The effects of age, enactment and cue-action relatedness on memory for intentions in the Virtual Week task.

Antonina Pereira[a], Judi A. Ellis[b] and Jayne E. Freeman[b]

a Institute of Molecular Medicine, University of Lisbon

b School of Psychology and Clinical Language Sciences, University of Reading

Abstract

The current study investigated the influence of encoding modality and cue-action relatedness on prospective memory (PM) performance in young and older adults using a modified version of the Virtual Week task. Participants encoded regular and irregular intentions either verbally or by physically performing the action during encoding. For half of the intentions there was a close semantic relation between the retrieval cue and the intended action, while for the remaining intentions the cue and action were semantically unrelated. For irregular tasks, both age groups showed superior PM for related intentions compared to unrelated intentions in both encoding conditions. While older adults retrieved fewer irregular intentions than young adults after verbal encoding, there was no age difference following enactment. Possible mechanisms of enactment and relatedness effects are discussed in the context of current theories of event-based PM.

Introduction

Remembering to perform intended activities (e.g. taking medication or attending an appointment) at an appropriate future occasion is a fundamental requirement for independent living across the lifespan (Kliegel & Martin, 2003). The processes that underpin success or failure of these delayed intentions are typically described as prospective memory (PM; Meacham & Leiman, 1982).

There has been considerable research over the past 20 years into the factors that are likely to improve or hinder prospective memory (PM) performance in laboratory settings (e.g. Ellis & Freeman, 2008). Most studies in this domain have focused on factors relating to the retrieval characteristics of event-based PM tasks (i.e. tasks in which the cue is an event that occurs during an ongoing activity). Generally, the findings arising from this research tend to suggest that intentions are more likely to be remembered when the retrieval cue is distinctive (e.g. McDaniel & Einstein, 1993; Brandimonte & Passolunghi, 1994), when it is closely related to the intended action (e.g. McDaniel, Guynn, Einstein & Breneisser, 2004; Loft & Yeo, 2007) and when it is processed focally as part of an ongoing task (e.g. Einstein et al., 2005; McDaniel, Einstein, & Rendell, 2008).

The influence of these variables on PM is frequently explained by the multiprocess account of retrieval, proposed by McDaniel & Einstein (2000; Einstein & McDaniel, 2005, Einstein & McDaniel, 2010). The central tenet of this account is that different retrieval processes are recruited for different PM tasks. Specifically, the multiprocess account suggests that some task conditions encourage or require the investment of strategic processing resources (e.g. monitoring) prior to the appearance of the cue. This is similar to the proposal of Smith (2003) that successful PM requires the application of preparatory attentional processes before the cue is presented as well as retrospective memory processes after cue presentation to verify the identity of the cue and retrieve the intended action. Einstein and McDaniel argue, however, that under other task conditions successful PM performance can occur in the absence of such preparatory processing, i.e. spontaneously. For example, in cases where there is a strong association between the cue and the intended action, re-processing of the cue during the ongoing task might lead spontaneously to the reflexive-associative retrieval of the action. Alternatively, spontaneous retrieval could occur when the individual detects a discrepancy in the fluency with which the cue is processed (compared to non-cue items), which then prompts a retrieval search to identify the cause of the discrepancy. This discrepancy plus search process is more likely to be engaged when distinctive PM cues are used (see McDaniel & Einstein, 2007).

While most research on PM has investigated retrieval-related factors, there has been some recent interest in the processes operating at the point of intention encoding. There is evidence, for example, that the semantic activation of retrieval cues prior to intention encoding can increase the likelihood that the cues will subsequently elicit a PM response. Mäntylä (1993) found superior PM performance when retrieval cues were drawn from categories that had been used in an earlier semantic fluency task than when they were drawn from non-primed categories (see also Hannon & Daneman, 2007). A number of studies have also highlighted the benefits of forming implementation intentions at encoding for subsequent PM performance (e.g. McDaniel, Howard &

Butler, 2008; McDaniel & Scullin, 2010; Meeks & Marsh, 2010). Generally, the findings suggest that asking participants to encode a precise specification of the action to be performed when a particular situational cue is encountered (typically involving a statement in the form of 'If I see x then I will do y') enhances prospective remembering compared to traditional encoding conditions (e.g. where participants simply read the PM instructions). One possible explanation for the benefit of implementation intentions is that they strengthen the association between the cue and the intended action thus allowing spontaneous retrieval of action when the cue is encountered (McDaniel & Scullin, 2010; but see Meeks & Marsh, 2010, for an alternative explanation).

