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The effects of aging on location-based and distance-based processes in memory for time

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### Abstract

Retrieving when an event occurred may depend on an estimation of the age of the event (distance-based processes) or on strategic reconstruction processes based on contextual information associated with the event (location-based processes). Young and older participants performed a list discrimination task that has been designed to dissociate the contribution of both types of processes. An adapted Remember/Know/Guess procedure (Gardiner, Java, & Richardson-Klavehn, 1996) was developed to evaluate the processes used by the participants to recognize the stimuli and retrieve their list of occurrence. The results showed that aging disrupts location-based processes more than distance-based processes. In addition, a limitation of speed of processing and working memory capacities was the main predictor of age-related differences on location-based processes, whereas working memory capacities mediated partly age differences on distance-based processes.

Keywords: Episodic memory, Aging, Consciousness States, Recognition Memory.

PsycINFO Classification: 2343 Learning and memory, 2380 Consciousness States.

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## 1. Introduction

Memory for the temporal context of events appears to be one important aspect of episodic memory (Johnson, Hashtroudi, & Lindsay, 1993; Tulving, 1999; Wheeler, Stuss, & Tulving, 1997). A number of studies have shown that the ability to remember when an event occurred declines with increasing age (Daum, Gräber, Schugens, & Mayes, 1996; Fabiani & Friedman, 1997; Kausler, Salthouse & Sauls, 1988; McCormack, 1982, 1984; Newman, Allen, & Kaszniak, 2001; Parkin, Walter, & Hunkin, 1995; Spencer & Raz, 1994; Vakil & Tweedy, 1994; Wegesin, Jacobs, Zubin, Ventura, & Stern, 2000; but see Perlmutter, Metzger, Nezworski & Miller, 1981, for contradictory findings). Moreover, this decline of memory for temporal context appears to be disproportionate compared to the effect of aging on item memory (Fabiani & Friedman, 1997; Newman et al., 2001; Parkin et al., 1995).

However, the reasons for this sensitivity of memory for temporal context to aging are not clear. Usually, the effect of age on memory for time has been explained by a frontal lobe dysfunction associated with aging. This hypothesis comes from two lines of evidence. On one hand, the prefrontal cortex is one of the cerebral regions preferentially affected by aging (see Raz, 2000, for a review). On the other hand, numerous neuropsychological data have demonstrated the vulnerability of temporal context memory to frontal lobe lesions (Kesner, Hopkins & Fineman, 1994; Kopelman, Stanhope & Kingsley, 1997; Mangels, 1997; McAndrews & Milner, 1991; Milner, Corsi & Leonard, 1991; Shimamura, Janowsky & Squire, 1990). Indirect support to the “frontal lobe decline” explanation for age-related differences on temporal context memory was provided by experiments that reported a significant correlation between performance on measures of executive functioning (especially

the Wisconsin Card Sorting test –WCST-- and verbal fluency) and performance on a list discrimination task (Parkin et al., 1995) or on recency judgments (Fabiani & Friedman, 1997). More direct evidence comes from functional neuroimaging (Cabeza, Anderson, Houle, Mangels & Nyberg, 2000) and event-related potentials (ERP, Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999; Wegesin, Friedman, Varughese, & Stern, 2002). More specifically, the right prefrontal activation (Cabeza et al., 2000) and the frontal late-onset ERP effect (Trott et al., 1999; Wegesin et al., 2002) that were associated with memory for the temporal context of events in young adults were absent in older adults.

The assumption behind the “frontal lobe decline” interpretation of age effects on memory for temporal context is that performance on tasks assessing memory for time depends on processes which are sensitive to frontal lobe function. For example, Mangels (1997) has suggested that the frontal lobes are important for providing the encoding and/or retrieval strategies necessary to reconstruct the temporal order of events. Recently, Friedman (1993, 1996, 2001) has proposed that memory for the times of events relies on at least two types of processes: distance-based and location-based processes. Distance-based processes involve evaluation of the time elapsed since the event occurred. The vividness, the elaborateness or the accessibility of the memories could give some indication regarding the age of the memories. Various theories have been proposed to describe how the amount of time elapsed since the occurrence of an event can be assessed. According to the strength theory (Hinrichs, 1970), which assumes that the strength of the memory trace declines with the passage of time, an individual can judge weak traces as more distant in time than stronger traces. Alternatively, Brown, Rips and Shevell (1985) suggested that the age of the memories could be assessed on the basis of the amount of information that can be recalled about the events. By contrast, location-based processes involve the reconstruction of the time of occurrence based on the contextual information encoded with the event. The reconstruction is made by reference to

time patterns, such as conventional patterns (e.g. the parts of the day), personal patterns (e.g. when I was at University) or experiment structures (e.g. the beginning of a study list). In other words, location-based processes depend on recollecting the contextual information associated to the event, linking this information with some time pattern, and inferring when the event probably occurred. If Brown et al.'s (1985) view of distance-based processes is correct, this would imply that both types of processes relied on an evaluation of the same kind of information: the associated contextual attributes. However, there are critical differences between them. Whereas distance-based processes involve a rapid assessment of rough distance in the past, location-based processes are an active search for, and an interpretation of contextual information, with high resolution. Thus, whereas distance-based processes are fast and require relatively few resources, location-based processes are slow, effortful and strategic. In addition, Friedman (2001) hypothesised that the frontal lobes may be particularly important for location-based processes, as neuropsychological studies have shown that frontal lobe damage altered the ability to reconstruct both temporal and non-temporal information (Mangels, Gershberg, Shimamura, & Knight, 1996; Shimamura, Janowsky, & Squire, 1990).

Usually, the experimental paradigms used to assess memory for time do not allow separation of the contributions of these two types of processes. Recently, Curran and Friedman (2003) have developed a method for dissociating distance-based and location-based processes. In this procedure, the participants studied three lists of pictures on two consecutive days. The first day, the first study list (list 1) was presented. On the second day, the other two lists (lists 2 and 3) were studied, followed by two memory tests. Importantly, the study context was manipulated by changing the environment in which the list was presented and the type of processes required by the encoding task. Lists 1 and 2 were both presented in the same context, but the context was different for list 3. A first memory test (Day test) required participants to discriminate between pictures from list 1, pictures from list 2 and new pictures.

The task consisted in indicating whether each picture had been presented on the first day (“yesterday”, list 1), on the second day (“today”, list 2) or was a new one. As the context was constant across both lists, location-based processes involving contextual details should be difficult to use in this task. By contrast, because of the long interval between the study of lists 1 and 2, distance-based processes should be more effective (Friedman, 1996). The second memory test (Context test) involved pictures from list 2 and list 3 and new pictures.

Participants were asked to indicate whether the picture had been presented in the first or the second list studied “today” or was a new one. As lists 2 and 3 were close in time, distance-based processes should be less useful. But, as each list was studied in a different context, participants should rely more on location-based processes. Moreover, test instructions encouraged the participants to use distance-based processes in the Day test and location-based processes in the Context test. Post-task questionnaires confirmed that distance-based processes were more frequent in the Day test and location-based processes were more often used in the Context test.

Further, Curran and Friedman (2003) examined event-related brain potentials associated with these two temporal memory tests. They found that the late-onset frontal ERP effect (800-1800 ms) often found in source memory tasks (e.g. Donaldson & Rugg, 1998; Tendolkar & Rugg, 1998; Trott et al., 1999; Wilding, 1999) were related to location-based processes, but not to distance-based processes. This supports the idea that the frontal regions may play an important role in memory for the times of events by underlying the location-based processes.

In line with the hypothesis that the age-related decrements of memory for the temporal context result from neuroanatomical changes in the prefrontal cortex, we hypothesized that aging should particularly affect the location-based processes. By contrast, distance-based processes may be more resistant to aging. In order to test this hypothesis, we adapted the

method developed by Curran and Friedman (2003), also using pictures as materials, and administered it to a group of young adults and a group of older adults. The main changes to the procedure consisted of modifying the testing phase. A two-step recognition procedure was used, where the participants were first asked to say whether they recognized the test items, and second to indicate in which list the recognized items were encountered. In addition, the processes used by the participants to discriminate between old and new items and between two lists were assessed on an item-by-item basis, by means of the Remember/Know/Guess procedure (Gardiner, Java, & Richardson-Klavehn, 1996). The possibility to report Guess responses was provided in order to avoid that guesses and extremely low confidence responses are included in Know responses. The Remember/Know/Guess procedure was adapted to allow a classification of the list discrimination judgments according to the distinction between location-based and distance-based processes.

In addition, tests measuring speed of information processing and working-memory capacities were administered. Indeed, it has been suggested that the effect of age on memory could be mediated, at least partly, by a general slowing of the processing (Salthouse, 1996) and lower working-memory capacities (Salthouse, 1991). Therefore, we examined whether speed of information processing and working memory resources, first decrease with increasing age and, second predict list discrimination performance based on location-based or distance-based processes.

