments of the individual learner impact on the effectiveness of teaching methods. Executive and memory impairments interacted with instruction type in determining the rate of errors and the accuracy of retrieval. This interaction is in line with previous research that has also found that the advantage of techniques which encourage more effortful learning trial processing (such as the intentional instructions in the present study) over techniques that restrict the learner's response options (such as the automatic instructions in the present study) is likely to be greater, the less impaired the memory function of the learner is (Clare & Jones, 2008; Ehlhardt et al., 2008; Kessels, van Loon, & Wester, 2007;

Laffan et al., 2010; Middleton & Schwartz, 2012; Riley & Heaton, 2000); and the less impaired their executive function is (Ehlhardt et al., 2008; Fillingham, Sage, & Lambon-Ralph, 2006). The present study also suggests the need to progress this line of research by developing and testing hypotheses that relate to more specific neuropsychological impairments (such as a deficit in the consolidation of intentional memories), rather than more general ones (executive or memory impairments).

More attention also needs to be given to the nature of the instructions used in teaching. Intentional and automatic instructions led to significantly different outcomes in the present study. More specifically, the present study used a novel form of instructions to encourage the use of automatic memory that focused on eliciting the co-operation of the learner in avoiding the intention to retrieve. This contrasts with the more usual form used in VC in which no reference is made to previous learning trials, the learner is told to say the first word that comes to mind, and it is hoped that they will not use their explicit/intentional memory (e.g. Bier et al., 2008). These two approaches need to be compared directly to determine which is the more effective in encouraging an avoidance of the intention to remember, and which is more effective as a teaching method. If the form of automatic instructions used in the present study proves more effective, this will have implications for the instructions used in other forms of teaching such as errorless learning and spaced retrieval. Some versions of errorless learning instructions offer ample opportunity for the learner to attempt to recall the material being learnt (i.e. to activate intentional memory). If the aim of the procedure is to encourage the use of automatic memory (because, for example, the learner has severe intentional memory impairments), such instructions may be not be particularly effective. For example, in the errorless procedure used by Laffan et al. (2010) to teach face-name associations, the participant was shown a picture of a person and asked to provide the name only if they were certain they knew the correct answer. They then had to lift up a card to reveal the name and read out the name. The gap in time between being shown the photograph and seeing the correct name clearly provided an opportunity to engage intentional memory, and asking them only to provide the name if they were certain positively encouraged them to try to remember the name (i.e. to activate intentional memory). In other applications of errorless learning, the opportunity and motivation for activating intentional memory is less obvious but may still be present. For example, Kessels et al. (2007) taught a route by showing a photograph of the decision point and immediately telling the participant which way to go. Although this offers less opportunity than the procedure used by Laffan et al., it is possible that some participants activated intentional memory by, for example, trying to anticipate the next decision point before the photograph was shown. As pointed out by Clare and Jones (2008), it is very difficult to control what the participant is doing covertly and seemingly errorless procedures may involve numerous covert errors. When the aim is to discourage intentional memory, it may be better, as with the instructions used in the present study, to actively enlist the co-operation of the learner in avoiding efforts to remember.

Other broad implications of the present study include the importance of including an evaluation of the delayed effects of teaching methods. Although the low-executive-low-memory group benefitted more from intentional instructions on the immediate retrieval test, this benefit was temporary and automatic instructions led to better performance on the delayed test. This is consistent with other research that has observed that differential effects of teaching procedures are not always sustained over time (e.g. Bier et al., 2008). The present study also provided evidence that the additive model of automatic and intentional memory (Jacoby, 1991) may not be valid and that the two systems may interact. The additive model underlies the process dissociation approach, a technique used to estimate the relative contribution of automatic and intentional processes to performance. This approach has been applied to a number of topics in the field of errorless learning, such as the issue of whether the advantage of errorless learning lies in explicit or implicit memory (Anderson & Craik, 2006; Kessels et al., 2005). The results of these applications may need to be interpreted with caution.

More specific implications of the present study concern the use of VC. Unless there are more severe memory and executive impairments, intentional instructions appear to be more effective. In cases of more severe impairments, automatic instructions may be preferable. A direct comparison between the automatic instructions used in this study and standard 'implicit' instructions (e.g. Bier et al. 2008) would allow a more definite recommendation about what form these automatic instructions should take. Further research on the role of consolidation impairments may also provide more precise guidance on how to identify those who would benefit more from the use of automatic instructions.

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Footnotes

[1] Age-adjusted scaled scores (derived from the test manuals) were also considered as the basis for categorising the participants into the executive and memory groups. All participants were classified in the same way whether using raw Tower Test scores or age-adjusted ones, and three participants were differently classified using raw Word List scores compared to age-adjusted ones. When the high-low memory classifications using the age-adjusted scores were used in the analyses instead of those based on the raw scores, there were negligible differences in terms of the outcome of the analysis and the overall pattern of significant/non-significant results was the same.

[2] Galea et al. (2010) used the concepts of procedural and declarative memory, rather than automatic and intentional memory. However, within a process-oriented approach (Jacoby, 1991), the emphasis is on process rather than content, and the procedural/declarative distinction is subsumed under the broader automatic/ intentional framework.