One variable that has received little attention in the context of prospective memory is that of encoding modality (i.e. whether an intention is encoded verbally or motorically through enactment). There is considerable evidence from the retrospective memory literature that recall and recognition are superior for material performed during encoding than for verbally encoded items (i.e. the subject-performed task effect; e.g. Cohen, 1989). Moreover, there is some indication that the benefit of enactment is preserved (e.g. Knopf & Neidhardt, 1989; Nilsson & Craik, 1990; Mangels & Heinberg, 2006; Feyereisen, 2009) or even enhanced (e.g. Nyberg, Nilsson, & Bäckman, 1992; Bäckman, 1985) in older adults. One theoretical view is that enactment facilitates the episodic integration of the action and other information relevant to that action (e.g. Mangels & Heinberg, 2006; Kormi-Nouri, 1995). That is, enactment enhances the integration of different components of the encoding episode to form a distinctive and unitised memory representation. To the extent that enactment heightens integration of the individual elements in an event then this might also serve to enhance the associative encoding of the cue and the action in a PM task. In other words, physical (symbolic) enactment of an intention during encoding (e.g. check oil level next time you go to your car) might strengthen the link between the action (check oil) and retrieval cue (car) thus allowing a reliance on spontaneous (reflexive-associative) retrieval processes and removing the need for preparatory attentional processing.

One interesting question in this regard is whether any effect of enactment during encoding on PM performance is independent of the benefit observed for cue-action pairs which are semantically related as opposed to unrelated. McDaniel et al (2004) for example, have demonstrated that PM is superior when there is a pre-existing relation between the cue and intended action (e.g. write 'needle' when 'thread' appears in the ongoing task) than when the cue and action are unrelated (e.g. write 'pencil' when 'thread' appears). This advantage is assumed to reflect the obligatory reflexive-associative retrieval of the related response word when the cue is presented, which does not occur in the absence of a semantic relation.

If both enactment and semantic relatedness enhance PM performance by strengthening the association between the cue and the action then these manipulations might be expected to have interactive effects. One possibility, for example, is that the benefit of semantic relatedness might be stronger after verbal encoding than when heightened integration has already been provided by enactment. This prediction is consistent with findings that the effect of semantic relatedness on cued recall is greater for pairs that have been verbally encoded than for enacted pairs (e.g. Kormi-Nouri, 1995). The current study will examine whether semantic relatedness has similar benefits for PM performance in the context of both verbal encoding and enactment.

A further aim is to examine whether semantic relatedness and encoding enactment have equivalent effects on PM performance for young and older adults. Age effects in prospective remembering have been studied for a considerable time with substantial discrepancies in research findings (see Kvavilashvili, Kornbrot, Mash, Cockburn & Milne, 2009, for a recent review). Nevertheless there is some agreement that age-related declines, at least in laboratory settings, are more likely to occur under task conditions that increase the demand for strategic processing, such as the use of non-focal retrieval cues (e.g. Henry, MacLeod, Philips & Crawford, 2004; Kliegel, Jäger & Phillips, 2008; McDaniel, Einstein & Rendell, 2008). This is in keeping with the generally held notion that healthy ageing is associated with a decline in the ability to use self-initiated, strategic processing (Craik, 1986). It follows that if both encoding enactment and a strong cue-action relation reduce the need for strategic preparatory processing then these manipulations should be of particular benefit to older adults and might serve to attenuate or even eliminate age-related declines in PM performance.

To our knowledge, only one study has examined the influence of cue-action semantic relatedness on PM in older adults. Cohen, West and Craik (2001) found that intention retrieval improved with an increase in cue-action relatedness (from unrelated to somewhat related to related) for both young and older adults. Moreover, while there was an age difference in performance for unrelated and somewhat related cues, older adults performed at the level of young adults when related cue-action pairs were used. This suggests that a close cue-action relationship is particularly beneficial for older adults as it may allow reflexive-associative retrieval to occur and thus reduce the need for resource demanding retrieval operations. In support of this, McDaniel et al. (2004) observed detrimental effects of divided attention on PM performance in young adults when unrelated cue-action pairs were used but not when the cue and action were closely related. This suggests that the reflexive-associative retrieval speculated to occur under these conditions can proceed with relatively few attentional resources (although reflexive-associative retrieval may not always be entirely automatic, see McDaniel & Einstein, 2010, for discussion of this issue).

In sum, the current experiment examines the influence of encoding modality and cue-action semantic relatedness on PM performance in young and older adults. We address this issue using a modified version of the Virtual Week task, originally devised by Rendell and Craik (2000). In the original task, participants are presented with a board designed to represent a virtual day, with seven circuits of the board representing a virtual week. The board includes time squares displaying the hours between 7 am and 10 pm (i.e. typical waking hours) and event squares. When participants land on or pass over an event square they collect an event card which describes an activity that might plausibly be occurring at that time of day. The card also details three alternative courses of action which the participant is instructed to choose between (e.g. 'You go to University by subway. Do you attend: a lecture, tutorial or meeting?'). As participants play the game they are given various PM tasks which they are required to retrieve either when a particular event occurs in the game (e.g. take photos to a family lunch) or when a particular time square is passed (e.g. meet your friend Michael for coffee at 4pm). These tasks are either of a regular (performed on every virtual day) or irregular (performed only once during the week) nature. The Virtual Week task (and its more recently computerised version) have been used in a number of studies to examine PM performance in older adults and a variety of clinical populations (see Rendell & Henry, 2009, for a review), and to explore the underlying processes (e.g. vigilance and working memory) that might support intention retrieval across different PM tasks (e.g. Rose et al, 2010). We adapted the original version of the task for the current study to include both related and unrelated event-based cue-action pairs.