## 2. Method

### *2.1. Participants*

A group of 48 young adults (from 18 to 28 years old) and a group of 48 older adults (from 60 to 79 years old) took part in this experiment. Detailed characteristics of the two groups are presented in Table 1. There were 24 women and 24 men in each group. The young

group reported on average more years of education than the older group,  $t(94) = 3.07$ ,  $p < 0.01$ . On a vocabulary test (Mill Hill, part B, 33 items; Deltour, 1993), older adults performed better than the young group,  $t(94) = -2.55$ ,  $p < 0.05$ . All the participants were given a questionnaire about medical antecedents, current health state and potential perceptual (visual and auditory) disorders. None of them reported a neurological or a psychiatric condition which could interfere with cognitive functioning. On a scale assessing current health state (10-point scale from 1 *very bad* to 10 *excellent*), older participants rated their health state as less good as did the young participants, but still high on the scale,  $t(94) = 2.23$ ,  $p < 0.05$ . In addition, the participants were able to use an appropriate correction for visual or auditory disorders when necessary. Finally, the older participants were also screened for cognitive decline by means of the Mattis Dementia Rating Scale (Mattis, 1973), adapted in French (GRECO, 1995, 1997). Their scores ranged from 129 to 143 (out of 144) and were within the normal range according to their age and education.

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## 2.2. Materials

Six sets of 42 line drawings (representing animals, fruits, tools, etc.) were composed on the basis of two picture databases (Martein, 1995; Snodgrass & Vanderwart, 1980). The sets were matched on the basis of the ratings provided in the databases, for visual complexity (on a 5-point scale, from 1 = *very simple* to 5 = *very complex*,  $M = 3.05$ ,  $F(5, 205) = 0.84$ ,  $p > 0.52$ ) and familiarity of the pictures (on a 5-point scale, from 1 = *very unfamiliar* to 5 = *very familiar*,  $M = 4.91$ ,  $F(5, 205) = 1.00$ ,  $p > 0.42$ ). Four sets were used for the study phase: one served for the study list on Day 1, two sets were mixed to create the first list of Day 2 (at retrieval, one of the set would be included in the Day test and the other in the Context test),



and one set was used for the second list on Day 2. The last two sets served as distractor items for the test phase, one for the Day test and one for the Context test. The assignment of a set to a list was counterbalanced across participants so that each set were used equally often as target list for the Day test, target list for the Context test and distractors.

### 2.3. Design and procedure

The participants were tested individually on two consecutive days. Each participant began the session at the same time on both days.

The list discrimination task was administered across the two days. On Day 1, a study list of 42 pictures was presented. On Day 2, a list of 84 pictures and a list of 42 pictures were presented one after another. The stimuli appeared in the middle of a computer screen and stayed for 4 s each. Within each list, the pictures were presented in a random order, different for each participant. The participants had to name each picture aloud.

In order to create two different contexts, the environment of the experiment and the type of processing made on the stimuli were manipulated. There were two types of environment. In the first one (environment A), the testing room was a 3 by 4 m well-lighted room with a lot of furniture. The participants faced a window. The stimuli were presented against a yellow background on a fixed personal computer with a 17-inch screen. In the second environment (environment B), the testing room was a darker 3 by 4 m room, including only a table, two chairs, a cupboard and a piano. The curtains were closed and the participants seated with their backs to the window. The stimuli were presented on a portable personal computer with a 12-inch screen, and against a red background screen. In addition, the type of processing made on the stimuli consisted of two different types of judgment. The first judgment was a pleasantness rating. The participants had to say for each picture whether they found it pleasant on a 5-point scale (from 1 *very unpleasant* to 5 *very pleasant*). The second

judgment was a frequency rating. The participants had to say whether they encounter the objects represented on the picture frequently or not in their everyday life (from 1 *very infrequent* to 5 *very frequent*). The association of an environment with a type of judgment was counterbalanced across the participants. Half of the participants made the pleasantness judgments in the environment A and the frequency judgments in the environment B, and the other half made the pleasantness judgments in the environment B and the frequency judgments in the environment A.

The list presented on Day 1 and the first list of Day 2 were presented in the same context. After the presentation of the first list on Day 2, the participants moved to the other room and viewed the second list in the other context. The contexts in which the first two lists and the third list were presented were rotated across the participants. After the presentation of the second list on Day 2, the participants moved to a third room, different from the other two. Then, after a distracting task of around 5 min (letter comparison task), they performed two list discrimination tests, a Day test and a Context test. The test items were presented on a portable personal computer, on a white background screen. Half of the participants began with the Day test, and the other half with the Context test.

In the Day test, the 42 pictures from the list presented on Day 1 and 42 pictures from the first list of Day 2 were mixed with 42 distractors. They were presented one by one, in a semi-random order fixed for all the participants. The first 6 items consisted of 2 items from each list and served as practice items. They were not considered when calculating performance scores. The test involved 4 successive judgments. For each picture, the participants had to say first whether they had seen it in the study phase (recognition part). In addition, when recognizing a picture, they had to indicate whether they recollected it (Remember), found it familiar (Familiar) or just guessed. They were instructed that Remember responses were to be given when they remembered the encoding episode of the

picture, whereas Familiar responses corresponded to a feeling of familiarity in the absence of recollection. Written instructions were provided (see Appendix). The experimenter also gave additional examples orally and encouraged the participant to propose an example. Then, for pictures that the participants recognized, they had to indicate whether the picture was presented on Day 1 (yesterday) or on Day 2 (today) (list discrimination part). For each response, they reported whether they remembered the list of occurrence because they retrieved the encoding episode (Remember), attributed the picture to such list on the basis of its familiarity (Familiarity), or picked up a list by chance (Guess). Written instructions were provided (see Appendix) and understanding of the instructions was checked by asking the participant to propose an example of each type of response. In addition, participants were asked to provide verbal justifications for each response.

In the Context test, the remaining 42 pictures from the first list of Day 2 and the 42 pictures of the second list of Day 2 were mixed with 42 distractors. The procedure was the same as for the Day test, with the exception that, for recognized items, they had to indicate whether the picture appeared in the first or the second list of Day 2 (rather than “yesterday or today”).

As there were many different responses to make, each question was presented via successive messages. First, for the recognition part, each picture was accompanied by a label at the bottom of the screen, instructing participants to indicate whether they recognized the picture by pressing one of two keys. If the answer was “no”, the next test item was shown. After “yes” answers, a message appeared on the screen, asking for the Remember/Familiar/Guess judgment on the recognition decision. Then, the instructions “In which list have you seen this picture?” (“Yesterday or today?” in the Day test and “list 1 or list 2?” in the Context test) were presented, followed by a message asking for a Remember/Familiar/Guess judgment on the list-discrimination response.

Additionally, an updating task was administered. This task, adapted from Morris and Jones (1990; Van der Linden, Brédart, & Beerten, 1994), provides a measure of working-memory capacities. In this task, the participants watched strings of 6, 8, 10 or 12 consonants and then had to recall serially the last 6 letters. They did not know in advance what would be the length of the sequence. There were four trials at each length. The measure was the total number of correctly recalled items in each serial position for the lists of 8, 10 and 12 letters, that is the lists that required updating operations.

Furthermore, a measure of speed of processing was obtained by means of a letter comparison task constructed after Salthouse and Babcock (1991). Pairs of consonants appeared on the screen. The participants had to indicate as quickly as possible whether the two letters were identical or different. Mean reaction time for correct “identical” responses was taken as the measure of speed.

The session on Day 1 began with the administration of the Mattis Scale to the older participants and the questionnaire on past and current health status and perceptual disorders. Then, the participants performed the updating task. This was followed by the presentation of the first list of 42 pictures in one of the context (room 1 or 2). Finally, the participants were administered the Mill Hill vocabulary test. The session on Day 2 began with the presentation of the second list of pictures in one context and of the third list in the other context. Then, when the participants had moved to the third room, they performed the letter comparison task and, finally, the two list discrimination tests. The Mattis Scale, the questionnaire, the updating task and the Mill Hill vocabulary test were always administered in the third room, which was used for the test phase of the list discrimination task.

### 3. Results

Due to a technical problem during the administration of the Context test, the data of one young participant were discarded. In addition, as young and older groups differed in terms of number of years of education, the latter was introduced as a covariant in all the analyses. The two age groups also differed in terms of reported subjective health, but when this variable was introduced as a covariate, the results remained the same.

#### 3.1. Recognition memory

The mean proportions (and standard deviations) of “yes” responses to target pictures (hits) and distractor pictures (false alarms) of each age group in the Day test and the Context test are presented in Table 2. These two scores were submitted to an analysis of variance (ANOVA) with Age Group (young versus older) as between-subject variable and Task (Context test versus Day test) as repeated measure. Regarding the hit rates, there was a main effect of Age group,  $F(1, 92) = 5.76, p < 0.05$ , indicating that the young participants ( $M = 0.93$ ) recognized more target pictures than the older participants ( $M = 0.89$ ). There was no effect of the Task,  $F(1, 93) = 2.09, p > 0.15$ , and no interaction,  $F(1, 93) = 0.45, p > 0.50$ . Concerning the false alarms, older participants falsely recognized distractor items more often than did the young participants,  $F(1, 92) = 24.70, p < 0.01$ . There were also more false alarms in the Day test than in the Context test,  $F(1, 93) = 24.56, p < 0.01$ . The interaction approached significance,  $F(1, 93) = 3.28, p < 0.07$ .

