

# Development of auto-noetic autobiographical memory in school-age children: Genuine age effect or development of basic cognitive abilities?

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**Short title:** Development of auto-noetic autobiographical memory

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## **Abstract**

This study investigated the mechanisms behind episodic autobiographical memory (EAM) development in school-age children. Thirty children (6 to 11 years) performed a novel EAM test. We computed one index of episodocity via auto-noetic consciousness and two indices of retrieval spontaneity (overall and EAM-specific) for a recent period (previous school year) and a more remote one (preschool years). Executive functions, and episodic and personal semantic memory were assessed. Results showed that recent autobiographical memories (AMs) were mainly episodic, unlike remote ones. An age-related increase in the indices of episodocity and specific spontaneity for recent AMs was mainly mediated by an age-related increase in the efficiency of the three cognitive abilities. Remote AMs varied only slightly with age (overall spontaneity), reflecting improvements in semantic abilities. Thus, EAM development in school-age children is essentially bound up with the increasing efficiency of cognitive abilities. Results are discussed in the light of models of childhood amnesia.

**Keywords:** autobiographical memory, episodic memory, executive function, semantic memory, auto-noetic consciousness, Remember/Know, emotion, visual imagery, childhood amnesia, children.

## Introduction

Autobiographical memory (AM) is now recognized as being multifaceted, containing a corpus of general knowledge, as well as unique experiences specific to an individual, which have been accumulated since childhood and allow the latter to construct a feeling of identity and continuity (Conway & Pleydell-Pearce, 2000; Tulving, Schacter, McLachlan, & Moscovitch, 1988). According to current conceptions of episodic memory (Tulving, 2001, 2002), episodic AM (EAM) refers not only to personal events recollected in the context of a particular time and place, but also to the phenomenological experience of remembering (see Piolino, Desgranges, & Eustache, 2009, for a review). Tulving's conception of episodic memory is inextricably bound up with subjectively-sensed time and the subjective phenomenological recollective experience. As such, it encompasses perceptual, affective and spatiotemporal contextual details, and auto-noetic consciousness, which is defined as a sense of self in time and the mental reliving of subjective experiences arising from the encoding context (Wheeler, Stuss, & Tulving, 1997). Hence, EAM makes it possible to travel mentally through subjective time, from present to past, and thus to recollect, one's own previous experiences via auto-noetic consciousness. Therefore, not all memories that are autobiographical have an auto-noetic character mediated by the episodic memory system. For instance, the semantic component of AM is characterized by the retrieval of general facts and events pertaining to oneself through "just knowing" instead of remembering. Tulving's theory (Tulving, 1985, 2001, 2002; Wheeler, 1999) suggests that EAM develops later in ontogeny than semantic AM.

Although extensive research on the early development of AM indicates that preschoolers are quite adept at recounting the past (Bauer, 1996; Howe, Cicchetti, Toth, & Cerrito, 2004; Meltzoff, 1995; Nelson, 1988), their narratives certainly do not meet the strict

definition of EAM. Young children's narratives are mainly about scripted events (Nelson, 1986), and before 4 or 5 years, children have difficulty answering questions about the context and causal sequence of unique personal events (Farrar & Goodman, 1992; Hudson, 1990; Pillemer, Picariello, & Pruett, 1994; Uehara, 2000; Van Abbema & Bauer, 2005). Older children, on the other hand, can recount specific and unique aspects of their experiences. Nevertheless, the scant literature on AM in school-age children reveals that even 7- to 10-year-old children do not necessarily meet all EAM criteria: in particular, they often fail to mention the people who were present and the spatiotemporal context (Bauer, Burch, Scholin, & Güler 2007). Crucially, the auto-noetic consciousness (i.e. sense of reliving the encoding context) associated with the recall of unique events situated in time and place with details continues to develop throughout childhood and into adolescence (Piolino, Hisland, Ruffeveille, Matuszewski, Jambaqué, & Eustache, 2007). Overall, these findings support Tulving's view that mental travel through subjective time, which allows us to re-experience the past through self-awareness, is one of the last features of AM to become fully operational.

Piolino, Hisland et al. (2007) have found that increasing age is a major contributing factor not only to specificity (of events and of details) and to auto-noetic consciousness, but also to spontaneity of recall. Some of the few studies to have investigated this effect so far have reported that older children recall a great deal of information and details in response to open-ended questions, whereas younger children needed more prompts, suggesting that age differences in recall could be partially due to retrieval difficulties by young children.

Retrieval difficulties have also been suggested as a potential explanation for the phenomenon of childhood amnesia (see de Haan, Mishkin, Baldeweg & Vargha-Khadem, 2006; Piolino & Eustache, 2001, for reviews). This phenomenon concerns the small number of memories that are encoded before the age of 5 years, with a practically total absence of memories before the age of 3 (Newcombe, Lloyd, & Ratliff, 2007). Whereas many studies

have investigated adult recall of memories encoded during the first five years of life (Rubin, 2000), very few have been carried with school-age children. Whatever the age of the children at recall (6 to 19 years old), Peterson, Grant and Boland (2005) reported that the largest proportion of memories recalled from this period concerned snapshots of a particular moment in time, rather than contextually rich episodes. Moreover, Van Abbema and Bauer (2005) showed that 7- to 9-year-old children only recalled half the events that had been encoded during the period of childhood amnesia (i.e. when children were 3 of age) and that these recollections included only half as many details as memories of recent events. However, these studies did not explore the essential character of EAM, i.e. auto-noetic consciousness.