For our purposes, there are a number of advantages of the Virtual Week task compared to artificial laboratory-based tasks (see note 1). First, the Virtual Week paradigm demonstrates considerably higher levels of reliability than has been reported in traditional lab tasks (e.g. Henry, Rendell, Kliegel & Altgassen, 2007; McDaniel & Einstein, 2007; Aberle, Rendell, Rose, McDaniel & Kliegel, 2010; Rose, Rendell, McDaniel, Aberle, & Kliegel, 2010). This may be attributable to the relatively high number of PM responses required during the Virtual Week. Second, while there has been considerable variation in the age differences observed across traditional lab tasks (Henry et al, 2004), the Virtual Week, in both its original and computerised form, has been shown to be consistently sensitive to the effects of both healthy (e.g. Rendell & Craik, 2000; Aberle, et al., 2010; Rose, et al., 2010) and pathological ageing (e.g. Will et al., 2009; Thompson, Henry, Rendell, Withall, & Brodaty, 2010). Finally, while clearly still a laboratory-based task, the nature and variety of ongoing activities and intentions used (including both regular and irregular tasks) arguably allow the Virtual Week to capture some of the structure and complexity of everyday life.

Method

Participants

Thirty-two young adults aged 18-33 years (M = 20.94, SD = 3.86), and 32 older adults aged 64-84 years (M = 73.09, SD = 4.54) participated in this study. The younger adults were Psychology students at the University of Reading who received course credit for their participation. The older adults were community dwelling members of the School of Psychology and Clinical Language Science's Older Adult Research Panel. They were reimbursed for the cost of travelling to the University, receiving a small remuneration (£5) for their participation. None of the participants had a self-reported history of psychiatric, neurological or alcohol problems, and none of the older adults were considered to have probable dementia on the basis of their Mini-Mental State Examination performance (i.e. a score of 24 or less; Folstein, Folstein, & McHugh, 1975).

Younger adults had spent relatively more years in full-time education than older adults, and this difference was significant; $t(62) = 2.071$, $p.=.044$ (young adult range = 13-19 years of education, M = 15.22, SD = 1.77; older adult range = 8-25 years of education, M = 13.69, SD = 3.79).

Design

A 2 X 2 X 2 mixed factorial design was used, with Age Group (young, older) and Method of Encoding (verbal, enactment) as between-subject factors and Cue-Action Relatedness (related, unrelated) as a within-subject factor. The effect of these variables on the number of PM tasks completed correctly during "The Virtual Week" board game was examined.

Materials

A modified "Virtual Week" board game was created. This consisted of a dice and a plastic token, as well as a piece of coloured laminated 42 x 30 cm cardboard. The board was divided into 96 squares, each representing a 10-minute interval during the typical waking hours of 7 am to 11 pm. Thus one circuit of the board represented a complete day. An iconographic representation of waking up (which consisted of a 1 x 1.3 cm colour image of a person waking up) was located at the start of the board and a similarly-sized colour image of a person sleeping was located at the end. Fifteen clock icons were strategically placed around the board, each displaying the time of day associated with a particular square.

Seventy-seven different event-cards, also made of laminated cardboard, were created. Participants received one event card at the start of each day and picked up an additional 10 event cards as the virtual day unfolded. Each event card described a plausible daily activity with three options related to that activity. As an example, the event card might be "Tuesday Evening" and the activity might be the following: "You were just about to watch your favourite TV show, but you realised that it has been cancelled today. Will you: just watch something else instead, choose a good book to read, or get back to your daily tasks?".

Where appropriate, the event cards also gave instructions for a future activity (an event-based PM task). The range of daily activities and PM tasks was selected with the aim of constituting a virtual week which would not only be sequentially coherent, but also believable and reasonable for different age groups that usually lead quite distinct daily lives.

A total of thirty PM activities were created for this experiment. Six PM tasks were given on each virtual day. Two were ‘regular’ tasks that had to be performed every day, and 4 were ‘irregular’ tasks that would be different for each day. The regular tasks were to have a glass of orange juice with breakfast (related) and take the rubbish out after dinner (unrelated). Two of the irregular tasks were given on the first event card of the virtual day. The other two were described on event cards collected as the participant moved around the board. For half of the regular and irregular PM tasks there was a high semantic relation between the cue-action pair (e.g. call the dentist to book an appointment if your tooth aches again; post a letter when you pass by the post box), whereas for the other half there was a low semantic relation (e.g. return a DVD to the store on your way to the gym; buy a present for your nephew after going to the library).

Procedure

Participants were tested individually. They were first shown the Virtual Week board and instructed that they would move around the board with the roll of a dice. They were told that the times of the day people are typically awake were marked on the board and that they would circuit the board 7 times in a simulation of a week (each circuit representing a day). As they moved around the board they would be required to make choices about daily activities. Participants were also instructed that there would be some tasks that they would be asked to remember later when they encountered a specified event. They would not be required to perform these tasks but should inform the researcher about the relevant task when the appropriate event occurred. As an example, they were told that a PM instruction could consist of a request to pick up dry-cleaning when next out shopping during that virtual day. When reading an event card, later in the virtual day, that described the activity of going out shopping, they should remember to tell the researcher that they needed to pick up dry-cleaning. They were instructed to do this even if they remembered it after the relevant event had occurred.