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Global recognition accuracy and response bias were measured by the Signal Detection measures, the  $d'$  score and the criterion  $c$  (Macmillan & Creelman, 1991). An ANOVA

performed on  $d'$  scores indicated that recognition accuracy was higher in the young participants ( $M = 3.37$ ) than in the older participants ( $M = 2.59$ ),  $F(1, 92) = 35.86$ ,  $p < 0.01$ . Discrimination performance was also greater in the Context test ( $M = 3.22$ ) than in the Day test ( $M = 2.73$ ),  $F(1, 93) = 43.52$ ,  $p < 0.01$ . The interaction was not significant,  $F(1, 93) = 0.01$ ,  $p > 0.91$ . As for the criterion  $c$ , analyses revealed that young participants ( $M = 0.07$ ) had a more conservative response criterion than the older participants ( $M = -0.06$ ),  $F(1, 92) = 5.54$ ,  $p < 0.05$ . The response bias also differed between the Context test ( $M = 0.06$ ) and the Day test ( $M = -0.06$ ),  $F(1, 93) = 11.64$ ,  $p < 0.01$ . There was no interaction,  $F(1, 93) = 0.52$ ,  $p > 0.47$ . Globally, the criterion  $c$  values were very close to 0, thus suggesting that the different proportions of old and new items in the recognition test did not affect the response bias, as it was neither liberal, nor severe.

Phenomenal characteristics of recognition memory were examined by looking at the Remember, Familiar and Guess responses. The proportions of each type of response for targets and distractors are presented in Table 2. Around 38 % of the Guess responses were made to targets and 62 % to distractors, thus suggesting that this category succeeded in attracting very low confidence responses. Each type of response was submitted to an ANOVA with Age Group as a between-subject variable and Task as a within-subject variable. Concerning responses to the targets, the analysis of Remember responses indicated that young participants reported this type of response more often than older participants,  $F(1, 92) = 13.53$ ,  $p < 0.01$ . Remember responses were also more frequent in the Context test than in the Day test,  $F(1, 93) = 89.94$ ,  $p < 0.01$ . In addition, the significant interaction,  $F(1, 93) = 8.12$ ,  $p < 0.01$ , suggested that the age differences on Remember responses were greater in the Context test ( $F(1, 92) = 18.23$ ,  $p < .01$ ) than in the Day test ( $F(1, 92) = 5.86$ ,  $p < .05$ ).

As for the Familiar responses, they were more frequent in older participants than in young participants,  $F(1, 92) = 5.73$ ,  $p < 0.05$ . The effect of the task was significant,  $F(1, 93) =$

45.84,  $p < 0.01$ , showing that Familiar responses were more often used in the Day test than in the Context test. Finally, there was a significant interaction,  $F(1, 93) = 7.13$ ,  $p < 0.01$ . Planned comparisons showed that older participants reported more Familiar responses than young participants in the Context test ( $F(1, 92) = 10.27$ ,  $p < 0.01$ ), but not in the Day test ( $F(1, 92) = 1.37$ ,  $p > 0.24$ ). Jacoby, Yonelinas and Jennings (1997) have suggested that if recollection and familiarity are independent, the contribution of familiarity to recognition is underestimated by the proportion of Know (here, Familiar) responses. When familiarity was measured by the Independent Remember/Know (IRK) procedure (Familiarity = proportion of Know responses /  $1 -$  proportion of Remember responses, Jacoby et al., 1997), the analyses did not reveal any significant effect (effect of Age group,  $F(1, 92) = 0.22$ ,  $p > 0.63$ ; effect of Task,  $F(1, 93) = 0.32$ ,  $p > 0.57$ ; interaction,  $F(1, 93) = 0.38$ ,  $p > 0.53$ ).

Finally, the analysis of the Guess responses given to targets revealed that these responses were more often used by the older participants than by the young group,  $F(1, 92) = 4.44$ ,  $p < 0.05$ . There was a main effect of Task, indicating that guesses were more frequent in the Day test than in the Context test,  $F(1, 93) = 54.85$ ,  $p < 0.01$ . There was no interaction,  $F(1, 93) = 1.06$ ,  $p > 0.30$ .

Concerning the distractors, they were falsely recognized and classified as Remember responses in less than 2 % of the trials. The ANOVA did not reveal any significant effect. The analysis of Familiar responses to distractors showed that they were more frequent in older participants than young participants,  $F(1, 92) = 19.75$ ,  $p < 0.01$ . There were also more Familiar responses to distractors in the Day test than in the Context test,  $F(1, 93) = 6.68$ ,  $p < 0.05$ . The interaction was not significant,  $F(1, 93) = 1.88$ ,  $p > 0.17$  (similar effects were found when the IRK procedure was applied to Familiar responses). Finally, older participants gave more Guess responses to distractors than young participants,  $F(1, 92) = 10.50$ ,  $p < 0.01$ . These

responses were also more frequent in the Day test than in the Context test,  $F(1, 93) = 29.58$ ,  $p < 0.01$ . The interaction did not reach significance,  $F(1, 93) = 3.51$ ,  $p > 0.06$ .

### 3.2. List discrimination

Mean proportions of correct discrimination (and standard deviations) for each group in the Context test and in the Day test are reported in Table 3. An ANOVA with Age Group as a between-subject variable and Task as a within-subject variable was performed on these scores. The results indicated a main effect of Age Group,  $F(1, 92) = 72.97$ ,  $p < 0.01$ , where young participants remembered correctly the list of occurrence of the recognized pictures more often than older participants. There was also a main effect of Task,  $F(1, 93) = 19.06$ ,  $p < 0.01$ . List discrimination performance was better in the Day test than in the Context test. The interaction was significant,  $F(1, 93) = 16.10$ ,  $p < 0.01$ . Planned comparisons indicated that age-related differences were present in both tasks (Day test:  $F(1, 92) = 14.77$ ,  $p < 0.01$ , Context test:  $F(1, 92) = 81.81$ ,  $p < .01$ ). But, while young participants had similar performance in the Context test and in the Day test [ $F(1, 93) = 0.06$ ,  $p > 0.80$ ], older participants performed significantly better in the Day test than in the Context test [ $F(1, 93) = 35.46$ ,  $p < 0.01$ ].

When list discrimination performance was measured by a corrected score, which takes into account the probability of obtaining a given score by chance<sup>1</sup> (score  $z$ , Hunkin, Parkin, & Longmore, 1994), the results of the analyses were identical to those reported for the proportions of correct discrimination.

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Insert Table 3 about here

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Examination of the Remember, Familiar and Guess responses indicated which processes the participants used to retrieve the list of occurrence of the pictures. The verbal justifications revealed that Remember responses corresponded to processes which can be classified as location-based processes. Indeed, the majority of the responses were described as the utilization of an element of the context to infer the list of appearance of the picture by reference to temporal patterns. In the Context test, for 91 % of the responses, the participants recollected the type of judgment they made at encoding to retrieve the list of occurrence (e.g. “I said it was pleasant, so it was in list 1”). The next most frequent justifications were references to an element of the room where the subjects were (3 %, “I remember that when I saw this picture, I looked back and saw the piano”), retrieval of the position of the item in the list (3 %, “it was one of the last pictures I saw today”) and recollection of the color of the background (1 %, “I remember that the lemon, which is usually yellow, was on the red background”). In the Day test, the most frequent responses were remembering the position in the list (62 %) and an association with something the person did on the day of the presentation (27.5 %, “I know I have seen this fruit yesterday, because I ate one yesterday”). By contrast, Familiar responses were given for list discrimination based on distance-based processes. Indeed, almost all the responses (97 %) were justified as evaluating whether the picture was seen a long time ago or recently. Exceptionally (2.6 % of the responses), participants justified a Familiar response as “I just know it was this list”. Thus, in the remainder of the paper, we will speak of Remember responses/location-based processes and Familiar responses/distance-based processes in list discrimination, although the equivalence between Remember and Familiar responses on one hand and location-based and distance-based processes on the other hand may not be perfect.

The proportions of each response type are reported in Table 3. Each of them was submitted to a 2 (Age group) by 2 (Task) ANOVA, with Age Group being a between-subject

variable and Task a repeated measure. First, young participants reported using more Remember responses/location-based processes when discriminating the list than older participants,  $F(1, 92) = 24.15, p < 0.01$ . Remember responses/location-based processes were also more frequent in the Context test than in the Day test,  $F(1, 93) = 283.72, p < 0.01$ . In addition, the interaction was significant,  $F(1, 93) = 25.74, p < 0.01$ . Examination of the scores suggested that the age effect on the use of Remember responses/location-based processes was greater in the Context test than in the Day test, although the age differences were significant in the two tasks (Day test,  $F(1, 92) = 5.45, p < 0.05$ ; Context test,  $F(1, 92) = 22.32, p < 0.01$ ). It should be noted that, for both groups, the proportion of Remember responses/location-based processes were close to floor in the Day test.