In short, all these studies suggest that EAM undergoes developmental changes between early childhood and adolescence. Nevertheless, it may be difficult to interpret the effect of age on EAM because, in most cases, recollection involves a controlled retrieval process that relies on executive functions (see Conway & Pleydell-Pearce, 2000; Conway, 2005; Piolino, Desgranges, Manning, North, & Eustache, 2007). This process, which comprises elaborative, strategic and evaluative processes, provides access to event-specific episodic knowledge (e.g. spatiotemporal and sensory-perceptual details) from a semantic knowledge base (e.g. lifetime periods and generic events). Thus, problems in accessing and recalling specific events and episodic details, may stem not only from episodic memory difficulties *per se*, but also from difficulties related to the controlled retrieval process (i.e., executive functions). Executive function ability (Huizinga & van der Molen, 2006; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003) is thought to emerge gradually throughout adolescence and into early adulthood, in parallel with the maturation of the prefrontal cortex (Casey, Galvan, & Hare, 2005; Giedd, Blumenthal, Jeffries, Castellanos, Liu, Zijdenbos et al., 1999; Sowell, Thompson, Holmes, Jernigan, & Toga, 1999; Sowell, Thompson, Tessner, & Toga, 2001). Studies are needed to test this executive/frontal hypothesis within the framework of

EAM development. Moreover, in addition to executive functions, differences in semantic memory may also contribute to developmental changes in EAM. More specifically, higher-level personal semantic knowledge (e.g. knowledge about “being a schoolgirl at La Bruyère primary school in Paris”) is known to govern access to lower-level, event-specific sensory-perceptual episodic information (e.g. “my first day at school”; Barsalou, 1988; Conway, 2001, 2005; Conway & Pleydell-Pearce, 2000). Although Nelson and Fivush (2004) have suggested that episodic and semantic memory abilities may be the most influential factors in AM development, no study has thoroughly tested the involvement of these memory systems in EAM development.

Beyond the possible involvement of cognitive abilities in EAM development (see Gathercole, 1998), few studies have looked at whether the processes subtending the retention and recall of EAMs may also be determined by other factors, such as memory rehearsal (Cheatham & Bauer, 2005; Principe, Ornstein, Baker-Ward, & Gordon, 2000; Usher & Neisser, 1993; but see Ornstein, Baker-Ward, Gordon, Pelphrey, Tyler, & Gramzow 2006), emotional value (Fivush, Sales, Goldberg, Bahrack, & Parker, 2004; Peterson & Bell, 1996; Ornstein, 1995) and visual mental imagery (Pillemer & White, 1989). In adults, visual mental imagery and emotional experience are regarded as critical phenomenological characteristics of EAM retrieval (Conway, 2005). Moreover, the repetition of memories (thinking or talking about a particular event) has been shown to influence autobiographical recollection either by reinforcing the persistence of phenomenological details over time (Rubin & Kozin, 1984) or by causing a shift from specific to general experiences (Cermak, 1984).

The purpose of the present study was therefore to explore the development of EAM in school-age children according to the encoding period: recent memories (previous school year) *versus* remote memories encoded during the period of childhood amnesia (first five years of

life). Our objective was not so much to study the effect of remoteness, as to compare memories from the period of childhood amnesia with other more recent memories that were relatively comparable in terms of retention mechanisms, i.e. based on self-relevance (contrasting with very recent memories based on mundane daily experiences that often vanish within a few days or weeks; Conway, 2001, 2005). We wanted first to shed light on the effect of age on EAM across these two periods, then to study the developmental retrieval mechanisms underpinning EAM improvement in school-age children. We tackled this issue by using a previously validated AM test adapted for children (Piolino, Hisland et al., 2007). This test allows episodic memories to be strictly assessed, using the Remember/Know procedure (Tulving, 1985) to disentangle the remembering of specific and detailed events (autonoetic consciousness) from the “just knowing”. We also added measurements of critical attributes of EAM, such as frequency of rehearsal, emotion and visual mental imagery. Furthermore, the contribution of three potential cognitive mechanisms thought to facilitate encoding and access to EAM (see above) was tested: executive functions, episodic memory and personal semantic memory. In this way, we expected to be able to ascertain whether an age-related increase in EAM ability exists above and beyond the indirect effect of age on other cognitive skills. In accordance with previous studies (Piolino, Hisland et al., 2007; Van Abbema & Bauer, 2005), we assumed that there would be an age-related increase in EAM for the recent period, but not for the remote period of childhood amnesia. We also expected developmental differences in accessing highly specific autonoetic memories to be attributable to developmental differences not just in frontal/executive functions (Piolino, Hisland, et al., 2007) but also in episodic and semantic memory (Conway, 2005; Nelson & Fivush, 2004; Tulving, 2005).

## **Methods**

## Subjects

Thirty healthy schoolchildren, 15 girls and 15 boys aged between 6 years 6 months and 11 years 3 months ( $M = 8$  years 9 months,  $S.D. = 1$  year 7 months), were recruited from elementary schools in Lower Normandy, France, to take part in the study. Subjects primarily came from middle- and upper middle-class families, and were mainly Caucasian. None of the subjects had any neurological or psychiatric medical history. They were all in mainstream schooling and none of them had repeated a year. We checked that all the subjects had so far had a normal childhood and had not suffered any traumatic events. All children could read and had normal intellectual abilities, as indicated by their score on the Similarities subtest of the WISC-III (i.e. minimum scores of 10,  $M = 12.57$ ,  $S.D. = 2.01$ ; Wechsler, 1991). Informed consent was obtained from all participants, as well as from their parents.

Each child was tested individually in a quiet area of the school in two sessions, each lasting approximately one hour. In the first session, participants performed the WISC-III Similarities subtest (Wechsler, 1991), followed by the AM test. In the second session, subjects underwent an extensive additional battery of cognitive tests designed to assess episodic memory, executive functions and personal semantic memory. Tests were administered in a fixed sequence.