Participants first undertook a practice circuit, which did not contain any PM tasks. This was intended to clarify the procedure and to provide an opportunity for them to ask questions. At the start of the game, participants were given the instructions for the regular PM tasks and were asked to either read aloud or physically simulate each task twice. They were also asked to follow this procedure (either reading aloud or physical enactment) when they received the instructions for the irregular PM tasks, either at the start of a virtual day or on specific event cards picked up during the circuit. The experimenter observed participants throughout the task to ensure that they followed the appropriate encoding procedure whenever a new intention was formed.

Each virtual day started with the participant rolling a ‘6’ on the dice and picking up a start (event) card. This card stated the day of the week and provided instructions for two of the irregular PM tasks to be carried out that day. An additional event card (ten in total) was picked up whenever the participant landed on or passed over an event square on the board.

Each event card described a plausible activity appropriate to the virtual time of day and presented three alternative courses of action that might realistically follow (e.g. Monday breakfast. During breakfast you read the paper. For breakfast, do you have: cereals, waffles or bacon and eggs?). Once participants had selected one of the options they were required to turn the card over to find out what dice throw would be needed before they could move on (e.g. ‘throw a 5’ or ‘through an odd number’). Each virtual day finished when the participant reached the start square again. PM responses were classified as on time if they occurred before the participant made the next dice roll. As suggested by Rendell and Craik, the various activities required by the game (e.g. moving around the board, reading about the activities and making choices about what to do next) were intended to engage the participant in the task and to provide a realistic context for the PM tasks that would be reflective of everyday life.

The above procedure closely follows that of Rendell and Craik (2000), with the exception that we did not include any time-based intentions. The original Virtual Week paradigm involved two time-checking tasks which required participants to inform the experimenter when a particular time was displayed on a visible stop-watch. Two other tasks required participants to retrieve an intention whenever they passed a particular time square on the board (see Note 2). As we were interested in manipulating the degree of relatedness between actions and event-based retrieval cues, these time-based tasks were excluded from the current study and two additional irregular event-based intentions were used instead.

Results

Unless stated otherwise, all data were analysed using a 2 X 2 x 2 mixed ANOVA, with Age group and Method of Encoding as between-subject factors and Cue-Action Relatedness as a within-subjects factor.

Prospective memory performance

It was considered possible that the benefits of enactment and cue-action relatedness on PM performance might vary for regular and irregular tasks, thus the two types of intention were analysed separately. The proportion of each type of intention retrieved at the correct moment over the course of the Virtual Week is displayed in Table 1. Given the high levels of performance for regular intentions these data were not analysed further.

(Table 1 about here)

The data for the irregular intentions were non-normally distributed therefore a logarithmic transformation was applied. Analysis of the transformed data revealed reliable main effects of Cue-Action relatedness, $F(1,60) = 81.16$, $p < 0.001$, $\eta_p^2 = .58$, Encoding Method, $F(1,60) = 34.33$, $p < 0.001$, $\eta_p^2 = .36$ and Age Group, $F(1,60) = 16.08$, $p < 0.001$, $\eta_p^2 = .21$. There were also reliable 2-way interactions between Cue-Action relatedness and Encoding Method, $F(1,60) = 23.19$, $p < 0.001$, $\eta_p^2 = .28$, between Cue-Action relatedness and Age Group, $F(1,60) = 9.07$, $p = 0.004$, $\eta_p^2 = .13$, and between Encoding Method and Age Group, $F(1,60) = 14.89$, $p < 0.001$, $\eta_p^2 = .20$. These interactions were qualified, however, by a reliable 3-way interaction between Encoding Method, Cue-Action relatedness and Age Group; $F(1,60) = 5.90$, $p = 0.018$, $\eta_p^2 = .09$.

The 3-way interaction was explored by examining the effects of Age Group and Cue-Action Relatedness for each Encoding Method separately. For verbally encoded intentions, there was a reliable Age Group x Cue-Action Relatedness interaction; $F(1, 30) = 8.82$, $p = 0.006$, $\eta_p^2 = .23$. While there was a clear benefit for related pairs over unrelated pairs for both age groups, Table 1 suggests that this advantage was somewhat greater for older adults, $t(30) = 5.85$, $p < 0.001$, than for younger adults, $t(30) = 5.85$, $p < 0.001$. Moreover, there was an age difference in PM performance for both types of cue-action pair following verbal encoding, however the effect of age appears to be larger for unrelated pairs, $t(30) = -4.49$, $p < 0.001$, than for related pairs, $t(30) = -4.18$, $p < 0.001$. For intentions that were enacted during encoding, there was a main effect of Cue-Action Relatedness only, $F(1,30) = 27.47$, $p < 0.001$, $\eta_p^2 = .48$. The main effect of Age and the Cue-Action relatedness x Age interaction were not significant; both Fs < 1. Thus following enactment both young and older adults showed a similar improvement in PM performance when related cue-action pairs were used as compared to unrelated pairs.

