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# The effect of aging in recollective experience: The processing speed and executive functioning hypothesis

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**Abstract**

This study was designed to investigate the effects of aging on consciousness in recognition memory, using the Remember/Know/Guess procedure (Gardiner, J. M., & Richarson-Klavehn, A. (2000). Remembering and Knowing. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford Handbook of Memory*. Oxford University Press.). In recognition memory, older participants report fewer occasions on which recognition is accompanied by recollection of the original encoding context. Two main hypotheses were tested: the speed mediation hypothesis (Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 3*, 403–428) and the executive-aging hypothesis (West, R. L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin, 120*, 272–292). A group of young and a group of older adults took a recognition test in which they classified their responses according to Gardiner, J. M., & Richarson-Klavehn, A. (2000). Remembering and Knowing. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford Handbook of Memory*. Oxford University Press. remember-know-guess paradigm. Subsequently, participants completed processing speed and executive function tests. The results showed that among the older participants, R responses decreased, but K responses did not. Moreover, a hierarchical regression analysis supported the view that the effect of age in recollection experience is determined by frontal lobe integrity and not by diminution of processing speed.


*Keywords:* Aging; Recollective experience; Executive functioning and processing speed

## 1. Introduction

Episodic memory is defined as the kind of memory that enables conscious recollection of personal happenings and events from the past (Wheeler, Stuss, & Tulving, 1997). Previous studies have indicated that people experience at least two relatively distinct states of awareness in recognition memory. Tulving's (1985) distinction between autonoetic and noetic forms of consciousness has provided the conceptual basis for a substantial

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amount of research into episodic memory. Autonoetic consciousness is associated with the type of memory that allows us to recreate and relive subjective experiences in our past. By contrast, noetic consciousness accompanies memories related to the storage of knowledge and facts in the absence of such intimate recollections of their acquisition. Tulving's (1985) distinction between autonoetic and noetic consciousness provided a focus for the work of Gardiner and his associates (Gardiner, 1988; Gardiner & et Java, 1993), who separated remembering and knowing responses in recognition experiments. Gardiner and Richarson-Klavehn (2000) suggested that 'remembering' involves autonoetic consciousness which corresponds to episodic memory, while 'knowing' refers to the expression of noetic awareness, which corresponds to semantic memory.

Originally, these two states of awareness have been operationalized with the Remember/Know paradigm assumed to reflect episodic and semantic memory, respectively (Gardiner, 2001; Gardiner & Richarson-Klavehn, 2000; Tulving, 1985). This paradigm has been applied particularly in recognition tasks and consists of asking participants to state the nature of their recollective experience at the time of the recognition task. Participants have to classify each recognized item into one of two categories: Remember (R) or Know (K). An R response involves some specific contextual recollection of a previous encounter with the stimulus, and a K response indicates that the participant is sure that the item is a target, but has no specific contextual recollection of its prior presentation. Gardiner and Conway (1999) suggested a third category, a Guess response (G), when participants are not sure if the item was seen during the learning task or not, avoiding the use of the K response. A large number of studies using this method have found that manipulating certain experimental variables had different effects on the proportions of type-R and type-K responses (for reviews, see Gardiner & et Java, 1993; Gardiner & Richarson-Klavehn, 2000; Rajaram, 1999).

Different models interpret R/K responses in other ways than the memory systems hypothesis of Tulving (1985), who considered R responses as episodic memory. Some authors have proposed a dual process signal detection in which Remember and Know responses are broken down into a discrete recollection component and a continuous familiarity component based on an equal variance signal detection model (Yonelinas, Kroll, Dobbins, Lazzara, & Knight, 1998). Others have proposed single process models, with R responses seen as a high confidence recognition memory (Donaldson, 1996; Dunn, 2004), or a two-dimensional signal detection model in which R and K judgments are broken down into ''global memory'' and ''specific memory'' components (Rotello, Macmillan, & Reeder, 2004). The purpose of this research is not to resolve this theoretical issue but to study the age-related differences in recollective experience using the R/K paradigm.