### **AUTOBIOGRAPHICAL MEMORY TEST: THE TEMPAU TASK**

A semi-structured autobiographical questionnaire was based on a new EAM paradigm validated in school-age children (Piolino, Hisland et al., 2007), called the TEMPAu task (Test Episoque de Mémoire du Passé Autobiographique). This assesses the sense of re-experiencing events from different periods using the Remember/Know procedure. This procedure makes it possible to differentiate between auto-noetic and noetic consciousness (Gardiner, 1988, 2001; Tulving, 1985), i.e. between episodic and semantic memory retrieval (see Piolino, Hisland et

al., 2007, for further details). For the purposes of the present study of EAM, the task explored the recent personal past (i.e. the previous school year) *versus* the remote personal past (i.e. the first 5 years, or preschool years). The periods were introduced in random order, either the most remote followed by the most recent or vice-versa. General instructions were provided, as well as practice tests at the beginning of the procedure, to make the nature of the recall tasks clear. The time allowed for recall was unrestricted, but generally lasted one hour.

The children, individually tested, were asked to remember specific, personally experienced events prompted by 3 general topics for each time period: a school or kindergarten event, a trip or vacation event and a family event. The general instructions stated that, regardless of the time period, memories had to concern unique personal events which lasted less than a day - “a short moment” situated in time and space -, and which they could mentally relive with details, e.g. “Give details of a particular event, which took place in your family life”. The subjects were always asked to give as many details as possible, so that we could be sure that no details had been left untold. Where necessary, if the children had difficulty carrying out the task, they were given further cues (e.g. “A day with a teacher or a school friend”) and/or encouraged to be more specific (“Does this remind you of a particular day?”, “Did this only happen once?”). After 3 cues and/or encouragements, the tester switched to another topic.

After recalling each event, the children had to indicate whether or not they could consciously recollect its prior occurrence, by making separate Remember/Know judgments for the content, place and date of the event (What, Where and When, respectively). They could also say whether they had simply guessed the event (Mäntylä, 1993). It is important to note that the judgment categories (Conway, Gardiner, Perfect, Anderson, Cohen, 1997; Gardiner, 2001) were explained very carefully to each child until each concept used in this test was thoroughly understood and that a visual reminder was placed in front of the children

during the task. First of all, the children were instructed to select one of these categories (i.e. Remember, Know or Guess) with reference to the factual content (What) of the event they had recalled, and then with reference to the place and date of that event. For example, they might give a Remember response concerning a particularly enjoyable birthday party (i.e. “What” R response) that had taken place in a particular environment (i.e. “Where” R response) 2 months previously (i.e. “When” R response). Given that separate responses were given for each of the three contents (What, Where, When), the children might also, for example, give a Remember response for the factual and spatial content, but a Know response for the temporal content. Lastly, a procedure was performed to check whether the children had correctly recalled a specific event (i.e. unique, situated in time and space) and could justify each of their R judgments. Accordingly, for each R response they had provided, whether it was for What, Where or When, they had to supply additional contextual details about the original specific event, if they had not already provided them in full during the memory recall task. For example, the child might mentally relive the specific atmosphere and his/her thoughts and feelings (justified “What” R response), as well as recollecting highly specific visual details about the scene, his/her location in the scene (justified “Where” R response), and the thoughts he/she had about the time of the day and about the fact that the party was taking place exactly 2 days after his/her own birthday (justified “When” R response).

Moreover, in order to determine the nature of the memory retrieval process, we recorded children’s self-assessments about features that are crucially involved in EAM (see Introduction). Accordingly, after recalling each memory and performing the R/K/G procedure, the children were asked to rate their memories on analogue scales (15-cm lines; subjective measurement, Aubrun, 1998) in terms of frequency of rehearsal (0 = never to 15 = very frequent), emotion (0 = no emotion to 15 = very strong emotion), and visual mental

imagery (0 = no images to 15 = very numerous images; instructions for the analogue scales are given in Appendix A).

### **Scoring**

As the aim of our study was to investigate strictly episodic AM, based on its current definition, we focused the present study on three different scores recorded for each time period: two **indices of spontaneity** and one **index of episodicity**. Scores were calculated separately for each period.

The two indices of spontaneity represented the ease with which subjects accessed AMs. They were based on the number of cues and/or encouragements to be specific that the subject required for each recollection using a four-point scale (max: 12, i.e. 4 points per topic and 3 topics per period). For example, the spontaneous retrieval of a specific event was given a score of 4 points, whereas retrieval achieved after three cues and/or encouragements was given a score of 1. Absence of recall despite cues and/or encouragements was scored zero. Conversely, the **overall spontaneity** index was based on the total number of cues and/or encouragements given by the experimenter. For each period, the maximum score was 12 (4 points per topic and 3 topics per period). The score was converted into a percentage of the maximum score per period. By contrast, the **specific spontaneity** index only concerned the topics that allow children to access a memory. Consequently, it was calculated by dividing the number of cues and/or encouragements given by the experimenter by the maximum score for the number of events evoked.

In the same vein, the index of **episodicity** took into account the number of memories evoked. It corresponded to the total number of R responses provided, whatever the type of information (What, Where or When), justified in terms of single events situated in time and place with retrieval of actual episodic details, divided by the maximum number of responses

possible according to the number of events recalled. For each period, the maximum score was 9 (i.e. 3 justified R responses per topic and 3 topics per period).

While scores of **frequency of rehearsal, emotional intensity and visual mental imagery** reflected the quality of the memories recalled, they were also dependent upon the number of memories evoked. The scores on the analogue scales were calculated by adding together the scores recorded for each personal event recalled (maximum score of 45, i.e. 3 memories given the maximum rating of 15). In order to allow comparisons to be made between indices and scales, they were all converted into a percentage of the maximum score per period.