Consideration of Table 1 suggests that while young adults showed evidence of an enactment effect, at least for unrelated pairs, enactment may have been particularly beneficial for older adults as it eliminated the age-related decrement for both related and unrelated intentions that had been observed following verbal encoding.

To summarise, when intentions were verbally encoded both young, and particularly, older adults benefited when there was an existing semantic association between the cue and the intended action. There was also an advantage of cue-action relatedness for both age groups following enactment. Older adults carried out fewer intentions following verbal encoding than young adults, particularly when the cue and action were unrelated. Crucially, however, the age difference for both types of cue-action pair was eliminated when intentions were enacted during encoding.

Discussion

The aim of this study was to examine the influence of enactment at encoding and cue-action relatedness on memory for intentions in young and older adults using the Virtual Week task. After verbal encoding, PM performance was better for both young and older adults when there was a close semantic association between the retrieval cue and the intended action than when unrelated cue-action pairings were used. This is consistent with previous findings of a beneficial influence of cue-action relatedness on PM performance for both age groups (e.g. Cohen et al., 2001; McDaniel et al., 2004). While the benefit of relatedness for verbally encoded intentions appeared to be somewhat greater for older adults than for young adults, there was a significant age-related decline in PM performance after verbal encoding in both relatedness conditions.

It had been hypothesised, on the basis of the multiprocess account (e.g. McDaniel & Einstein, 2000; Einstein & McDaniel, 2010), that a close semantic cue-action relation might benefit PM by allowing retrieval to proceed via a reflexive-associative (hippocampal) mechanism, which delivers the intended action to mind spontaneously when the retrieval cue is re-processed in the ongoing task. This type of retrieval is assumed to be minimally influenced by the availability of attentional resources (e.g. McDaniel et al., 2004), and should be relatively insensitive to the effects of healthy ageing. It is possible that reflexive-associative retrieval was employed for related intentions in the current study. If this was the case, however, the observed age difference for these items after verbal encoding would have to reflect an age-related decline in some other aspect of PM-related processing, for example, task-switching or ongoing task inhibition. That is, while both age groups may have spontaneously retrieved the related actions following cue presentation, older adults may have had greater difficulty carrying out the additional processes necessary for intention execution.

An alternative, and perhaps more likely, possibility is that the use of multiple intentions (six per 'day') in the Virtual Week task precluded a reliance on associative-reflexive retrieval, in the verbal encoding condition at least, and instead induced participants to strategically monitor for the PM cues (cf. Meeks, Hicks & Marsh, 2007; Meeks & Marsh, 2010). This proposal is consistent with previous findings that the number of PM cues influences the allocation of preparatory attentional resources to the PM task. Using costs to the ongoing task as an index of attention allocation (see Smith, 2003), Cohen, Jaudas and Gollwitzer (2008) found little evidence that resources were being invested to support PM performance when only one or two retrieval cues were used. However, ongoing task performance was significantly impaired by an increase in the number of PM cues, indicating a diversion of attention toward intention-related processing under multiple cue conditions. On the basis of this, it seems likely that cue detection after verbal encoding in the current paradigm may have required the application of strategic monitoring; hence PM performance was lower for older adults than for young adults in both relatedness conditions.

In the context of strategic monitoring, a strong semantic cue-action relation might benefit PM performance by supporting retrieval of the intended action once a cue has been detected. That is, having successfully identified a cue in the ongoing task, the intended action is more likely to be retrieved when it is related to the cue than when it is unrelated. This is in keeping with findings from the retrospective memory literature that cued-recall is typically enhanced for related as compared to unrelated pairs in both age groups (e.g. Naveh-Benjamin, Craik, Guez & Kreuger, 2005). Semantic relatedness may have been disproportionately beneficial for older adults after verbal encoding as it provides a form of environmental support which serves to offset the impaired ability to carry out self-initiated retrieval processes (Craik, 1986).

Perhaps the most striking observation to arise from the current research is that the age-related decline in PM performance observed for verbally encoded intentions was absent when enactment was used at encoding. If the age difference for verbal intentions was driven by impaired monitoring (for multiple retrieval cues), then the equivalent performance of young and older adults after enactment suggests that enacted intentions can be retrieved without the need for preparatory attentional processing. In line with the multiprocess account of PM, there are two possible approaches to intention retrieval in the absence of strategic monitoring; reflexive-associative retrieval and discrepancy plus search. We consider our findings in the light of both of these accounts.