Several studies have investigated R and K responses in aging with two patterns of results. Some studies have shown that age affects R responses only (Bunce, 2003; Clarys, Isingrini, & Gana, 2002; Comblain, D'Argembeau, Van Der Linden, & Aldenhoff, 2004; Fell, 1992; Lövden, Rönnlund, & Nilsson, 2002; Perfect & Dasgupta, 1997), while others have shown an increase in the number of K responses with increasing age in addition to a decrease in R responses (Bastin, Van der Linden, Michel, & Friedman, 2004; Bunce & Macready, 2005; Parkin & Walter, 1992; Perfect, Williams, & Anderton-Brown, 1995, exp 2b; Piolino et al., 2006; Prull, Dawes, Martin, Rosenberg, & Light, 2006). However, all studies have revealed an age-related difference in R responses, and it is interesting to find an explanation for this decrease and highlight the factors involved.

To explain age-related deficits in R responses, a global approach is often used. This approach typically aims to identify factors that are predictive or mediators of age-related differences in episodic memory (Luszcz, Bryan, & Kent, 1997). The assumption of this approach is that if these factors are responsible for age-related differences in memory, their inclusion in a hierarchical regression analysis should reduce age-related variance. Several competing candidates may play this role of mediator: working memory (Baddeley, 1986), inhibition (Hasher & Zacks, 1988), processing speed (Salthouse, 1996) or executive functioning (West, 1996). In the present study, we focused on processing-speed and executive function.

One possible explanation of the differences in the proportion of R responses between younger and older people is processing speed. An explanation of how processing speed might influence memory has been described by Salthouse (1996) who suggested that the speed at which the central nervous system processes information could influence not only the quantity but also the quality of memory performance. According to this view, mental operations slow down with aging and require extra time, and as a result there is less time to perform later operations. Salthouse (e.g., 1991) argued that general processing speed accounts for much of the age-related variance in memory and other cognitive domains. Numerous empirical investigations have supported such a view (see Salthouse, 1996). In relation to recollective experience, two recent studies found that age differences in remembering were eliminated after controlling for processing speed (Bunce & Macready, 2005; Lövden et al., 2002). Another study that took both working memory and processing speed into account (Clarys et al., 2002) also concluded that the latter construct was more influential in explaining the age-related variance in remembering.