All memories were scored according to the information supplied in the test and checked with the participants' parents over the phone. The vast majority of recalled events was confirmed (see also Peterson et al., 2005; Piolino, Hisland et al., 2007); the few inconsistencies concerned the date of remote events for the younger children.

## **COGNITIVE ASSESSMENT**

Practice trials were administered prior to each task in order to ensure that the children understood the instructions. They were repeated if necessary.

### ***Executive functions***

Three elementary executive functions identified by Miyake, Friedman, Emerson, Witzki, Howerter, and Wager (2000) in adults and seemingly crucial to children, too (see Letho et al., 2003), were assessed.

*Shifting* abilities were measured using a children's version of the *Trail making test* (Reitan, 1958). In the first part of the test, children were asked to connect a set of numbers in

ascending order (1 to 13) randomly positioned on a sheet of paper. Part 2 resembled Part 1 except that the participants were asked to connect a set of 13 letters in alphabetical order (A to M) instead of numbers. Finally, Part 3 featured a combination of digits (from 1 to 7) and letters (from A to E). Children had to link up digits in ascending order and letters in alphabetical order whilst alternating between digit and letter (e.g. 1–A–2–B–3–C, etc.). Completion times for each part (Parts 1, 2 and 3) were recorded and a formula applied to yield a flexibility score:  $\text{Part 3} - ((\text{Part 1} + \text{Part 2})/2)$ .

A *running span* test (adapted from Morris & Jones, 1990) was used as the *updating* measure. Lists of consonants were read aloud by the tester at the rate of one per second. Participants were instructed to recall the last three letters they had heard in the right order. However, they were also told that they would not know in advance how many consonants would be in the list. Some lists were only three items long, so they could not afford to ignore any letters. There were 12 lists, 3 in each length (3, 5, 7 or 9 items). The 12 lists were randomly ordered, and this order was kept constant across participants. The dependent measure was the number of lists for which the subject correctly recalled the consonants.

The *Stroop interference* test (Stroop, 1935) was used to provide a measure of cognitive *inhibition*. This test was made up of four tasks. During each of them, subjects had 45 seconds to process a maximum number of stimuli. The first task consisted in reading aloud the names of colors printed in black (BLUE, GREEN, RED, YELLOW). In the second task, children had to read the names of colors printed in conflicting ink colors (e.g. BLUE printed in red ink). The third task required participants to name the color of colored rectangles, whereas the fourth one once more involved the processing of color names printed in conflicting ink colors. This time, however, they were asked to inhibit the most automatic process and carry out the least automatic one (naming the color of the ink rather than the word). Inhibition abilities

corresponded to the number of trials successfully performed in Task 4 subtracted from the number of correct trials in Task 3.

A composite executive function score was calculated for each subject. As the scores on the three executive function tests (shifting, updating and inhibition) were based on different scales, Z scores were used. The participants' performances on each of the three tests were converted into Z scores, and these three Z scores were then averaged to obtain a composite measure representing the participant's general executive ability.

### ***Episodic memory***

The *Stories* subtest of the Children's Memory Scale (Cohen, 2001) was used to assess *verbal episodic memory*. Two short stories, which depended on the age of the children, were read slowly by the tester. After each story, subjects had to recall as much of it as they could. Thirty minutes later, delayed recall was performed; one point was allocated for each item of information that was correctly recalled (i.e. person, action, details, location, or temporal context).

The *Family Pictures* subtest (CMS, Cohen, 2001) assessed *visual episodic memory*. Four pictures depicting scenes with different characters were shown to the children, who had to memorize as many components as possible (what, who and where). A delayed recall score (30 minutes later) was calculated by allocating one point to each person or location that was correctly recalled and 2 points to each action.

An overall measure of episodic memory, reflecting overall episodic learning abilities, was calculated by converting each of the delayed recall scores to Z scores and averaging them to yield a composite episodic measure.

### ***Personal semantic memory***

*The recall of personal semantic information* was measured by means of a test derived from Piolino, Hisland et al. (2007). This investigated the same two periods as the TEMPau task (previous school year and preschool years) using 3 topics: 3 names of acquaintances together with their status (e.g. friends, neighbors), 3 personally relevant famous names together with their status (e.g. heroes, movie stars) and 4 items of information about school life (e.g. school's name and address, a lesson or poem, characteristics of the classroom, i.e. floor and location of child's desk). A point was given for each piece of information that was accurately recalled (i.e. confirmed by the mother) and half a point was given if the information was incomplete (e.g. a person's name without his or her status; the school's name but not its address). The number of points was added up for each period (maximum = 10) and converted into a Z score.

The overall measure of personal semantic memory corresponded to the average of the Z score individually calculated for each lifetime period.

## **RESULTS**

### **Statistical analyses**

As the treatment of age as a continuous variable serves as a more sensitive measure of developmental trends than the use of age as a grouping variable, exact age was used in all subsequent statistical analyses.

Each analysis was conducted separately for each lifetime period to examine whether the effect of age on EAM and its underlying mechanisms differed according to the encoding period (recent period *versus* remote period).

As preliminary analyses failed to reveal any gender differences either for EAM performances or for other cognitive performances, the data were collapsed across gender for

all subsequent analyses.