Second, concerning the Familiar responses/distance-based processes in list discrimination, the main effect of Age group was significant,  $F(1, 92) = 4.40, p < 0.05$ . In addition, Familiar responses/distance-based processes were more frequent in the Day test than in the Context test,  $F(1, 93) = 4720.02, p < 0.01$ . The Age Group by Task interaction was also significant,  $F(1, 93) = 6.48, p < 0.05$ . This was due to the fact that young and older participants used Familiar responses/distance-based processes equally often in the Context test [ $F(1, 92) = 0.10, p > 0.75$ ], whereas older participants reported less use of Familiar responses/distance-based processes in the Day test than young participants [ $F(1, 92) = 13.94, p < 0.01$ ].

Finally, the analysis of Guess responses indicated that older participants picked up the list of occurrence of the pictures by chance more often than did the young participants,  $F(1, 92) = 15.42, p < 0.01$ . There was no main effect of Task,  $F(1, 93) = 0.39, p > 0.53$ , but the interaction was significant,  $F(1, 93) = 6.03, p < 0.05$ . Planned comparisons showed that older participants did not significantly differ in the proportion of Guess response in the two tests ( $p$

> 0.19), whereas the young group guessed more often in the Day test than in the Context test ( $p < 0.05$ ).

*Subgroups matched on item recognition memory.* In order to examine whether the age-related decline on memory for temporal context was disproportionate compared to item memory, a median split procedure was used to compare subgroups of young and older participants matched on item recognition performance, as measured by  $d'$  scores. The 24 young adults with the lowest  $d'$  scores and the 24 older adults with the highest  $d'$  scores were included in these subgroups. A comparison of their  $d'$  scores in both tasks indicated that they were properly matched (Context test, young:  $M = 3.15$ , old:  $M = 3.47$ ; Day test, young:  $M = 2.81$ , old:  $M = 2.72$ ;  $F(1, 46) = 0.97$ ,  $p > 0.32$ ). In addition, these subgroups did not significantly differ in terms of years of education,  $t(46) = -1.90$ ,  $p > 0.06$ .

The analysis of list discrimination performance (proportions of correct discriminations) showed the same results as previously reported. Indeed, a main effect of Age Group [ $F(1, 46) = 27.76$ ,  $p < 0.01$ ] and a main effect of Task [ $F(1, 46) = 18.04$ ,  $p < 0.01$ ] appeared. In addition, the significant interaction [ $F(1, 46) = 10.00$ ,  $p < 0.01$ ] showed that the age difference was significant on performance in the Context test ( $p < 0.01$ ), but not in the Day test ( $p > 0.08$ ). Moreover, although young participants performed in the same way in both tasks ( $p > 0.44$ ), older adults retrieved the correct list of appearance of the pictures more often in the Day test than in the Context test ( $p < 0.01$ ).

As for Remember responses/location-based processes, they were more frequent in young participants than in older participants,  $F(1, 46) = 10.31$ ,  $p < 0.01$ . These processes were also used more often in the Context test than in the Day test,  $F(1, 46) = 132.80$ ,  $p < 0.01$ . In addition, the significant interaction [ $F(1, 46) = 7.34$ ,  $p < 0.01$ ] revealed that the age-related decline of Remember responses/location-based processes was greater in the Context test than

in the Day test. Regarding Familiar responses/distance-based processes, the age-related difference did not reach significance,  $F(1, 46) = 3.76, p > 0.05$ . Moreover, these processes were used more often in the Day test than in the Context test,  $F(1, 46) = 222.39, p < 0.01$ . There was no interaction,  $F(1, 46) = 0.04, p > 0.83$ . Finally, Guess responses during list discrimination were more frequent in older participants than in younger participants,  $F(1, 46) = 16.32, p < 0.01$ . In addition, whereas older participants did not differ in how often they guessed in the two tasks ( $p > 0.10$ ), the young group reported more guesses in the Day test than in the Context test ( $p < 0.05$ ).

It should be noted that, in the above analysis, half of the results were dropped. Another way to control for recognition differences in the analysis of list discrimination performance consists in including recognition accuracy ( $d'$  scores) as covariate in the ANOVA performed on all the data. When doing so, the results led to similar conclusions as the median split procedure, with two exceptions: there was a trend for age differences in the Day test, but the difference was not statistically significant ( $F(1, 91) = 3.54, p > .06$ ) and there was no age difference in the use of Familiar responses/distance-based processes ( $F(1, 91) = 1.57, p > .21$ ).

### *3.3. Analysis of the list discrimination performance as a function of the recognition processes*

An item-by-item analysis was conducted in order to examine the probability of correctly retrieving the list of occurrence of a picture based on location-based and distance-based processes given that the participants made Remember and Familiar recognition decisions to the targets. Concerning first the Remember responses to the targets, in the Context test, they were followed by correct list discrimination decisions based on Remember responses/location-based processes in 83 % of the trials in the young group and in 64 % of the trials in the older group (the age-related differences were significant,  $F(1, 92) = 22.32, p < 0.01$ ) and Familiar responses/distance-based list discrimination were reported in only 10 % of

the trials (young: 9 %; old: 11 %, there was no effect of Age Group,  $p > 0.21$ ). By contrast, in the Day test, Remember responses/location-based processes were used less often (young: 9 %; old: 6 %) after the participants made a Remember response to the targets (the effect of Age Group was significant,  $F(1, 92) = 5.44$ ,  $p < 0.05$ ). However, in this test, most of the correct list discrimination decisions were based on Familiar responses/distance-based processes after Remember responses to the targets (young: 77 % and old: 67 %, the age differences being significant,  $p < 0.05$ ).

Second, when the recognition of the targets was based on familiarity, participants never reported Remember responses/location-based processes when attributing this familiar item to the correct list. Instead, they used primarily Familiar responses/distance-based processes to correctly retrieve the list, especially in the Day test (Day test, 65 % and Context test: 41 %,  $F(1, 93) = 193.43$ ,  $p < 0.01$ ) and there were no age-related differences,  $F(1, 92) = 0.09$ ,  $p > 0.76$ . As for list discrimination made using Guess responses, they were reported after Familiar responses to the targets in 21 % of the trials in the Context test and 11 % of the trials in the Day test,  $F(1, 93) = 21.65$ ,  $p < 0.01$ . In addition, they were more frequent in older participants than in young participants in the Context test ( $p < 0.01$ ), but not in the Day test ( $p > 0.06$ ).

### *3.4. Additional measures*

The mean scores (and standard deviations) obtained by young and older participants in the updating task, and the letter comparison task are reported in Table 4. Performance on these tests was submitted to an ANOVA with Age Group as a between-subject variable and years of education as a covariant. In the updating task, young participants performed better than older participants,  $F(1, 92) = 53.52$ ,  $p < 0.01$ . Finally, in the letter comparison task, older participants were significantly slower than young participants,  $F(1, 92) = 68.38$ ,  $p < 0.01$ .

Table 5 shows the Pearson correlations between age, speed of processing, the working memory measure, recollective experience in the Day and the Context test and list discrimination performance in the Day and the Context test. All the correlations were significant, except the correlation between recollective experience in the Context test and list discrimination performance in the Day test ( $p > .12$ ).

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 Insert Tables 4 and 5 about here  
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### 3.5. Hierarchical Multiple Regression analysis

*Recollective experience in recognition memory.* In order to determine whether age-related differences in processing speed or working memory abilities mediate age-related changes in recollective experience, hierarchical multiple regression analyses were conducted. Table 6 and Table 7 present the results for Remember responses to targets in the Day test and the Context test respectively. The amount of variance predicted by age after inclusion of mediating variables was calculated for each equation. It was given by the difference between the amount of age-related variance in Remember performance before and after entering the mediating variables, divided by the amount of age-related variance before the mediators had been entered, multiplied by 100. The first equation of Table 6 shows that age predicted 10 % of the variance in Remember responses in the Day test (this represents 100 % of the age-related variance). Equation 2 shows that processing speed accounted for 11 % of the variance in Remember responses and for 85.6 % of the age-related variance. Working memory (as measured by the updating task) predicted 4 % of the variance in Remember responses and 40 % of the age-related variance. However, when processing speed was entered first, neither working memory nor age any longer predicted Remember responses (equation 4). By contrast, after entering working memory, processing speed still accounted for around 7 % of

the variance in Remember responses (equation 5). The results for Remember responses in the Context test were broadly the same, except that age continued to predict 5 % of the variance in performance after controlling processing speed and working memory (equations 4 and 5, Table 7).