Another way to explain differences in proportion of R responses between younger and older people could be executive functioning. The executive decline hypothesis for cognitive performance (West, 1996), and particularly for memory, has received considerable empirical support (Moscovitch & Winocur, 1992; Parkin, 1997). According to this hypothesis, age-related differences in memory arise from a decline in executive functioning which may be particularly sensitive to the effects of aging (Raz, 2000). Executive functioning is believed to support goal-directed strategic cognitive operations known collectively as executive functions (Parkin & Walter, 1992). Further evidence of the role of executive functioning comes from studies showing that older participants perform less well than younger ones in tasks in which patients with frontal lobe damage also show impaired performance, such as control of interference (Dempster, 1992), memory of temporal order (Fabiani & Friedman, 1997; Parkin, Walter, & Hunkin, 1995), metamemory (Souchay, Isingrini, & Espagnet, 2000) and conscious awareness (Bunce, 2003; Parkin & Walter, 1992). With regard to the underlying neural mechanisms, Wheeler et al. (1997) suggested that the frontal cortex is implicated on conscious awareness. This facilitates the ability to intimately relive the past that remembering refers to. Furthermore, elderly groups show impairment in source memory tasks (Craik, Morris, Morris, & Loewen, 1990; Glisky, Polster, & Routhieaux, 1995), which can be considered as a deficit in the ability to encode the spatial and temporal context associated with an event (Parkin & Walter, 1992). For R responses, the content and context must be integrated at encoding, and information regarding their co-occurrence must be stored in memory. Integrative encoding processes depend on the frontal lobes (see Buckner, 2003, for a review; Wheeler et al., 1997) which are needed to initiate and carry out the control processes ensuring that all aspects of an experience are encoded. Failure to take account of more than one aspect of a stimulus, only the content for example, is particularly likely in older adults with executive function decline. The few studies that have investigated this possibility through the Remember and Know paradigm have produced conflicting results. Some studies found weak (Bunce & Macready, 2005; Perfect & Dasgupta, 1997) or no evidence (Perfect et al., 1995), whereas Parkin and Walter (1992) showed correlations between measures of executive functioning and the amount of reported recollective experience in the oldest participants. Higher levels of R responses in the older adults were reliably correlated with better performance on the Wisconsin Card Sorting Test. These data suggest that contextually based recognition (R responses) decreases as executive function impairment increases. In another study, Bunce and Macready (2005) manipulated the time available for encoding operations and also recorded independent measures of executive functions and processing speed. In this experiment, they used two measures of executive functioning, a FAS Word Fluency Test and a backward digit span task, and two processing speed tests, the digit symbol test and the four-choice reaction time task. Their results suggested first that younger adults used the longer encoding period more effectively and produced significantly more correct R responses, whereas older participants produced more K responses than younger adults. Secondly, they showed that processing speed but not executive functioning explained age-related variance in both remembering and knowing in the longer encoding condition. However, as the authors acknowledged, this result could be explained by the fact that the frontal tasks chosen did not assess the executive processes involved in elaborative rehearsal and structuring with sufficient rigour. With regard to the first task, while there is a large literature on letter fluency in normal adults, the findings concerning age-related changes are not consistent. A recent meta-analysis of the FAS Word Fluency Test during the lifespan of normal adults demonstrated a fairly robust age-associated decline in this task (Loonstra, Tarlow, & Sellers, 2001). However, not all authors have reported this pattern (Parkin & Java, 1999; Perlmuter & Tun, 1987). Indeed, the FAS test is not particularly pure because it evaluates spontaneous flexibility as well as the level of vocabulary. Moreover, this test was used in Parkin and Walter's (1992) original study and the authors did not find a relationship between R responses and this test. Concerning the second test, the backward digit span is classically used to evaluate working memory rather than executive functioning. Consequently, as the measures used by Bunce and Macready (2005) were not sufficiently pertinent to evaluate executive functioning, we replicated the same study using different tasks to examine the involvement of these factors in the age-related decrease in recollective experience.

This study was designed to investigate which factors might be responsible for the age-related differences in R responses. We combined two different theoretical frameworks: the executive-aging hypothesis (West, 1996) and the speed mediation hypothesis (Salthouse, 1996). The first objective was to confirm the age-related difference in R responses. For K responses, the pattern of results which can be predicted is less clear because some authors have found an age-related difference while others have not. The second and main objective was to examine the relationships between the age-related decline in remembering, processing speed and executive function. We expected that processing speed and executive functioning would share a considerable amount of age-related variance in predicting remembering. With regard to knowing, no involvement of processing resources should appear independently of the R/K measurement model used, and no relationship has been found between this type of answer and processing resources (Bunce, 2003; Bunce & Macready, 2005; Clarys et al., 2002; Lövden et al., 2002). In contrast to Bunce and Macready (2005), we selected the Wisconsin Card Sorting Test (WCST), because it produced interesting results in a previous study by Parkin and Walter (1992). Moreover, it is conventionally used to evaluate executive functioning and is the most representative of the executive function factor (Miyake et al., 2000).

## 2. Method

### 2.1. Participants and background measures

A total of 48 adults living in a medium-sized metropolitan area participated in the study. They were divided into two groups: the first consisted of 24 non-student young adults (age range 18–29 years) and the second of 24 elderly adults (age range 60–85 years). The older adults came from the general community and lived in their own homes. They scored above the 27-point cut-off on the Mini-Mental Status Examination (MMSE; Folstein, Folstein, & McHugh, 1975). All participants were volunteers and reported themselves to be in good physical and mental health, and free from medication known to affect the central nervous system. They were also selected according to their educational background.

The demographic characteristics of the two groups are shown in Table 1. The groups did not differ on years of education or verbal ability according to the Mill-Hill test (Deltour, 1993), a multiple choice synonym vocabulary test.