### **Do AMs vary according to encoding period?**

Descriptive statistics of the children's scores on the autobiographical test are provided in Table 1. The t-test for paired samples revealed that remote recollections were less numerous and less episodic than recent ones and required more cues overall (overall spontaneity; see Table 1;  $p < .01$  to  $p < 10^{-5}$ ). By contrast, the specific spontaneity index did not vary according to the encoding period, suggesting that the numerous cues given in an attempt to access the childhood amnesia period had no impact on recall. Moreover, whatever the encoding period, memories were rarely rehearsed or highly emotional, and only rarely associated with visual mental imagery. Only the latter differed according to the encoding period, with remote memories being associated with less mental imagery ( $p < .01$ ). Finally, children rarely associated their memories with Guess responses, whatever the period (10.48% and 14.81 % for the recent and remote periods, respectively – data not shown). Whereas only a quarter of recent memories were judged to be familiar (Know response; 25.81%), almost half the childhood amnesia memories were judged to be so (40.12%).

Complementary analyses revealed that the topics provided by the experimenter affected the nature of the memories recalled, for although the same number of memories were recalled whatever the topic ( $\chi^2 = .17$ ,  $\chi^2 = 2.33$ ,  $df = 2$ , ns for the remote and recent periods respectively), the recall of specific, unique and detailed events (EAMs) varied according to the topic for the remote period. Thus, whereas the number of recent EAMs recalled did not vary with the topic ( $\chi^2 = 0.27$ ,  $df = 2$ , ns), remote EAMs predominantly concerned kindergarten events ( $\chi^2 = 6.2$ ,  $df = 2$   $p < .05$ ). Similar numbers of preschool and school EAMs were produced for the recent and remote periods ( $\chi^2 = 0.88$ ,  $df = 1$ , ns), while family and vacation EAMs were less numerous for the remote period ( $\chi^2 = 4.45$  and  $\chi^2 = 6.4$ ,  $df = 1$ ,  $p < .05$ , respectively).

In sum, the encoding period had a considerable impact on the ability of 6- to 11-year-old children to recall events. Compared with recent memories, events encoded during the first five years of life were less numerous, less episodic and associated with less mental imagery, while specific memories more rarely concerned family and vacation events.

### **Does EAM develop with age?**

The Pearson product-moment correlation coefficient between chronological age and the three indices recorded using the TEMP Au test revealed a large effect of age for the recent period, contrasting with smaller developmental differences for the remote period (see Table 2.). More specifically, the specific spontaneity and episodicity indices showed a large age effect ( $r = .55, p < .001$ ;  $r = .32, p < .05$ , respectively) for the recent period.

By contrast, remote memories were less sensitive to age, as the overall spontaneity index was the only score that correlated with age ( $r = .39, p < .05$ ). In the light of the descriptive data (Table 1), the absence of any correlation between age and the episodicity index for the remote period would appear to be due to the low level of performances regardless of the children's age. Not only were remote memories less numerous than recent ones, but fewer than a third of these remote memories were episodic (29.96%). Most of them (70.04%) were non-detailed and vague or repeated events, i.e. general experiences. Moreover, qualitative analyses of the data showed that whatever the children's age at recall, remote EAMs never concerned the first two years.

Finally, the sole phenomenological characteristic that varied with age was the quantity of visual imagery associated with recollections, which increased with age ( $r = .32, p < .05, r = .30, p = .05$  for recent and remote periods, respectively). Furthermore, the episodicity index was positively linked with two phenomenological characteristics. Whatever the encoding period, the episodicity index correlated with emotion, suggesting that remote memories that persist are

more emotional ( $r = .38$ ,  $r = .36$ ,  $p < .05$  for recent and remote memories, respectively). Only for recent memories was this index associated with quantity of imagery ( $r = .51$ ,  $p < .01$ ). No correlation concerned the frequency of rehearsal.

### **EAM development: direct age effect or indirect age effect through the development of other cognitive abilities?**

Table 3 presents the correlations between chronological age, EAM indices and the 3 cognitive measures (episodic memory, executive functions and personal semantic memory). The correlation matrix showed moderate to high correlations between age and all the cognitive measures, with  $r$ s ranging from .41 to .70 ( $p < .05$  to  $p < .01$ ). Moreover, the cognitive measures were significantly linked to all the AM indices for the recent period, whereas semantic memory was the only cognitive ability to correlate with an AM index for the remote period (overall spontaneity).

As age significantly correlated with all the cognitive measures, which in turn correlated with EAM indices (Table 3), the age-related effect on some AMs described earlier (Table 2) may have been due to age-related differences in some cognitive abilities. We therefore conducted two successive sets of regression analyses to test the possibility that the apparently direct correlations between age and AM might actually reflect indirect influence through other cognitive abilities. Initially, a forward step-wise regression analysis was conducted, with the EAM indices that increased with age as a dependent variable and the three cognitive abilities as independent variables. Thus, the best cognitive predictors were determined for the episodicity and specific spontaneity indices for the recent period and for overall spontaneity for the remote period. Further regressions were then conducted, forcing the predictors into the equation first, followed by age. The reasoning was that if chronological age was no longer a significant predictor of EAM indices after controlling for cognitive

abilities, then age-related differences in AM must be due to differences in these abilities, which are known to improve with age (for a comparable statistical method, see Pak, Czaja, Sharit, Rogers, & Fisk, 2006; Souchay & Isingrini, 2004).

First, results showed different predictors according to the index and the period under consideration (Table 4). Regarding the recent period, all three cognitive abilities contributed significantly to AM. The executive function score was the main predictor of the specific spontaneity index, accounting for 16% of the variance. Furthermore, performance on episodic memory and, to a lesser extent, on personal semantic memory, accounted for 23% and 17% of the total variance of the episodicity index. Concerning the remote period, the semantic memory score was the main predictor of the overall spontaneity index, accounting for 16% of the variance.