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 Insert Table 6 and 7 about here  
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*List discrimination.* Hierarchical multiple regression analyses were also used to determine the extent to which processing speed and working memory predicted variance and age-related variance in list discrimination in the Day test (Table 8) and in the Context test (Table 9).

In the Day test, age accounted for 19 % of the variance in list discrimination performance. Processing speed and working memory predicted respectively 11 % and 13 % of the variance in list discrimination performance and respectively 59.7 % and 62.8 % of age-related variance (equations 2 and 3). Equation 4 shows that, after processing speed had been factored out, working memory added a significant 4 % to the variance in list discrimination performance, and both variables accounted for 76 % of age-related variance. After entering working memory, processing speed no longer predicted list discrimination performance (equation 5). The effect of age remained significant after working memory and/or processing speed were factored out.

In the Context test (Table 9), age predicted 55 % of the variance in list discrimination performance. When introduced separately, processing speed and working memory predicted respectively 41 % and 29 % of the variance in list discrimination performance (equations 2 and 3). Equation 4 shows that, after controlling processing speed, working memory accounted for 4 % of the variance in list discrimination performance and age still predicted 12 % of the

variance. Both processing speed and working memory accounted for 77.7 % of the age-related variance. Finally, equation 5 indicated that, after entering working memory, processing speed added 16 % to the variance in list discrimination performance. Nonetheless, age still predicted 12 % of the variance in list discrimination performance after controlling for working memory and processing speed.

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Insert Tables 8 and 9 about here  
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#### 4. Discussion

The present experiment explored the effects of aging on tasks designed to separate the contribution of location-based and distance-based processes in memory of the times of events. In order to have a direct estimation of the processes used by the participants, the Remember/Know/Guess procedure was adapted and used for both item recognition and temporal memory. We will consider in turn the results concerning item memory, memory for the list of occurrence and finally the relationships between them.

##### *4.1. Item memory*

Regarding recognition memory, the main findings were that recognition of the pictures appears to be less good in older participants than in young participants and was also poorer in the Day test than in the Context test. Age differences in recognition of the pictures were mainly due to a decrease in recollection in the older group. By contrast, Familiar responses were more often reported by older participants (at least, in the Context test). When the contribution of familiarity was estimated following the independence assumption (Jacoby et al., 1997), it appeared that familiarity was not affected by aging. These results are consistent with the findings of previous studies which have examined the effects of aging on recollection



and familiarity (Bastin & Van der Linden, 2003; Mäntylä, 1993; Parkin & Walter, 1992; Perfect, Williams, & Anderton-Brown, 1995; Perfect & Dasgupta, 1997).

Moreover, the mediators of the age effect on recollective experience were examined. Some previous studies (Parkin & Walter, 1992) found significant relationships between a diminution of Remember responses and poorer performance on executive measures in a group of older participants, but others did not (Perfect et al., 1995; Perfect & Dasgupta, 1997). More recently, Clarys, Isingrini and Gana (2002) showed that age-related changes in recollection were mediated by a slower processing speed, combined with limited working-memory capacities. In the present study, processing speed was the best predictor of age-related variance in recollective experience. When processing speed was controlled, working memory no longer predicted the proportion of Remember responses to targets. These findings are consistent with studies that showed that speed of information processing is a fundamental predictor of age-related differences in episodic memory (Bryan & Luszcz, 1996; Park et al., 1996; Salthouse, 1996). The present results are also consistent with Clarys et al.'s (2002) study, which showed that speed of processing was the most important predictor of recollective experience with increasing age. Actually, in their study using a covariance structural modeling, processing speed mediated age-related differences in working memory, which in turn predicts Remember responses. Here, a reduction of processing speed may have prevented older participants from elaborately encoding the pictures, thus leading to an impoverished basis for later recollection (Perfect & Dasgupta, 1997; Salthouse, 1994) and/or may have hindered strategic retrieval processes, which are important for recollection (Bryan & Luszcz, 2000).

Another aspect of the recognition data which deserves comment is the fact that both groups discriminated better between targets and distractors in the Context test than in the Day test. More specifically, recognition memory was based more on recollection in the Context

test than in the Day test, whereas familiarity was more often used in the Day test than in the Context test (or as often in both tests when familiarity was assessed by the Independence Remember/Know procedure). Guess responses were also more frequent in the Day test than in the Context test. All these findings may be due to differences in the length of the study-test delay. Both tests had in common the fact that half of the target items came from the first list studied on Day 2 (studied around 30-45 min before the test). In addition, in the Day test, the other half of the target items was studied 24 hours before the test. By contrast, in the Context test, the other targets were the most recently studied items (they were studied less than half an hour before the test). Gardiner and Java (1991) have shown that Remember responses decreased when the length of the study interval increased from 10 minutes to 1 day, whereas Know responses remained unchanged. An analysis of recollective and familiar experience (responses to targets) as a function of the study list partly confirmed this interpretation. Indeed, Remember responses decreased from the 24-h delay to the 30-45-min delay and from this one to the less-than-30-min delay,  $F(3, 279) = 75.20, p < 0.01$ . As for Familiar responses, they did not change from the 24-h delay to the 30-45-min delay in the young group,  $F(1, 93) = 0.88, p > 0.34$ , but increased significantly between these two intervals in the older group,  $F(1, 93) = 12.61, p < 0.01$ . By contrast, Familiar responses decreased in both groups between the 30-45-min delay and the shortest delay ( $ps < 0.05$ ). Finally, in both groups, Guess responses were more frequent for items studied 24 hours ago than for the two shortest intervals, which did not differ from each other,  $F(3, 279) = 50.51, p < 0.01$ .

One could expect that items presented in the first list of Day 2 (30-45-min delay) give rise to similar proportions of Remember and Familiar responses whether they were tested in the Day test or the Context test. However, the young group gave more Remember responses when items from this list were tested in the Context task than in the Day task,  $F(1, 93) = 11.29, p < 0.01$ . In contrast, in the older group, Remember responses did not differ between

the two test,  $F(1, 93) = 1.60$ ,  $p > 0.20$ . Moreover, in both groups, the proportion of Familiar responses was higher when the items studied in the first list of Day 2 were tested in the Day task than in the Context task ( $p < 0.01$ ). As for Guess responses, these did not vary between the Day test and the Context test for items studied 30-45 min earlier,  $F(1, 93) = 0.37$ ,  $p > 0.54$ . This suggests that, in addition to the length of the interval, another factor may have contributed to produce different patterns of Remember, Familiar and Guess responses between both tasks. It may be that participants tended to base both the recognition and list discrimination decisions on similar or different information, depending on which types of information they found the most useful for the list discrimination part. For example, in the Context task, recollection of contextual information may have been often used to retrieve the list of occurrence, and thus to recognize the pictures themselves. In other words, while making the recognition decisions, the participants may have anticipated what information should be useful for the list discrimination task and decided to rely on this one, even if other processes were available<sup>2</sup>.

#### *4.2. List discrimination<sup>3</sup>*

It appears that the contribution of location-based and distance-based processes to list discrimination performance can be measured by adapting the Remember/Know/Guess instructions, as indicated by the analysis of the verbal justifications provided for the different types of responses. In addition, the present experiment provides additional support for the validity of the method developed by Curran and Friedman (2003) for dissociating both types of processes. Indeed, participants reported that they used location-based processes more often in the Context test than in the Day test, whereas they used distance-based processes more frequently in the Day test compared to the Context test.

As shown by previous studies (McCormack, 1984; Parkin et al., 1995; Wegesin et al., 2000), older participants remembered the list of occurrence of the pictures less well than did young participants. More importantly, these age differences were greater in the Context test than in the Day test. Indeed, older participants performed significantly better in the Day test than in the Context test, whereas young participants showed similar levels of accuracy in both tests. Therefore, the results suggest that aging adversely affects list discrimination depending on location-based processes more than list discrimination based on the estimation of the age of the memories. This interpretation is supported by the subjective reports of the participants. In the Context test, older participants reported using location-based processes less often than the young participants, but both groups reported using distance-based processes to the same extent in this task. Thus, age-related differences on list discrimination performance in the Context test may be due to a decrease in the use of location-based processes with age. Further, in the Day test, it seems that a diminution of both location-based and distance-based processes contributed to the effects of age on list discrimination performance. Indeed, older participants reported significantly less location-based and distance-based responses than did the young participants, although not too much weight should be placed on the results for location-based responses because of the floor effect observed for these responses. Nonetheless, older participants still performed better in the Day test than the Context test. This may be due to the fact that most of their responses relied on distance-based processes. These processes seem appropriate for relatively good discrimination, as suggested by the observation that most responses of the young participants were also distance-based.

The paradigms traditionally used to evaluate memory for temporal context, including list discrimination and recency judgments, probably require a mixture of location-based and distance-based processes. However, as laboratory experiments often run over a relatively short period of time (usually less than one hour), it may be that distance-based processes are

difficult to use and that performance of young participants mostly depends on location-based processes. Therefore, it may be that the age differences observed in previous experiments (Fabiani & Friedman, 1997; Newman et al., 2001; Parkin et al., 1995; Wegesin et al., 2000) reflect age-related decline of location-based processes.