## 3. Materials and procedure

Participants performed a recognition memory task (Remember/Know/Guess procedure), and executive and processing speed tasks. All participants were tested individually and were informed that the experiment involved memory.

### 3.1. Remember/Know/Guess measures

For the R/K/G paradigm, the material was the same as that used by Clarys et al. (2002). Seventy-two taxonomically unrelated concrete nouns were selected and divided randomly into two sets of 36 words, matched for frequency and length. One set was presented at encoding and these words were used as target items in the succeeding recognition test, while the other set provided the lures. Half of the participants were presented with

Table 1
Means and standard deviations of participant's characteristics for the two age groups

| | Young ($n = 24$) | | Old ($n = 24$) | | $F(1.46)$ |
|---|---|---|---|---|---|
| | *M* | SD | *M* | SD | |
| Age (in years) | 23.37 | 3.16 | 70.96 | 7.67 | |
| MMSE | — | — | 29.83 | .48 | |
| Education (years) | 13.41 | 2.08 | 11.87 | 4.46 | 2.35 |
| Mill Hill | 25 | 3.14 | 27.37 | 4.88 | 3.65 |

one list, half with the other, and they were not told how many items they had previously seen. Moreover, the two sets of stimuli were counterbalanced across the two age group. For the study phase, the words were presented on a computer with Microsoft Power Point at the rate of 3 s/word. The participants were told to read the words aloud and to remember them for a test to be given afterwards. The test phase was introduced following a retention interval of 5 min. During this interval, the participants took the processing speed test.

For the recognition test, the complete set of 72 words (36 targets and 36 fillers) was presented on the computer with Microsoft Power Point in random order. For each word, the participants were told to say if they recognized it from the list seen earlier. In addition, for each word recognized, the participants had to indicate if it was a remember (R), know (K) or guess (G) response. They were instructed to give an R response when the recognized word evoked a specific recollection of the learning sequence. Examples given included remembering a word because it brought to mind a particular association, image, or some other personal experience, or because something about its appearance or position could be recalled. K responses were to be given for words which the participants felt confident about recognizing but failed to evoke any specific conscious recollection from the learning sequence. G responses were to be used when they were not sure whether they had seen the word in the study list. After the recognition phase, they were asked to explain at least two of their Remember and two Know judgments, thereby ensuring that they had used the two types of responses correctly. For R responses, we attempted that participants give episodic details associated with the word encoding. For K responses, we attempted that they recognized the word but could not remember any specific detail about their study experience with it. Any participant was excluded on the basis of their explanations.

The dependent variables were based on the absolute proportions (#hits/#targets, for the correct recognition, and #false alarms/#targets, for the false alarms) of overall recognition and were computed separately for R and K judgments. Guess responses were included to compute the hits proportion of overall recognition, but they were no analysed independently because they were used to enhance the quality of K responses and the number of responses was judged to be too low. Moreover, a nonparametric discrimination index (A′; e.g., Donaldson, 1996) is reported where appropriate, respectively for overall and R recognition, to allow for comparison with other approaches to the measures of R/K/G paradigm. As the measurement status of know responses is less clear (Gardiner, Ramponi, & Richardson-Klavehn, 1998; Jacoby, Yonelinas, & Jennings, 1997), only hits and false alarms were studied for this type of recognition.

### 3.2. Processing-speed test

In the *letter-comparison test* (Salthouse, 1990), participants were presented with a page containing pairs of letters (X-O). The participants were instructed to decide whether the two members of the pair were identical or not, and to tick the 'identical' or 'different' column accordingly. The dependent measure was the number of items answered correctly within 30 s.

### 3.3. Executive task

The *Wisconsin Card Sorting Test* (WCST-Modified, Nelson, 1976) is a standardized test designed to measure set formation and attentional shift, and as such is thought to assess executive function (Lezak, 1995). This test requires participants to classify cards varying in the color, shape and number of geometric drawings according to information provided by the examiner. The WCST is widely used in clinical settings to detect cognitive impairments associated with frontal lesions (Stuss & Benson, 1986). The specific measure retained here was the number of perseverative errors, which are those most affected by age and the most representative of the executive function factor (Bryan, Luszck, & Pointer, 1999).