Secondly, when variance related to other cognitive abilities was removed (significant predictors were forced into the regression equation first), age did not predict a significant amount of unique variance in AM performance beyond that accounted for by cognitive abilities (Table 4, 2<sup>nd</sup> regression analysis). The proportion of variance shared between age and the AM indices was small (1 to 8%) and never reached significance, whereas it shared a significant proportion when cognitive abilities were not controlled for (Table 2;  $r^2 = 10.2\%$  to  $r^2 = 30.2\%$ ,  $p < .05$  to  $p < .001$ ). Figure 1 depicts the underlying mechanisms that contributed to the age-related effect on AM for both periods.

Taken together, these results indicate that between 6 and 11 years, AMs were characterized by a large age-related increase for the recent period (in the specific spontaneity and episodicity indices), whereas remote memories varied only slightly with age (overall spontaneity index). Nevertheless, these age-related increases in AM mainly reflected an indirect, age-related effect, reflecting the involvement of cognitive abilities known to undergo an age-related improvement.

## DISCUSSION

The major focus of this study was to identify the cognitive mechanisms underlying the development of EAMs in school-age children. We begin by discussing the results of age-related changes in AM according to the encoding periods. We then tackle the issue of the cognitive mechanisms underlying these age related increases in AM.

### *Age-related changes in AM: episodicity and spontaneity*

The correlational analysis (see Table 2) revealed an increase with age in the episodicity index based on auto-noetic consciousness for the recent period. As such, it confirmed our previous AM study with school-age children (Piolino, Hisland et al., 2007) and earlier evidence using more conventional laboratory assessments of episodic memory (Billingsley, Smith, & McAndrews, 2002; Ofen, Kao, Sokol-Hessner, Kim, Whitfield-Gabrieli, & Gabrieli, 2007). We therefore demonstrated that the sense of remembering continues to develop beyond 5 years, which is postulated to be the age at which episodic memory with auto-noetic consciousness emerges (Perner & Ruffman, 1995; Wheeler, 1999). This finding reflects a growing ability to describe personal events from the perspective of the self (see Fivush, 2001), with abundant contextual details (i.e. recalling not only what happened but also where, when and how, with some phenomenological attributes); it suggests an improvement in the ability to truly relive a specific event, together with its external and internal encoding characteristics.

As regards the remote period however, the episodicity index was low (compared with the recent period) and characterized by an age-related invariance (fewer than a third of the narratives described unique episodic memories accessed via auto-noetic consciousness). In

other words, whatever the children's age, the majority of the remote memories concerned general experiences. There was one age-related effect for this period, however, as the overall spontaneity index for the first 5 years increased with age, unlike the specific spontaneity index. As age increased, so, too, did the number of early memories prompted by cues, though not their episodicity. With increasing age, cues did, however, bring about a rise in the number of episodic memories from the recent period.

These results confirm the special status of memories from the preschool years, covering the period of childhood amnesia, compared with remote memories from the early school years which show a large impact of age (see Piolino, Hisland et al., 2007). Our results reinforce the idea that childhood amnesia depends more on the age at encoding than on the length of the time interval or age at retrieval (see Newcombe et al., 2007; Peterson, 2002; Rubin, 2000; Van Abbema & Bauer, 2005; Wetzler & Sweeney, 1986, for reviews). More specifically, EAMs never concerned the first two years and only rarely concerned the period between 2 and 5 years of age, although they became more frequent thereafter. Thus, our results reinforce the distinction between these three different periods in the development of AM: infantile amnesia, childhood amnesia, and the period beyond 5 years of age (Newcombe et al., 2007). Even if events encoded during the first 5 years did not vary with age in terms of episodicity, we cannot rule out an effect of age on AM during this period. Many developmental studies have observed increasing abilities to encode and retain specific experiences over time (see Bauer et al., 2002, for an example). However, these studies used different methodologies, various scoring criteria and, more importantly, were based on different definitions of episodic memory (see Davis, Gross, & Hayne, 2008). Focusing on a strict episodic criterion based on autoegetic consciousness, our results confirmed the extreme scarcity of EAMs for the childhood amnesia period. Among the different explanations that have been put forward to explain the lack of very early EAMs (e.g. memories encoded in a

nonverbal form, not stored in a long-term system, present but inaccessible, etc; see de Haan et al., 2006, for a review), our results favor Tulving's theory (Tulving, 1985, 2002; Wheeler et al., 1997) that the end of childhood amnesia corresponds to the emergence of episodic memory and self-awareness at 4 to 5 years old. First memories are, in fact, mainly semantic, whereas "true" episodic memories only emerge at the end of the preschool period (Farrar & Goodman, 1992; Hudson, 1990; Perner & Ruffman, 1995; Pillemer, 1998; Pillemer et al., 1994; Uehara, 2000). Accordingly, older children and adults are unable to subjectively re-experience the circumstances of early personal events, not because of a problem of retrieval, but because of the virtual absence of truly episodic memory before that age (see also Neisser, 2004). That said, the encoding of genuine EAMs appears to be influenced by self-relevance for children, as we observed differences arising from the topic proposed by the experimenter. Kindergarten events appeared to be more self-relevant cues, contrasting with scant memories of family events (see also Peterson et al., 2005).

In sum, our results indicate that children aged from 6.6 to 11.3 years "just know" about general experiences from their 5 earliest years of life and hardly remember them at all (Wheeler, 1999). In accordance with Tulving's theory (1985, 2002), this phenomenon does not vary according to age at retrieval nor, therefore, to the length of the retention interval. Generic memories, on the other hand, become more accessible to recall as children grow older.

#### *Age-related changes in EAM: rehearsal, emotion and mental images*

As regards the characteristics of EAM, results suggest that phenomenological features, such as frequency of rehearsal, emotional intensity and visual mental imagery, contribute to retrieval. As in the study by Peterson et al. (2005), our findings failed to reveal any significant

age-related changes in these properties, except for the amount of imagery associated with recent memories (Table 2).