Moreover, the present findings showed that distance-based processes can also be affected by aging, even though to a lesser extent than location-based processes. In order to understand how aging could affect distance-based processes, it is important to consider what these processes are. According to the strength theory (Hinrichs, 1970), the amount of time elapsed since the occurrence of an event can be assessed from the strength of the memory trace. Alternatively, the age of the memories could be evaluated on the basis of the number of information that can be retrieved about the events (Brown, Rips and Shevell, 1985). In light of these theories, the effects of age on distance-based processes could be explained in two ways. First, it could be that both young and older participants used the same kind of processes, based either on the strength of the memory trace or on the number of recalled details about the item, and that this process is vulnerable to aging. Alternatively, older participants may use a different kind of distance-based processes than younger participants, a process that may be less efficient in allowing good list discrimination performance. Finally, the fact that the age differences on distance-based processes disappeared when recognition accuracy was controlled in the analysis could indicate that older participants' difficulty to judge on which day a picture occurred could be a consequence of poor memory for the pictures themselves. Further research is necessary in order to better understand the nature of distance-based processes and how they are affected by aging.

The hierarchical regression analyses provided some information regarding the mediators of age-related differences in list discrimination performance. Age-related differences in list discrimination performance in the Day test (presumably depending mostly

on distance-based processes) were mediated by a decrease in working-memory abilities, as measured by the updating task, as well as by reduced speed of processing. Moreover, when working memory was controlled, speed of processing no longer predicted the list discrimination performance in the Day test. For the Context test (assumed to depend on location-based processes), a limitation of both working memory abilities and processing speed significantly contributed to age differences in list discrimination. It should also be noted that in neither cases was the age-related variance eliminated, thus suggesting that aging may have also affected specifically the location-based and distance-based processes.

As location-based and distance-based processes are not yet fully understood, the interpretations of the regression results, formulated hereafter, are only speculative. If indeed distance-based processes are relatively automatic compared to location-based processes, it could be surprising that these processes are vulnerable to the reduced working-memory resources in aging. However, this notion of relative automaticity should rather be understood in a sense similar to the heuristic source attribution mechanism described by Johnson, Hashtroudi and Lindsay (1993; see also Mitchell & Johnson, 2000). Heuristic processes involve schemata which compare rapidly and relatively non-deliberatively the information retrieved about a past event with some criterion and infer the origin of this information. Similarly, distance-based processes may involve some heuristic rapidly inferring the age of a memory from whatever information is contained in its trace. Thus, one could argue that this heuristic requires, even minimally, working memory to maintain the retrieved information while the attribution mechanism operates. Alternatively, it might be that limited working memory capacities prevented the older participants from elaborately encoding the pictures, leading to a memory trace too vague for allowing sufficiently precise estimation of its age.

As for age-related differences in location-based processes, they appeared to be partly mediated by processing speed and working memory. As location-based processes require

more resources than distance-based processes, one would expect greater involvement of working memory in the former than in the latter. The regression analyses showed that the working memory mediator explained slightly more age-related variance in location-based list discrimination (48.37 %) than in distance-based list discrimination (37.17 %). The most obvious characteristic of location-based processes is that they involve several complex operations during the attempt to retrieve when the event occurred (recollecting contextual information associated with the stimulus, establishing relations between these elements and some time pattern, inferring when the stimulus occurred and evaluating the products of the reconstruction). Therefore, it is possible that, because of reduced speed of processing, the products of early processing are lost by the time the later processes are complete in older participants (Salthouse, 1996). The necessity to hold temporarily available and manipulate the outputs of various cognitive operations could also expose location-based processes to the effects of limited working-memory capacities. Finally, it may also be that the limitations of processing speed and working memory with increasing age interfered with the binding of contextual information to the target event, thus reducing the available information for later reconstruction of the temporal context of the event.

#### *4.3. Disproportionate decline of memory for temporal context compared to item memory*

As item memory was poorer in the older group, we have examined whether the age-related decline of list discrimination performance was disproportionate compared to the decline of item memory, by comparing subgroups of young and older participants matched on item recognition performance and by controlling for recognition differences in the analysis of the list discrimination performance. The results showed that the decline associated with aging on memory for temporal context and the greater age differences in the Context test compared to the Day test should not be viewed as merely a consequence of poor item memory. This is

consistent with previous studies (Fabiani & Friedman, 1997; Newman et al., 2001; Parkin et al., 1995; Spencer & Raz, 1995).

In addition, the item-by-item analysis showed that even when older adults recollected contextual information regarding the pictures, they used them to infer the list of occurrence less often than did young adults. This could reflect a specific difficulty engaging in strategic reconstructive processes, possibly as a consequence of limited speed of processing and working memory capacities. Alternatively, the type of contextual information that they recollected for some pictures may have been inefficient cues for retrieving the list. For example, recollection of associations made when viewing the pictures (e.g. thoughts unrelated to any temporal structure, like “It reminded me of my husband” for the stimulus *shovel*) may not be useful for inferring whether the picture occurred in list 1 or 2.

Finally, the fact that familiarity-based recognition decisions were never followed by location-based processes could be interpreted as additional evidence for the idea that location-based processes require the availability of contextual details associated to the target item.

## 5. Conclusions

The present findings showed that the age differences often found in memory for time could be mainly due to a difficulty using contextual information to infer when an event occurred by reference to some temporal patterns. The decrease of recollective experience during item recognition could indicate that this difficulty with location-based processes partly stems from a failure to remember the contextual information associated with the target item. However, the possibility that older participants were poorer at applying strategic reconstruction processes to available contextual information cannot be rejected. In addition, although the accuracy of distance-based processes was less affected by aging, they were less often used by older than young participants. In the future, a better understanding of the nature



of distance-based processes should help clarifying how these processes are affected by aging. Furthermore, functional neuroimaging seems a promising way to identify the neural substrate of the processes underlying memory for the time of events, as well as to examine the neural correlates of age-related changes in this aspect of episodic memory.

### References

- Bastin, C. & Van der Linden, M. (2003). The contribution of recollection and familiarity to recognition memory: A study of the effects of test format and aging. *Neuropsychology, 17*, 14-24.
- Brown, N. R., Rips, L. J., & Shevell, S. K. (1985). The subjective dates of natural events in very long-term memory. *Cognitive Psychology, 17*, 139-177.
- Bryan, J. & Luszcz, M. A. (1996). Speed of information processing as a mediator between age and free-recall performance. *Psychology and Aging, 11*, 3-9.
- Bryan, J. & Luszcz, M. A. (2000). Measures of fluency as predictors of incidental memory among older adults. *Psychology and Aging, 15*, 483-489.
- Cabeza, R., Anderson, N. D., Houle, S., Mangels, J., & Nyberg, L. (2000). Age-related differences in neural activity during item and temporal-order memory retrieval : A positron emission tomography study. *Journal of Cognitive Neuroscience, 12*, 197-206.
- Clarys, D., Isingrini, M., & Gana, K. (2002). Mediators of age-related differences in recollective experience in recognition memory. *Acta Psychologica, 109*, 315-329.
- Curran, T. & Friedman, W. J. (2003). Differentiating location- and distance-based processes in memory for time : An ERP study. *Psychonomic Bulletin and Review, 10*, 711-717.

Daum, I., Gräber, S., Schugens, M. M., & Mayes, A. R. (1996). Memory dysfunction of the frontal type in normal ageing. *NeuroReport*, 7, 2625-2628.

Deltour, J.-J. (1993). *Echelle de vocabulaire de Mill Hill de J.C. Raven. Adaptation française et normes comparées du Mill Hill et du Standard Progressive Matrices (PM 38). Manuel*. Braine-le-Château: Editions L'Application des Techniques Modernes.

Donaldson, D. I. & Rugg, M. D. (1998). Recognition memory for new associations : Electrophysiological evidence for the role of recollection. *Neuropsychologia*, 36, 377-395.

Fabiani, M. & Friedman, D. (1997). Dissociations between memory for temporal order and recognition memory in aging. *Neuropsychologia*, 35, 129-141.

Friedman, W. J. (1993). Memory for the time of past events. *Psychological Bulletin*, 113, 44-66.

Friedman, W. J. (1996). Distance and location processes in memory for the times of past events. In D.L.Medin (Ed.), *The psychology of learning and motivation* (pp. 1-41). Orlando: Academic Press.

Friedman, W. J. (2001). Memory processes underlying humans' chronological sense of the past. In C. Hoerl & T. McCormack (Eds.), *Time and memory : Issues in philosophy and psychology* (pp. 139-167). Oxford: Clarendon Press.

Gardiner, J. M. & Java, R. I. (1991). Forgetting in recognition memory with and without recollective experience. *Memory and Cognition*, 19, 617-623.

Gardiner, J. M., Java, R. I., & Richardson-Klavehn, A. (1996). How level of processing really influences awareness in recognition memory. *Canadian Journal of Experimental Psychology*, 50, 114-122.