First, it is possible that enactment eliminated age differences, and improved performance, in the Virtual Week task because it allowed participants to reject cue monitoring in favour of a discrepancy plus search approach. Of relevance here is the proposal that physically performing an action during encoding provides additional item-specific information about the action which heightens the distinctiveness of the action representation and makes it more accessible in memory (Zimmer, Helstrup & Engelkamp, 2000; Freeman & Ellis, 2003a). Moreover, this influence of enactment on item accessibility appears to be retained in the course of healthy aging (Freeman & Ellis, 2003b). Increased intention accessibility would presumably result in retrieval cue information being processed more fluently during the ongoing task than other non-enacted items. This, according to the discrepancy plus search model, should lead to cue identification without the need for age-sensitive preparatory attentional processing. In this context, semantic relatedness might further enhance PM peformance by supporting the processes that operate at the retrieval search stage (as discussed earlier in relation to strategic monitoring). It should be noted however, that discrepancy plus search retrieval processes have been found to be disrupted by diminshed attentional resources (McDaniel et al., 2004), and thus it is perhaps difficult to reconcile this with the absence of age differences following enactment in the current study.

A second possibility is that enacting an intention allows a particularly strong unitisation of the cue-action components of the intention representation (*cf.* Kormi-Nouri, 1995), which could support reflexive-associative retrieval even in the multi-intention context of the Virtual Week task. While we have argued that this type of retrieval is unlikely to have occurred for semantically related items after verbal encoding, the level of integration provided by enactment may have been sufficiently strong to allow reflexive-associative retrieval in the presence of a high intention load. The finding of an additional benefit of semantic relatedness for enacted intentions (albeit numerically smaller than that observed for verbally encoded intentions) suggests that these two manipulations may have at least partially independent mechanisms of action. This can be explained by the proposal of Engelkamp and colleagues (e.g. Engelkamp & Jahn, 2003; Engelkamp & Zimmer, 1997) that the effects of enactment and semantic relatedness on memory are mediated by seperate processing systems. Specifically, while the effects of semantic relatedness are assumed to be dependent on a conceptual memory system, the enactment effect is argued to operate via a non-verbal motor system, hence enactment and semantic relatedness may have additive effects on performance.

The current study does not allow us to distinguish definitively between the theoretical possibilities described. Taken together, however, our findings are arguably most consistent with the view that the use of multiple intentions in the Virtual Week militated against a reliance on spontaneous retrieval processes for verbally-encoded intentions. Instead, under verbal encoding conditions, we propose that PM may have involved strategically monitoring for the cue, and then retrieving the intended action once the cue has been detected. The latter operation involves retrospective memory processes which were supported for both young and (particularly) older adults by a strong semantic relation between the cue and the intended action. Following enactment, we argue that age differences were absent because strategic monitoring is no longer necessary, most likely because enactment enhances cue-action integration to such an extent that reflexive-associative retrieval can occur. Semantic relatedness is beneficial for both age groups in this context because it provides an additional source of cue-action integration (which is additive to that conferred by motoric processing).

The Virtual Week task was chosen for the current study, in part, because it requires the retention and retrieval of mutliple and various intentions, and thus may go further towards reflecting the complex demands of everyday life than do artificial tasks. Thus our finding that both semantic relatedness and enactment at encoding influenced memory for irregular intentions during the Virtual Week may be used to suggest potential techniques for supporting memory for naturally-occurring intentions in young and older adults.

For example, the benefit observed for related intentions in both age groups suggests that everyday PM performance could be enhanced if tasks are planned in such a way that the retrieval context for an intention is as closely related to the intended action as possible (e.g. buy flowers when passing the florist, rather than when shopping in the supermarket). Clearly this strategy would not be applicable to all PM tasks, for example those in which the retrieval context is fixed (e.g. return an item to a particular person when you see them). However, for tasks in which there is some flexibility in planning the moment of retrieval, our findings could inform the choice of the most appropriate context for the intended action. To take advantage of the enactment effect, an individual could symbolically perform (mime), during encoding, the action they intend to carry out in the future (see McDaniel & Einstein, 2007, for further discussion of the application of laboratory-based PM findings to work and naturalistic settings).

Further research is needed to establish the efficacy of these manipulations in real life settings involving a broad array of naturally-occurring intentions. Future work should also address whether the manipulations that have enhanced PM here for young and healthy older adults extend to older adults with mild cognitive impairment or Alzheimer's disease. Bird and Kinsella (1996), for example, have demonstrated the potential benefit of motor enactment at encoding on PM for individuals with

Alzheimer's disease when used in conjunction with a spaced retrieval technique. An important future step would be to examine the influence of enactment and semantic relatedness when used independently of other mnemonic techniques.

References

Aberle, I., Rendell, P.G., Rose, N.S., McDaniel, M.A. & Kliegel, M. (2010). The age prospective memory paradox: Young adults may not give their best outside of the lab. *Developmental Psychology, 46,* 1444-1453.

Bäckman, L. (1985). Further evidence for the lack of adult age differences on the free recall of subject-performed tasks: The importance of motor action. *Human Learning, 4*, 79-88.

Bird, M., & Kinsella, G. (1996). Long-tem cued recall of tasks in senile dementia. *Psychology and Aging, 11* (1), 45-56.

Brandimonte, M.A. & Passolunghi, M.C. (1994). The effect of cue-familiarity, cue-distinctiveness, and retention interval on prospective remembering. *Quarterly Journal of Experimental Psychology, 47(A)*, 565-588.