## 4. Results

The means and standard deviations for overall recognition, R, K and Guess responses and the scores for executive and processing speed measures, as the function of age, are presented in Table 2.

Separate analyses of variance (ANOVA) were performed on these measures.

Table 2
Means and standard deviations for recognition and false alarm measures, executive tasks and processing speed as a function of age

| | Young ($n = 24$) | | Old ($n = 24$) | | $F(1.46)$ |
|---|---|---|---|---|---|
| | *M* | SD | *M* | SD | |
| Hits | | | | | |
| Overall recognition | .64 | .14 | .51 | .19 | 6.66* |
| Remember | .30 | .16 | .18 | .13 | 6.71* |
| Know | .29 | .16 | .29 | .19 | 0.13 |
| Guess | .05 | .04 | .04 | .04 | 2.11 |
| A′ | | | | | |
| Overall recognition | .84 | .06 | .79 | .08 | 6.79* |
| Remember | .78 | .08 | .68 | .14 | 8.04* |
| False alarms | | | | | |
| Overall recognition | .12 | .01 | .14 | .13 | 0.81 |
| Remember | .02 | .02 | .03 | .05 | 1.52 |
| Know | .06 | .07 | .07 | .06 | 0.38 |
| Guess | .04 | .04 | .04 | .08 | 0.03 |
| Executive function | | | | | |
| WCST perseverative errors | 0.04 | 0.02 | 0.75 | 4.88 | 8.8** |
| Processing speed | | | | | |
| Letter-comparison | 35.08 | 5.04 | 25.5 | 6.34 | 33.57*** |

*Note.* *$p < .05$; **$p < .01$; ***$p < .001$; WCST, Wisconsin Card Sorting Test.

### *4.1. Remembering and knowing measures*

The analyses revealed a significant age effect on overall recognition and R responses, but not on K responses. For false alarms, the separate analyses of variance showed no significant age effect on overall recognition, nor on R or K responses. Analyses with the A′ discrimination index revealed the same pattern of results reported above for R responses and overall recognition. Thus, the recognition performance of older participants decreased, and more specifically their R responses. According to our hypothesis, recognition associated with conscious recollection (R responses) is impaired in aging, and the age-related decline observed in recognition performance is due to a decline in this type of response.

### *4.2. Executive functions and processing-speed measures*

As predicted, separate analyses of variance performed on these measures revealed a significant age effect, indicating that executive function and processing-speed performance decreased with age.

### *4.3. Correlations between group, processing speed, executive functioning and memory measures*

To examine the relationship between executive functioning, processing speed and responses corresponding to the two states of awareness, we computed correlations which are presented in Table 3. As recommended by

Table 3
Pearson correlations between age group, "R" responses, "K" responses, executive function and processing speed measures

| | Age group | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| 1. Remember (hits) | −.36** | | | | |
| 2. Remember (A′) | −.38** | .77*** | | | |
| 3. Know (hits) | .02 | −.51*** | −.48*** | | |
| 4. Executive function | .40** | −.48** | −.69*** | −.09 | |
| 5. Processing speed | −.64*** | .35* | .42** | −.05 | −.55*** |

*Note.* *$p < .05$; **$p < .01$; ***$p < .001$.

Bryan and Luszck (1996), the age group variable was used rather than individual age in correlations analyses and in all regression analyses. As participants were sampled from two age groups, age was not normally distributed in this study, and correlations involving this type of distribution tend to be inflated because of overestimation of the range of scores. Therefore, age was coded as a qualitative variable (young = 1, old = 2). The correlation matrix indicated that age group correlated with all measures, except K responses. R responses correlated with executive function and processing-speed measures. Moreover, processing-speed measure correlated with executive functioning measure. Another correlations analysis was realized using the individual age rather than age group, and it revealed the same pattern of results reported above. These results suggest that R responses were related to processing-resource whereas K responses were not. On the basis of these correlations, two regression analyses on R responses (hits proportion and A′) were performed to investigate the extent to which processing resources accounted for age-related differences in R responses.