GRECO (1995 and 1997). Dementia Rating Scale, French version adopted by the Reflection Group on Cognitive Assessment GRECO. Unpublished data.

Hinrichs, J. V. (1970). A two-process memory-strength theory for judgment of recency. *Psychological Review*, *77*, 223-233.

Hunkin, N. M., Parkin, A. J., & Longmore, B. E. (1994). Aetiological variation in the amnesic syndrome : Comparisons using the list discrimination task. *Neuropsychologia*, *32*, 819-825.

Jacoby, L. L., Yonelinas, A. P., & Jennings, J. M. (1997). The relation between conscious and unconscious (automatic) influences : A declaration of independence. In J.D.Cohen & J. W. Schooler (Eds.), *Scientific approaches to consciousness* (pp. 13-47). Mahwah, NJ: Lawrence Erlbaum Associates.

Johnson, M. K., Hashtroudi, S., & Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin*, *114*, 3-28.

Kausler, D. H., Salthouse, T. A., & Saults, J. S. (1988). Temporal memory over the adult lifespan. *American Journal of Psychology*, *101*, 207-215.

Kesner, R. P., Hopkins, R. O., & Fineman, B. (1994). Item and order dissociation in humans with prefrontal cortex damage. *Neuropsychologia*, *32*, 881-891.

Kopelman, M. D., Stanhope, N., & Kingsley, D. (1997). Temporal and spatial context memory in patients with focal frontal, temporal, and diencephalic lesions. *Neuropsychologia*, *35*, 1533-1545.

Macmillan, N. A. & Creelman, C. D. (1991). *Detection theory : A user's guide*. Cambridge: Cambridge University Press.

Mangels, J. A. (1997). Strategic processing and memory for temporal order in patients with frontal lobe lesions. *Neuropsychology*, *11*, 207-221.

Mangels, J., Gershberg, F. B., Shimamura, A. P., & Knight, R. T. (1996). Impaired retrieval from remote memory in patients with frontal lobe damage. *Neuropsychology*, *10*, 32-41.

- Mäntylä, T. (1993). Knowing but not remembering : Adult age differences in recollective experience. *Memory and Cognition*, *21*, 379-388.
- Martain, R. (1995). Norms for name and concept agreement, familiarity, visual complexity and image agreement on a set of 216 pictures. *Psychologica Belgica*, *35*, 205-225.
- Mattis, S. (1973). *Dementia Rating Scale*. Windsor, England: NFER-Nelson.
- McAndrews, M. P. & Milner, B. (1991). The frontal cortex and memory for temporal order. *Neuropsychologia*, *29*, 849-859.
- McCormack, P. D. (1982). Temporal coding and study-phase retrieval in young and elderly adults. *Bulletin of the Psychonomic Society*, *20*, 242-244.
- McCormack, P. D. (1984). Temporal coding by young and elderly adults in a list-discrimination setting. *Bulletin of the Psychonomic Society*, *22*, 401-402.
- Milner, B., Corsi, P., & Leonard, G. (1991). Frontal-lobe contribution to recency judgements. *Neuropsychologia*, *29*, 601-618.
- Mitchell, K. J. & Johnson, M. K. (2000). Source monitoring : Attributing mental experiences. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford handbook of memory* (pp. 179-195). New York: Oxford University Press.
- Morris, N. & Jones, D. M. (1990). Memory updating in working memory: The role of the central executive. *British Journal of Psychology*, *81*, 111-121.
- Newman, M. C., Allen, J. J. B., & Kaszniak, A. W. (2001). Tasks for assessing memory for temporal order versus memory for items in aging. *Aging, Neuropsychology, and Cognition*, *8*, 72-78.
- Park, D. C., Smith, A. D., Lautenschlager, G., Earles, J. L., Frieske, D., Zwahr, M., & Gaines, C. L. (1996). Mediators of long-term memory performance across the life-span. *Psychology and Aging*, *11*, 621-637.

Parkin, A. J. & Walter, B. M. (1992). Recollective experience, normal aging, and frontal dysfunction. *Psychology and Aging*, 7, 290-298.

Parkin, A. J., Walter, B. M., & Hunkin, N. M. (1995). Relationships between normal aging, frontal lobe function, and memory for temporal and spatial information. *Neuropsychology*, 9, 304-312.

Perfect, T. & Dasgupta, Z. R. R. (1997). What underlies the deficit in reported recollective experience in old age ? *Memory and Cognition*, 25, 849-858.

Perfect, T. J., Williams, R. B., & Anderton-Brown, C. (1995). Age differences in reported recollective experience are due to encoding effects, not response bias. *Memory*, 3, 169-186.

Perlmutter, M., Metzger, R., Nezworski, T., & Miller, K. (1981). Spatial and temporal memory in 20 and 60 years olds. *Journal of Gerontology*, 36, 59-65.

Raz, N. (2000). Aging of the brain and its impact on cognitive performance : Integration of structural and functional findings. In F.I.M.Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (Second ed., pp. 1-90). Mahwah, NJ: Lawrence Erlbaum Associates.

Salthouse, T. A. (1991). *Theoretical perspectives and cognitive aging*. Hillsdale, NJ: Erlbaum.

Salthouse, T. A. (1994). Aging associations: Influence of speed on adult age differences in associative learning. *Journal of Experimental Psychology : Learning, Memory and Cognition*, 20, 1486-1503.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review*, 103, 403-428.

Salthouse, T. A. & Babcock, R. L. (1991). Decomposing adult age differences in working memory. *Developmental Psychology*, 27, 763-776.

Shimamura, A. P., Janowsky, J. S., & Squire, L. R. (1990). Memory for the temporal order of events in patients with frontal lobes lesions and amnesic patients. *Neuropsychologia*, 28, 803-813.

Snodgrass, J. G. & Vanderwart, M. (1980). A standardized set of 260 pictures : Norms for name agreement, image agreement, familiarity and visual complexity. *Journal of Experiment Psychology : Human Learning and Memory*, 6, 174-215.

Spencer, W. D. & Raz, N. (1994). Memory for facts, source, and context : Can frontal lobe dysfunction explain age-related differences ? *Psychology and Aging*, 9, 149-159.

Tendolkar, I. & Rugg, M. D. (1998). Electrophysiological dissociation of recency and recognition memory. *Neuropsychologia*, 36, 477-490.

Trott, C. T., Friedman, D., Ritter, W., Fabiani, M., & Snodgrass, J. G. (1999). Episodic priming and memory for temporal source : Event-related potentials reveal age-related differences in prefrontal functioning. *Psychology and Aging*, 14, 390-413.

Tulving, E. (1999). On the uniqueness of episodic memory. In L.-G.Nilsson & H. J. Markowitsch (Eds.), *Cognitive neuroscience of memory* (pp. 11-42). Göttingen, Germany: Hogrefe & Huber Publishers.

Vakil, E. & Tweedy, J. R. (1994). Memory for temporal order and spatial position information : Tests of the automatic-effortful distinction. *Neuropsychiatry*, 7, 281-288.

Van der Linden, M., Brédart, S., & Beerten, A. (1994). Age-related differences in updating working memory. *British Journal of Psychology*, 85, 145-152.

Wegesin, D. J., Friedman, D., Varughese, N., & Stern, Y. (2002). Age-related changes in source memory retrieval : An ERP replication and extension. *Cognitive Brain Research*, 13, 323-338.

Wegesin, D. J., Jacobs, D. M., Zubin, N. R., Ventura, P. R., & Stern, Y. (2000).

Source memory and encoding strategy in normal aging. *Journal of Clinical and Experimental Neuropsychology*, 22, 455-464.

Wheeler, M. A., Stuss, D. T., & Tulving, E. (1997). Toward a theory of episodic memory : The frontal lobes and autonoetic consciousness. *Psychological Bulletin*, 121, 331-354.

Wilding, E. L. (1999). Separating retrieval strategies from retrieval success : An event-related potential study of source memory. *Neuropsychologia*, 37, 441-454.

## Appendix

Instructions for Remember, Familiar and Guess responses in recognition memory

*Remember*

You remember that you have seen this picture before and you remember exactly in which context you have seen it. You can retrieve something that happened in the same time as the picture was presented or that you have noticed on the picture, a thought or a feeling you had when seeing this picture, etc. For example, you could remember that, when you saw the picture of a car, you thought that you should bring yours to the garage. Hence, I ask you to say “Remember” when you recognize the picture on the basis of the retrieval of a component of the encoding episode.

*Familiar*

I ask you to say “Familiar” if you recognize a picture but do not remember any particular aspect of the encoding episode. But, still, you are certain that you have seen the picture, because you have a feeling of familiarity.

*Guess*

You are not certain that you have seen this picture before because it is not really familiar and you do not remember anything about its encoding context. However, you are not sure either that you never saw it. In this case, you can indicate that you are guessing.