Interestingly, the episodicity index was correlated with emotion for both periods. In accordance with several developmental studies, we therefore observed that the recall of EAMs was not only determined by age at encoding or retrieval, but also by emotional intensity (Fivush et al., 2004; Ornstein, 1995; Peterson & Bell, 1996). Heightened emotional feelings are described in the literature as a critical factor not only for the age of the earliest memories (Eacott & Crawley, 1998; Fivush & Hamond, 1990; Ornstein, 1995; Sheingold & Tenney, 1982; Usher & Neisser, 1993) but also, as shown in the present study, for the recollection of auto-noetic memories, however remote.

Like previous developmental studies (Pillemer & White, 1989), we also highlighted the key role of visual mental imagery in the auto-noetic experience and spontaneity of EAMs. The visual re-experiencing of an event is almost invariably involved in the subjective sense of remembering (Conway, 2001; Dewhurst & Conway, 1994; Piolino et al., 2009); its age-related increase seems to be a crucial factor in the development of auto-noetic experience. Moreover, visual mental imagery was also positively linked to the spontaneity of recent memories, confirming its role in providing rich cues that are crucial to the generative processes involved in EAM retrieval (Conway, 2005; Greenberg & Rubin, 1998; Piolino, Desgranges, Clarys, Guillery-Girard, Taconnat, Isingrini et al., 2006).

By contrast, the frequency of memory rehearsal did not appear to be a critical factor, as it neither varied with age, nor explained the quality of the memories or the ease with which children accessed AM. However, although memories did not seem to benefit from rehearsal (thinking or talking to others) in the present study, we cannot completely exclude the possibility that repetition may favor EAM retrieval, as it offers the child the opportunity to update the memory traces (see Fivush & Nelson, 2004).

In sum, the phenomenological characteristics of the memories modulate the quality and the ease with which subjects access AM during both childhood and adulthood (Piolino, Giffard-Quillon, Desgranges, Chételat, Baron, Eustache, 2004; Quas et al., 1999; Viard, Piolino, Desgranges, Chételat, Lebreton, Landeau, et al., 2007).

*Cognitive mechanisms of age-related changes in EAM: direct or indirect effect of age?*

Whereas the phenomenological characteristics of memories varied only slightly with age, all three cognitive abilities assessed here (executive functions, episodic memory and personal semantic memory) improved dramatically with age (Table 4). All three cognitive performances were also linked to the EAM indices for the recent period, while just personal semantic memory was linked to the overall spontaneity index for the remote period. Developmental changes in EAM could therefore be partly influenced by the age-related increase in these cognitive abilities, pointing to a possible indirect effect of age.

Based on several memory frameworks and the results of previous studies (Piolino et al., 2007), we assumed that the higher-order cognitive abilities, i.e. frontal/executive functions known to develop late in childhood (Davidson, Amso, Anderson, & Diamond, 2006; Klimkeit, Mattingley, Sheppard, Farrow, & Bradshaw, 2004; Letho et al., 2003), would constrain the development of EAM. Regression analyses confirmed that executive functions were the main predictor of the age-related increase in spontaneity for EAM for the recent period (Table 5). The age-related increase in the executive functions required during generative processes would appear to be responsible for the gradual improvement in the ability to access EAM.

Similarly, developmental improvements in episodic and personal semantic memory in school-age children appeared to be crucial cognitive mechanisms for age-related changes in EAM, in keeping with Nelson and Fivush's (2004) assumption (Table 5). On the one hand, episodic memory abilities (i.e. episodic learning) contributed partially to age-related changes in recent EAM. The absence of any very strong relationship between EAM and episodic learning was only to be expected, as they differ in many aspects (remoteness, self-relevance, assessment, etc.; see Wheeler et al., 2007). On the other hand, personal semantic memory mediated some of the changes in EAM regardless of the period. These results therefore support Conway's assumption that the autobiographical knowledge base improves extensively across the lifespan (Conway, 2005). Although the role of semantic memory (and more especially of its growth during childhood) in episodic memory development has been studied in the past, semantic memory has always been assessed through general knowledge, and episodic memory through laboratory-based episodic learning (e.g. McGuigan & Salmon, 2004; Murphy, McKone, Slee, 2003; Ornstein, Shapiro, Clubb, Follmer, & Baker-Ward, 1997). For the first time, and in line with Conway's self-memory system (2005), our results confirm the prominent role of personal semantic knowledge in EAM development. The more personal semantic knowledge was enriched with age, the easier AM retrieval became, especially for the first five years of life.

In sum, our findings confirm that the increase in EAM with age is facilitated by richer semantic and episodic abilities and executive functions that allow AM to be accessed more easily. It thus reinforces the assumption that the development of EAMs relies mainly on the development of more basic systems (Nelson & Fivush, 2004; Tulving, 2002, 2005). Moreover, no significant effect of age was observed above and beyond its effect on cognitive abilities, suggesting that the age-related increase in AM in children above 6 years, and therefore beyond childhood amnesia, was fully explained by our cognitive measures. Thus,

the effect of age on AM was indirect rather than direct (see Figure 1) as it depended on the improvement during childhood of other cognitive processes required for the retrieval of AMs. Nevertheless, the predictive measures assessed here did not account for all EAM variability and it is reasonable to assume that the developmental differences may also have been due to other factors. Even if the recent model proposed by Nelson and Fivush (2004) was designed to describe all the main factors involved in the emergence of AM, many of them may contribute to its later development, too. Multiple factors may indeed have a role (Harley & Reese, 1999; Nelson & Fivush, 2004), notably temporal-reconstructive abilities (Friedman & Lyon, 2005), working memory (Baddeley, 2000), language (Pillemer & White 1989) and narrative skill (Fivush, Haden, & Adam, 1995). Future studies are thus required, in order to measure the importance of the cognitive abilities assessed here, in comparison with other factors that must also contribute to the effect of age on AM.