### 4.4. Hierarchical regression analyses

As shown by the correlations matrix, there was a high correlation between executive functioning and processing speed ($r = -.55$). To avoid the possibility of the proportion of variance explained by one factor being simply a reflection of the considerable overlap of executive functioning and processing speed, four separate regression analyses were conducted. The mediating effect of executive and processing-speed measures on the relationship between age group and R responses (hits proportion and A′) was assessed using hierarchical multiple regression analyses. The results of these analyses are shown in Table 4.

Four regression analyses were evaluated for R responses, two for the proportion of hits and two for the A′ discrimination index. In the first (Analysis 1), we entered the different factors singly to examine whether processing speed accounted for a significant proportion of variance in R responses, and whether prior entry of this variable reduced the contribution of age group to a non-significant amount. It also examined whether the executive functioning continued to account for a significant amount of R response variance when processing speed measures were entered first. The same procedure was repeated for Analysis 2, with executive functioning replacing processing speed. It examined whether executive functioning accounted for a significant proportion of R response variance, and whether the processing speed continued to account for a significant amount of R responses variance with prior entry of executive functioning measure.

#### 4.4.1. R responses (hits)

Analysis 1 shows that processing speed predicted 14% of the variance in remembering when entered alone and that, after controlling for processing speed, age group added only 4% to the variance, which is not significant. Analysis 1 shows that executive functioning, after controlling for processing speed and age group, added 11% to the variance in R responses, which is significant. Analysis 2 shows that executive functioning accounted for 24% of the variance in remembering when entered first, and that age group did not continue to predict memory performance once executive functioning had been controlled. Analysis 2 shows that processing speed no longer predicted R responses after executive functioning had been entered. The first analysis underlines that

Table 4
Hierarchical regression analyses predicting "R" responses from age, executive and processing-speed measures

| Analyses | Remember responses (hits) | | | Remember responses (A′) | | |
|---|---|---|---|---|---|---|
| | Variable | $R^2$ | $R^2$ modified | Variable | $R^2$ | $R^2$ modified |
| Analysis 1 | Processing Speed | .14 | .14* | Processing speed | .17 | .17** |
| | Age group | .18 | .04 | Age group | .20 | .03 |
| | Executive functioning | .29 | .11* | Executive functioning | .49 | .29*** |
| Analysis 2 | Executive functioning | .24 | .24* | Executive functioning | .48 | .48*** |
| | Age group | .29 | .05 | Age group | .49 | .01 |
| | Processing speed | .29 | .00 | Processing speed | .49 | .00 |

*Note.* * $p < .05$; ** $p < .01$; *** $p < .001$.

executive functioning adds a significant and independent contribution to R response variance, over and above processing speed.

#### 4.4.2. R responses ($A'$)

Analysis 1 shows that processing speed predicted 17% of the variance in remembering when entered alone and that, after controlling for processing speed, age group added 3% to the variance, which is not significant. It shows that executive functioning, after controlling for processing speed and age group, added 29% to the variance in R responses, which is significant. Analysis 2 shows that executive functioning accounted for 48% of the variance in remembering when entered first, and that age group did not continue to predict remembering once executive functioning had been controlled. It shows that processing speed no longer predicted R responses after executive functioning had been entered. The second analysis confirmed that executive functioning adds a significant and independent contribution to R response variance over processing speed and thus that the greatest and central mediator of the variance on R responses was the executive factor and not the processing speed factor.

Two important findings emerge from these hierarchical regression analyses: firstly, the executive function factor appeared as the only reliable predictor of variance in R responses. Secondly, the percentage accounted for by the group factor was not significant in all analyses, which indicates that executive functioning was the mediator of the age-related variance in R responses.