Cohen, R. (1989). Memory for action events: The power of enactment. *Educational Psychology Review, 23*, 57-80.

Cohen, A.-L., Jaudas, A., & Gollwitzer, P. M. (2008). Number of cues influences the cost of remembering to remember. *Memory and Cognition, 36,*149-156.

Cohen, A.-L., West, R., & Craik, F. I. M. (2001). Modulation of the prospective and retrospective components of memory for intentions in younger and older adults. *Aging, Neuropsychology, and Cognition, 8*, 1-13.

Craik, F. (1986). A functional account of age differences in memory. In F. Klix & H. Hagendorf (Eds.). *Human memory and cognitive capabilities: Mechanisms and performances* (pp. 409-422). Amsterdam: Elservier.

Einstein, G., & McDaniel, M. (2005). Prospective memory: Multiple retrieval processes. *Current directions in Psychological Science,14*, 286–290.

Einstein, G.O., & McDaniel, M.A. (2010). Prospective memory and what costs do not reveal about retrieval processes: A commentary on Smith, Hunt, McVay, and McConnell (2007). *Journal of Experimental Psychology: Learning, Memory and Cognition, 36,* 1082-1088.

Einstein, G.O., McDaniel, M.A., Thomas, R., Mayfield, S., Shank, H., Morrisette, N. et al. (2005). Multiple processes in prospective memory retrieval: Factors determining monitoring versus spontaneous retrieval. *Journal of Experimental Psychology: General, 134*, 327-324.

Ellis, J.A. & Freeman, J. (2008). Ten years on: Realizing delayed intentions. In M. Kliegel, M.A. McDaniel, & G.O. Einstein (Eds.). *Prospective memory: Cognitive, Neuroscience, Developmental and Applied Perspectives* (ch. 1). New York: LEA

Engelkamp, J., & Jahn, P. (2003). Lexical, conceptual and motor information in memory for action phrases: A multi-system account. *Acta Psychologica, 113*, 147-165.

Englekamp, J., & Zimmer, H.D. (1997). Sensory factors in memory for subject-performed tasks. *Acta Psychologica, 96*, 43-60.

Feyereisen, P. (2009). Enactment effects and integration processes in younger and older adults' memory for actions. *Memory, 17*, 374-385.

Folstein, M., Folstein, S., & McHugh, P. (1975). "Mini-mental state": A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*, 189-198.

Freeman, J.E., & Ellis, J.A. (2003a). The representation of delayed intentions: A prospective subject-performed task? *Journal of Experimental Psychology: Learning, Memory and Cognition, 29,* 976–992.

Freeman, J.E., & Ellis, J.A. (2003b). Aging and the accessibility of performed and to-be-performed activities. *Aging, Neuropsychology, and Cognition, 10,* 298-309.

Hannon B, & Daneman M. (2007). Prospective memory: the relative effects of encoding, retrieval, and the match between encoding and retrieval. *Memory, 15*, 572-604.

Henry, J.D., MacLeod, M.S., Philips, L.H., & Crawford, J.R. (2004). A meta-analytic review of prospective memory and aging. *Psychology and Aging, 19*, 27-39.

Henry, J.D., Rendell, P.G., Kliegel, M., & Altgassen, M. (2007). Prospective memory in schizophrenia: Primary or secondary impairment? *Schizophrenia Research, 95*, 179-185.

Kliegel, M., Jäger, T. & Phillips, L.H. (2008). Adult age differences in event-based prospective memory: A meta-analysis on the role of focal versus nonfocal cues. *Psychology and Aging, 23,* 203-208.

Kliegel, M., & Martin, M. (2003). Prospective memory research: Why is it relevant? *International Journal of Psychology, 38*, 193-194.

Kormi-Nouri, R. (1995). The nature of memory for action events: an episodic integration view. *European Journal of Cognitive Psychology, 7* (4), 337-363.

Knopf, N. & Neidhardt, E. (1989). Aging and memory for action events: The role of familiarity. *Developmental Psychology, 25*, 780-786.

Kvavilashvili, L., Kornbrot, D., Mash, V., Cockburn, J., & Milne, A. (2009). Differential effects of age on prospective and retrospective memory tasks in young, young-old and old-old adults. *Memory, 17*, 180-196.

Loft, S. & Yeo, G. (2007). An investigation into the resource requirements of event-based prospective memory. *Memory and Cognition, 35*, 263-274.

Mangels, J., & Heinberg, A. (2006). Improved episodic integration through enactment: Implications for aging. *The Journal of General Psychology, 133*, 37-65.

Mäntylä, T. (1993). Priming effects in prospective memory. *Memory, 1,* 203-218.

McDaniel, M., & Einstein, G. (1993). The importance of cue familiarity and cue distinctiveness in prospective memory. *Memory, 1*, 23-41.

McDaniel, M., & Einstein, G. (2000). Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. *Applied Cognitive Psychology, 14,* s127-s144.

McDaniel, M., & Einstein, G. (2007). *Prospective memory: An overview and synthesis of an emerging field*. Los Angeles: Sage Publications.