Instructions for Remember, Familiar and Guess responses in the list discrimination task

*Remember*

You remember the list of occurrence of the picture because you remember in which context you have seen it or because you remember an event, a thought or a feeling that accompanied the appearance of the picture. For example, you could have seen the picture of the sun in the



second list and have thought that it was sunny outside. So, when you see the picture of the sun in the test, you are certain that it was presented in the second list because you remember the sunny sky during this list, whereas it was cloudy during the presentation of the first list. Hence, I ask you to say “Remember” if you remember the list because you retrieve a component of the encoding context.

*Familiar*

I ask you to say “Familiar” if you do not remember the list of occurrence of a picture on the basis of its encoding episode, but if you can say in which list this picture was presented because of its level of familiarity. For example, you have the impression that you saw it recently versus a long time ago.

*Guess*

You do not remember in which list the picture occur. You do not remember any event that was associated with this picture. As you must give a response, you can guess.

*Acknowledgements*

This work was supported by a grant from the French Community of Belgium, Direction Générale de l'Enseignement non obligatoire et de la Recherche Scientifique: "Actions de Recherche Concertées (convention 99/04-246)". We thank Marcel Casteleyn and Steve Majerus for their assistance in statistical analyses.

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## Footnotes

1. Z-score formula:  $z = (r - x)/SD$ , where  $r$  = number discriminated correctly,  $n$  = number recognized,  $p$  = probability of discriminating a recognized item correctly by chance,  $q = (1-p)$ ,  $x = n.p$ , and  $SD = \text{square root of } (n.p.q)$ .
2. It should be noted that the study environment B and the test environment had in common the use of a portable computer. Therefore, it may be that the items which have been studied on a portable computer were more easily remembered during the test than the others because of the congruence of context between study and test. However, there were also many differences between the two contexts, including the room and the color of the background screen. This may have reduced the impact of the use of portable computer in both the study environment B and the test environment.
3. List discrimination performance was analyzed when considering the items from all the lists. It could be argued that the differences in the length of retention interval between the Context test and the Day test may have confounded in the list discrimination results. Nonetheless, when the analyses were performed on items from the first list presented on Day 2 only, similar conclusions were reached.

Table 1

*Characteristics of the participants*

	Young participants	Older participants
Age	21.98 ± 2.10	67.75 ± 5.71
Education	13.81 ± 1.45	12.48 ± 2.62**
Mill Hill (raw score out of 33 items)	22.98 ± 3.60	25.10 ± 4.51*
Current Health State	8.53 ± 0.90	8.12 ± 0.88*

*Note.* \*  $p < .05$ , \*\*  $p < .01$

Table 2

*Mean Proportions (and Standard Deviations) of Remember (R), Familiar (F) and Guess (G) Responses to Targets and Distractors in the Context Test and the Day Test as a Function of Age Group*

Task	Group	Targets				Distractors			
		total	R	F	G	total	R	F	G
Context test	Young	0.94	0.54	0.38	0.02	0.04	0.003	0.01	0.03
		(0.06)	(0.20)	(0.21)	(0.03)	(0.06)	(0.01)	(0.01)	(0.05)
	Old	0.89	0.33	0.53	0.03	0.10	0.02	0.03	0.05
		(0.09)	(0.21)	(0.21)	(0.03)	(0.10)	(0.05)	(0.04)	(0.08)
Day test	Young	0.93	0.34	0.55	0.04	0.07	0.002	0.01	0.06
		(0.05)	(0.21)	(0.23)	(0.03)	(0.06)	(0.01)	(0.02)	(0.05)
	Old	0.89	0.22	0.60	0.06	0.17	0.01	0.05	0.11
		(0.07)	(0.18)	(0.20)	(0.04)	(0.11)	(0.03)	(0.05)	(0.08)

Table 3

*Proportion of Correct Discrimination as a Function of the Type of Responses Reported by Young and Older Groups (Remember/location-based Processes, Familiar/distance-based Processes or Guess) in the Context Test and in the Day Test*

Proportion of Correct Discrimination					
Task	Group	Total	Remember/location- based processes	Familiar/distance- based processes	Guess
Context test	Young	0.83 (0.06)	0.50 (0.22)	0.24 (0.17)	0.09 (0.07)
	Old	0.67 (0.10)	0.27 (0.21)	0.25 (0.15)	0.15 (0.07)
Day test	Young	0.84 (0.07)	0.03 (0.03)	0.70 (0.11)	0.11 (0.06)
	Old	0.76 (0.09)	0.01 (0.02)	0.61 (0.09)	0.14 (0.06)

Table 4

*Performance of Young and Older Participants on the Working Memory measure and on the Speed of Processing Measure*

	Young	Old
Updating task		
Total number of correctly recalled letters (max. = 72)	42.85 (8.73)	30.19 (7.07)**
Letter comparison task		
Mean reaction time (in ms)	662 (132)	1004 (219)**

*Note.* \*\*  $p < .01$

Table 5

*Correlations between Age, Speed of Processing, the Working Memory Measure, Recollective Experience in the Day and the Context Test and List Discrimination Performance in the Day and the Context Test*

Variable	1	2	3	4	5	6	7
1. Age	–						
2. Speed of processing	.72**	–					
3. Working memory	-.64**	-.57**	–				
4. Remember responses/Day test	-.32**	-.33**	.20*	–			
5. Remember responses/Context test	-.50**	-.46**	.34**	.71**	–		
6. List discrimination/Day test	-.44**	-.34**	.36**	.26*	.16	–	
7. List discrimination/Context test	-.74**	-.64**	.54**	.40**	.63**	.41**	–

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



Table 6

*Hierarchical Multiple Regression Analysis Predicting Remember Responses to Targets in the Day Test from Age, Processing Speed and Working Memory Abilities (Updating Performance)*

	$R^2$	$R^2$ change	$p$	% ARV
1				
Age	0.104	0.104	< 0.01	100
2				
Processing speed	0.110	0.110	< 0.01	
Age	0.125	0.015	n.s.	85.58
3				
Working memory	0.042	0.042	< 0.05	
Age	0.104	0.062	< 0.05	40.38
4				
Processing speed	0.110	0.110	< 0.01	
Working memory	0.111	0.001	n.s.	
Age	0.126	0.015	n.s.	85.58
5				
Working memory	0.042	0.042	< 0.05	
Processing speed	0.111	0.069	< 0.01	
Age	0.126	0.015	n.s.	85.58

Note. ARV = age-related variance, n.s. = non significant

Table 7

*Hierarchical Multiple Regression Analysis Predicting Remember Responses to Targets in the Context Test from Age, Processing Speed and Working Memory Abilities (Updating Performance)*

	$R^2$	$R^2$ change	$p$	% ARV
1				
Age	0.251	0.251	< 0.001	100
2				
Processing speed	0.212	0.212	< 0.001	
Age	0.272	0.060	< 0.01	76.11
3				
Working memory	0.119	0.119	< 0.001	
Age	0.252	0.133	< 0.001	47.05
4				
Processing speed	0.212	0.212	< 0.001	
Working memory	0.222	0.010	n.s.	
Age	0.272	0.050	< 0.05	80.09
5				
Working memory	0.119	0.119	< 0.001	
Processing speed	0.222	0.103	< 0.001	
Age	0.272	0.050	< 0.05	80.09

Note. ARV = age-related variance, n.s. = non significant

Table 8

*Hierarchical Multiple Regression Analysis Predicting List Discrimination Performance in the Day Test from Age, Processing Speed and Working Memory Abilities (Updating Performance)*

	$R^2$	$R^2$ change	$p$	% ARV
1				
Age	0.191	0.191	< 0.001	100
2				
Processing speed	0.116	0.116	< 0.001	
Age	0.193	0.077	< 0.01	59.68
3				
Working memory	0.132	0.132	< 0.001	
Age	0.203	0.071	< 0.01	62.83
4				
Processing speed	0.116	0.116	< 0.001	
Working memory	0.158	0.042	< 0.05	
Age	0.203	0.045	< 0.05	76.44
5				
Working memory	0.132	0.132	< 0.001	
Processing speed	0.158	0.026	n.s.	
Age	0.203	0.045	< 0.05	76.44

Note. ARV = age-related variance, n.s. = non significant

Table 9

*Hierarchical Multiple Regression Analysis Predicting List Discrimination Performance in the Context Test from Age, Processing Speed and Working Memory Abilities (Updating Performance)*

	$R^2$	$R^2$ change	$p$	% ARV
1				
Age	0.552	0.552	< 0.001	100
2				
Processing speed	0.411	0.411	< 0.001	
Age	0.575	0.164	< 0.001	70.29
3				
Working memory	0.292	0.292	< 0.001	
Age	0.559	0.267	< 0.001	51.63
4				
Processing speed	0.411	0.411	< 0.001	
Working memory	0.455	0.044	< 0.01	
Age	0.578	0.123	< 0.001	77.72
5				
Working memory	0.292	0.292	< 0.001	
Processing speed	0.455	0.163	< 0.001	
Age	0.578	0.123	< 0.001	77.72

Note. ARV = age-related variance