## 5. Discussion

The present study illustrated a number of points concerning the distinction between the two types of responses associated with recognition memory. The main goal of the study was to use the processing-speed and executive-function hypotheses to explain the age-related effect in remembering associated with an episodic memory task. Our first objective was to confirm differential age-related effects on R and K responses. The results showed that there was a difference in recognition between younger and older adults, the number of R responses decreasing with age. This result is in line with previous studies, in which older participants were impaired in recollective experience (Bastin et al., 2004; Bunce, 2003; Bunce & Macready, 2005; Clarys et al., 2002; Comblain et al., 2004; Fell, 1992; Lövden et al., 2002; Parkin & Walter, 1992; Perfect & Dasgupta, 1997; Perfect et al., 1995; Piolino et al., 2006; Prull et al., 2006). We also found that K responses were not disrupted in the older group. This finding is in line with six studies that found a decrease in R responses with age, but no change in K responses (Bunce, 2003; Clarys et al., 2002; Comblain et al., 2004; Fell, 1992; Lövden et al., 2002; Perfect & Dasgupta, 1997) but is disagreed with other (Bastin et al., 2004; Bunce & Macready, 2005; Parkin & Walter, 1992; Perfect et al., 1995, exp 2b; Piolino et al., 2006; Prull et al., 2006). According to the different measurement models of R/K, R responses can be interpreted in different ways, as loading relatively highly on recollection (Jacoby et al., 1997), episodic memory (Tulving, 1985), high confidence recognition memory (Donaldson, 1996), specific memory (Rotello et al., 2004), or associative memory (Murdock, 2006). Nevertheless, at the present time, it seems premature to interpret the results based on a single approach because there appears to be disagreement in the literature. For that reason, in our discussion we focus on the observable description, i.e. R responses, remembering or/and recollective experience.

The second main objective of this paper was to determine whether the age-related differences in remembering could be explained by age-related differences in executive functioning and processing speed. First, with regard to the executive function hypothesis, this experiment confirmed that older participants show a marked decline in executive functioning (see, West, 1996). We also observed a correlation between executive functioning and R responses, higher levels of R responses being reliably correlated with the number of perseverative errors on the WCST. This observation supports Parkin and Walter's (1992) findings of a correlation between the WCST and R responses among elderly subjects. In the same, concerning processing speed, we observed that younger adults were faster at the processing speed task than older participants. This finding is in line with Salthouse's (1996) processing speed theory and with various studies (Bryan & Luszck, 1996; Fisk & Warr, 1996; Sliwinski & Buschke, 1997; Verhaeghen & Salthouse, 1997). On the one hand, our study showed a positive correlation between processing speed and R responses, whereas K responses were not processing speed dependent. These observations are in line with previous studies (Bunce & Macready, 2005; Clarys et al., 2002; Lövden et al., 2002).

The hierarchical analysis showed two important findings. Firstly, it indicated that the variance in R responses was related to executive functioning and that executive functioning mediated age-related variance in remembering. Secondly, it indicated that age-related variance in remembering was also related to processing speed. Indeed, when processing speed was entered alone, it explained a significant proportion of variance in R responses, and the age group factor was no longer significant after entering the processing speed factor. However, regression analysis showed that when executive functioning was entered first, processing speed added no substantial variance to remembering. By contrast, the reverse was not true, and executive functioning added substantial variance once processing speed had been entered. Thus, our data suggest that executive functioning is a more fundamental factor mediating age-related differences than processing speed. As executive functioning is crucial to the relationship between age and remembering, it is important to examine the reason for the relationship between executive functioning and R responses.