Table 1: Demographic details and neuropsychological test results

Age: M=50 SD=10	Gender: M=80% F=20%	Cause of Injury: TBI=56% Stroke=26% Other=18%	Years Since Injury: M=17 SD=16	Wechsler Word Lists Raw /Scaled Scaled: M=5 SD=3	Tower Test Raw /Scaled Scaled: M=8 SD=3	WTAR IQ M=90.3 SD= 16.7	Executive-memory group
61	M	TBI	45	23 / 6	7 / 4	96	LELM
61	M	TBI	38	16 / 3	10 / 6	101	LELM
36	M	TBI	3	20 / 4	13 / 7	90	LELM
43	M	TBI	22	24 / 5	18 / 11	51	HEHM
40	M	TBI	10	14 / 2	20 / 12	85	HELM
63	M	TBI	48	15 / 3	8 / 5	50	LELM
37	M	other	10	27 / 6	13 / 7	66	LEHM
58	M	TBI	6	28 / 9	19 / 12	104	HEHM
37	M	TBI	17	26 / 6	17 / 10	99	HEHM
56	M	stroke	9	22 / 5	19 / 12	89	HELM
50	M	TBI	47	29 / 8	10 / 6	-	LEHM
64	F	TBI	11	9 / 1	7 / 4	80	LELM
63	F	TBI	8	39 / 15	13 / 8	106	LEHM
53	M	other	11	25 / 6	10 / 6	-	LEHM
52	M	stroke	2	26 / 7	7 / 4	103	LEHM
45	F	TBI	29	7 / 1	16 / 10	74	HELM
42	M	TBI	3	25 / 6	22 / 14	74	HEHM
61	F	TBI	14	28 / 9	17 / 11	117	HEHM
48	M	stroke	4	33 / 11	20 / 12	106	HEHM
58	F	stroke	11	27 / 8	11 / 7	78	LEHM
32	M	TBI	11	25 / 6	16 / 9	104	HEHM
54	M	stroke	7	23 / 5	19 / 12	-	HELM
28	M	other	9	31 / 8	15 / 9	94	HEHM
52	M	TBI	12	2 / 1	9 / 5	76	LELM
36	F	stroke	6	10 / 1	21 / 13	99	HELM
37	M	other	4	31 / 8	17 / 10	108	HEHM
53	F	stroke	16	10 / 1	0 / 1	99	LELM
49	M	stroke	6	26 / 7	20 / 12	101	HEHM
55	M	TBI	35	23 / 6	17 / 11	113	HELM
44	M	other	29	26 / 6	11 / 6	94	LEHM
62	M	other	3	15 / 3	7 / 4	101	LELM
52	M	other	41	13 / 2	7 / 4	96	LELM
53	M	stroke	2	19 / 4	9 / 5	90	LELM
63	M	TBI	10	14 / 2	13 / 8	87	LELM

TBI = traumatic brain injury; other = other type of acquired brain injury

WTAR IQ = Pre-morbid IQ estimated from the Wechsler Test of Adult Reading

Executive-memory groups: HEHM = high-executive-high-memory; LEHM = low-executive-high-memory; HELM = high-executive-low-memory; LELM = low-executive-low-memory

Table 2: Summary of procedure

Session	Sequence of tasks	Allocated list-instructions combinations
Week 1	• Six blocks of learning trials using allocated list-instructions combination • Two-minute non-verbal filler task • Test (immediate free recall) • Two-minute non-verbal filler task • Test (immediate cued recall) • Questionnaire about following instructions	1. List A – intentional 2. List B – intentional 3. List A – automatic 4. List B - automatic
Week 2	• Test for list learnt in previous session (delayed free recall) • Two-minute non-verbal filler task • Test for list learnt in previous session (delayed cued recall) • Two-minute non-verbal filler task • Six blocks of learning trials using allocated list-instructions combination • Two-minute non-verbal filler task • Test for list learnt this session (immediate free recall) • Two-minute non-verbal filler task • Test for list learnt this session (immediate cued recall) • Questionnaire about following instructions	1. List B – automatic 2. List A – automatic 3. List B – intentional 4. List A - intentional
Week 3	• Test for list learnt in previous session (delayed free recall) • Two-minute non-verbal filler task • Test for list learnt in previous session (delayed cued recall) • Wechsler Test of Adult Reading • Tower Test • Wechsler Word Lists	

Table 3: ANCOVA for number of words recalled in immediate free recall and delayed cued recall tests

	Immediate Free Recall			Delayed Cued Recall		
	Means adjusted for covariates	F	p	Means adjusted for covariates	F	p
Main effects						
Instruction type	Automatic =4.19 Intentional= 5.66	11.83	.002	Automatic=4.61 Intentional=5.72	10.52	.003
Memory group	High group=6.61 Low group=3.15	31.94	<.001	High group=6.09 Low group=4.24	10.76	.003
Executive group	High group=4.93 Low group=4.83	0.03	.876	High group=5.87 Low group=4.46	5.50	.026
Interaction effects						
Instruction-x-memory		0.40	.531		6.27	.018
Instruction-x-executive		0.10	.754		5.52	.026

Table 4: Paired samples t-tests comparing performance in the automatic and intentional conditions for each executive-memory groups on the immediate free recall and delayed cued recall tests

	Immediate Free Recall				Delayed Cued Recall			
	Mean for Intentional	Mean for Automatic	t	p	Mean for Intentional	Mean for Automatic	t	p
LELH	3.09	2.27	4.06	.002	2.82	3.36	-1.40	.191
LEHM + HELM	5.92	4.23	7.67	.000	6.15	4.46	4.14	.001
HEHM	7.50	6.20	8.34	.000	7.80	6.00	10.96	.000

LELM = low-executive-low-memory; LEHM = low-executive-high-memory; HELM = high-executive-low-memory; HEHM = high-executive-high-memory

With alpha set at .05 (two-tailed), critical t-value of Bonferroni multiple comparison test for 6 comparisons with 8 degrees of freedom (= lowest df for any of the 6 tests) is 3.48.

Figure captions

Figure 1: Mean number of errors made during learning trials in the automatic and intentional conditions according to memory and executive group

Figure 2: Mean number of words recalled on immediate and delayed recall tests in the automatic and intentional conditions according to executive-memory group