McDaniel, M. A., Einstein, G. O., & Rendell, P. G. (2008). The puzzle of inconsistent age-related declines in prospective memory: A multiprocess explanation. M. Kliegel, M. A. McDaniel, & G. O. Einstein (Eds.), *Prospective memory: Cognitive, neuroscience, developmental, and applied perspectives* (pp. 141-160). New York: Erlbaum.

McDaniel, M., Guynn, M., Einstein, G., & Breneisser, J. (2004). Cue-focused and reflexive-associative processes in prospective memory retrieval. *Journal of Experimental Psychology: Learning, Memory and Cognition, 30*, 605-614.

McDaniel, M.A., Howard, D.C. & Butler, K.M. (2010). Implementation intentions facilitate prospective memory under high attention demands. *Memory & Cognition, 36*, 716-724.

McDaniel, M.A., & Scullin, M.K. (2010). Implementation intention encoding does not automatize prospective memory responding. *Memory and Cognition, 38,* 221-232.

Meacham, J., & Leiman, B. (1982). Remembering to perform future actions. In U.

Neisser (Ed.), *Remembering in natural contexts* (pp. 327-336). San Francisco: Freeman.

Meeks, J., Hicks, J., & Marsh, R. (2007). Metacognitive awareness of event-based prospective memory. *Consciousness and Cognition, 16*, 997-1004.

Meeks, J.T. & Marsh, R.L. (2010). Implementation intentions about nonfocal event-based prospective memory tasks. *Psychological Research, 74*, 82-89.

Naveh-Benjamin, M., Craik, F.I.M., Guez, J. & Kreuger, S. (2005). Divided attention in young and older adults: Effects of strategies and relatedness on memory performance and secondary task costs. *Journal of Experimental Psychology: Learning, Memory and Cognition, 31*, 520-537.

Nilsson, L.-G., & Craik, F.I.M. (1990). Additive and interactive effects in memory for subject-performed tasks. *European Journal of Cognitive Psychology, 2*, 305-324.

Nyberg, L., Nilsson, L.-G, & Bäckman, L. (1992). Recall of actions, sentences, and nouns: Influences of adult age and passage of time. *Acta Psychologica, 79,* 245-254.

Rendell, P. G., & Craik, F. I. M. (2000). Virtual week and actual week: Age-related differences in prospective memory. *Applied Cognitive Psychology, 14,* S43-S62.

Rendell, P.G. & Henry, J.D. (2009). A review of Virtual Week for prospective memory assessment: Clinical implications. *Brain Impairment, 10*, 14-22.

Rose, N.S., Rendell, P.G., McDaniel, M.A., Aberle, I., & Kliegel, M. (2010). Age and individual differences in prospective memory during a “Virtual Week”: The roles of working memory, vigilance, task regularity, and cue focality. *Psychology and Aging, 25*, 595-605.

Smith, R. E. (2003). The cost of remembering to remember in event-based prospective memory: Investigating the capacity demands of delayed intention performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29* (3), 347-361.

Thompson, C., Henry, J.D., Rendell, P.G., Withall, A. & Brodaty, H. (2010). Prospective memory function in mild cognitive impairment and early dementia. *Journal of the International Neuropsychological Society, 16* , 318-325.

Will, C.M., Rendell, P.G., Ozgis, S., Pierson, J.M., Ong, B., & Henry, J.D. (2009). Cognitively impaired older adults exhibit comparable difficulties on naturalistic and laboratory prospective memory tasks. *Applied Cognitive Psychology*. 23, 804-812.

Zimmer, H.D., Helstrup, T., & Engelkamp, J. (2000). Pop-out into memory: A retrieval mechanism that is enhanced with the recall of subject-performed tasks. *Journal of Experimental Psychology: Learning, Memory and Cognition, 26*, 658-670

Notes

1. By artificial lab tasks, we refer to tasks in which participants are given an abstract ongoing activity (e.g. lexical decision or word rating) and asked to make a key press (or similar) response whenever a target time or event occurs. In event-based tasks, participants are typically given just one or two different cues to respond to (e.g. Einstein & McDaniel, 1990).

2. Although these are described by Rendell & Craik as time-based tasks it has been commented (e.g. Rose et al., 2010) that these are in fact more akin to non-focal event-based tasks insofar as they require the participant to respond when a particular time-square is passed on the board.

	Verbal encoding		Enactment at encoding	
	Unrelated cue-action	**Related cue-action**	**Unrelated cue-action**	**Related cue-action**
Regular intentions				
Older adults	**.95 (.10)**	**.97 (.07)**	**.98 (.06)**	**1.00 (0)**
Young adults	**.97 (.09)**	**.98 (.08)**	**.99 (.04)**	**1.00 (0)**
Irregular intentions				
Older adults	**.35 (.15)**	**.66 (.12)**	**.75 (.18)**	**.88 (.11)**
Young adults	**.63 (.16)**	**.85 (.12)**	**.76 (.14)**	**.88 (.14)**

Table 1. Mean proportion of regular and irregular intentions retrieved at the appropriate moment in each Method of Encoding X Cue-Action Relatedness condition for young and older adults.