The executive function could enable appropriate strategies to be used at encoding and recognition to improve the memory trace. This is in line with the idea that frontal lobe dysfunction does not produce a decrease of the storing capacity in memory but leads to modifications in strategic processes accompanying mnemonic activity, such as initiation, execution and control of strategies occurring during information encoding and retrieval (Moscovitch, 1992). One possibility is that the reduction of the executive function has an effect during information encoding (Bunce, 2003). In concrete terms, executive function deterioration reduces elderly people's ability to initiate the encoding of target information appropriately for a durable explicit representation. The more episodic details are associated with the word encoding, the more the conscious experience of re-living an event is likely to occur (Mäntylä, 1993; Perfect & Dasgupta, 1997). Peripheral information, such as episodic details, may require more controlled frontal processing to ensure that it is attended to, adequately encoded, and represented in memory. Integrative encoding processes depend on the frontal lobes (see Buckner, 2003, for a review; Wheeler et al., 1997) which are needed to initiate and carry out the control processes ensuring that all aspects of an experience are encoded. In fact, executive functioning contributes to the ability to use self-initiated strategies when encoding information, such as the organisation of material or abundant cue encoding (Gershberg & Shimamura, 1995; Stuss et al., 1994). Bunce (2003) showed experimentally a relationship between the cognitive support of the task and executive functioning. He suggested that the provision of cognitive support to guide elaboration and structuring attenuates memory deficits in older adults due to lower frontal lobe function. Another possibility is that executive deficit reduces the efficiency of retrieval processes. These ideas concerning the role of executive functioning in the retrieval of episodic details are clearly speculative and were not directly addressed by the present experiment. Nevertheless, other evidence has suggested a role for executive functioning at retrieval (Senkfor & Van Petten, 1998; Van Petten, Senkfor, & Newberg, 2000), and we suspect that there may be a trade-off between encoding and retrieval in the extent to which executive functioning is involved in recollective experience. Remembering aspects of an experience, which is the case with R responses, may be more difficult than just recalling words and thus may require more controlled processing. When memory retrieval is not simple or effortless, executive functioning may be required to formulate and initiate search strategies and to engage in complex decision processing concerning the outcome of the search. The possibility that executive function decline reduces the efficiency of retrieval processes requires further investigation.

With regard to processing speed, the regression analysis shows clearly that it can be considered as a mediator of age-related variance in remembering. Indeed, when it was entered as the sole predictor, it explained a significant variance of age-related variance in R responses. This observation does not contradict the findings of previous studies that age differences in recollective experience are determined by processing speed (Bunce & Macready, 2005; Clarys et al., 2002; Lövden et al., 2002). However, when the two factors of processing resources compete, the processing speed factor does not continue to explain the age-related variance in R responses, which contradicts Bunce and Macready's (2005) study.

One possibility to explain this discrepancy is the different tests used. In the earlier study (Bunce & Macready, 2005), the digit-symbol substitution test (DSST) of the WAIS-R (Wechsler, 1981) was used. There are good reasons to suppose that the DSST does not just measure relatively low-level perceptual processes, and when it is used as a covariate in explaining age-related memory variance, performance could be determined by participants' ability to remember the digit symbol pairs. In this connection, Parkin and Java (1999) showed that the DSST attenuated age-related differences in executive function, in contrast to the digit cancellation task (DC; Bishop & Curran, 1995) which is a speed task requiring virtually no memory load, minimal attentional demands and only a small motor component. The authors concluded that the influence of the DSST on age-related cognitive changes was linked to its association with higher intellectual processes and not to perceptual speed. Thus one can suggest that this task assessed executive functioning more than processing speed. Therefore, if previous study showed the involvement of processing speed to explain the age-related difference in remembering, this could be because they used the DSST which is based on high level processing. In contrast to this study, we used a task which specifically evaluates perceptive processing speed without involving high level processing, and we found no evidence that this factor is involved in the age-related decrease in R responses.

In summary, the results of this study indicate that when executive functions and processing speed are tested concurrently, executive function is a better predictor of the age-related change in remembering than processing speed. By contrast, "knowing" did not rely on processing resources (processing speed and executive function) and was unaffected by aging. The association of R/K paradigm and the executive decline hypothesis (West, 1996) seems to provide some interesting perspectives. In order to study executive functioning and its links with episodic memory in aging, it would be interesting to study more specifically the precise nature and organisation of executive functions involved in the age-related decrease in remembering, using recent theoretical models of executive control such as that proposed by Miyake et al. (2000).

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