## **CONCLUSION**

Taken together, our findings support the claim that developmental differences in remembering EAMs persist into early adolescence. More specifically, with age, children became increasingly capable of recalling recent autobiographical memories with details, displaying auto-noetic consciousness. By contrast, the quality of memories retrieved from the first five years did not change with age - they were mainly general memories - although older children could access this period more easily. Moreover, our study substantiates the view that AM in 6- to 11-year-olds is formed in a gradual way, in concert with other aspects of cognitive development. The development of AM seems to be essentially bound up with the age-related improvement in the efficiency of other cognitive abilities (executive functions, episodic and personal semantic memory). Further studies are now needed if we are to unravel

the complete set of mechanisms subtending EAM in childhood and adolescence, and understand how this complex form of memory emerges in the first place.

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## References

Aubrun, F. (1998). How to assess postoperative pain? *Annales Françaises d'Anesthésies et de Réanimation*, *17*, 462-470.

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, *4*, 417-423.

Barsalou, L. W. 1988. The content and organization of autobiographical memory. In U. Neisser, & E. Winograd (Eds.), *Remembering reconsidered: Ecological and traditional approaches to the study of memory*, pp. 193-243. New York: Cambridge University Press.

Bauer, P. J. (1996). What do infants recall of their lives? Memory for specific events by 1 to 2 year olds. *American Psychologist*, *51*, 29-41.

Bauer, P. J., Burch, M. M., Scholin, S. E., & Güler, O. E. (2007). Using cue-words to investigate the distribution of autobiographical memories in childhood. *Psychological Science*, *18*, 910-916.

Billingsley, R. L., Smith, M. L., & McAndrews, M. P. (2002). Developmental patterns in priming and familiarity in explicit recollection. *Journal of Experimental Child Psychology*, *82*, 251-277.

Bird, A., & Reese, E. (2006). Emotional reminiscing and the development of an autobiographical self. *Developmental Psychology*, *42*, 613-626.

Casey, B. J., Galvan, A., & Hare, T. A. (2005). Changes in cerebral functional organization during cognitive development. *Current Opinion in Neurobiology*, *15*, 239-244.

Cermak, L. S. (1984). The episodic-semantic distinction in amnesia. In L. R. Squire & N. Butters (Eds.), *Neuropsychology of memory*, pp. 55–62. New York: Guilford Press.

Cheatham, C. L., & Bauer, P. J. (2005). Construction of a more coherent story: Prior verbal recall predicts later verbal accessibility of early memories. *Memory*, *13*, 516-532.

Cohen, M. J. (2001). *Echelle clinique de mémoire pour enfants*. Paris: Editions du Centre de Psychologie Appliquée.

Conway, M. A. (2005). Memory and the self. *Journal of Memory and Language*, *53*, 594-628.

Conway, M. A., Gardiner, J. M., Perfect, T. J., Anderson, S. J., & Cohen, G. M. (1997). Changes in memory awareness during learning: The acquisition of knowledge by psychology undergraduates. *Journal of Experimental Psychology: General*, *126*, 393–413.

Conway, M. A., & Pleydell-Pearce, C. W. (2000). The construction of autobiographical memories in the self-memory system. *Psychological Review*, *107*, 261-288.

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia*, *44*, 2037-2078.

De Haan, M., Mishkin, M., Baldeweg, T., & Vargha-Khadem, F. (2006). Human memory development and its dysfunction after early hippocampal injury. *Trends in Neurosciences*, *29*, 374-381.

Dewhurst, S. A., & Conway, M. A. (1994). Pictures, images, and recollective experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*, 1088–1098.

Eacott, M. J., & Crawley, R. A. (1998). The offset of childhood amnesia: Memory for events that occurred before age 3. *Journal of Experimental Psychology: General*, *127*, 22-33.

Farrar, M. J., & Goodman, G. S. (1992). Developmental changes in event memory. *Child Development*, *63*, 173-187.

Fivush, R. (2001). Owing experience: Developing subjective perspective in autobiographical narratives. In C. Moore & K. Lemmon (Eds.), *The self in time: Developmental perspectives*, (pp. 35–52). Mahwah, NJ: Erlbaum.

Fivush, R., Haden, C., & Adam, S. (1995). Structure and coherence of preschoolers' personal narratives over time: Implications for childhood amnesia. *Journal of Experimental Child Psychology*, *60*, 32–56.

Fivush, R., & Hamond, N. R. (1990). Autobiographical memory across the preschool years: Toward reconceptualizing childhood amnesia. In R. Fivush & J. A. Hudson (Eds.), *Knowing and remembering in young children*, pp. 223-248. Cambridge, NY: University Press.

Fivush, R., Sales, J. M., Goldberg, A., Bahrick, L., & Parker, J. (2004). Weathering the storm: Children's long-term recall of Hurricane Andrew. *Memory*, *12*, 104-118

Friedman, W. J., & Lyon, D. (2005). Development of temporal-reconstructive abilities. *Child Development*, *76*, 1202-1216.

Gardiner, J. M. (1988). Functional aspects of recollective experience. *Memory and Cognition*, *16*, 309-313.

Gardiner, J. M. (2001). Episodic memory and auto-noetic consciousness: A first-person approach. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 356, 1351-1362.

Gathercole, S. E. (1998). The development of memory. *Journal of Child Psychology and Psychiatry*, 39, 3-27.

Giedd, J. N., Blumenthal, J., Jeffries, N. O., Castellanos, F. X., Liu, H., Zijdenbos, A., et al., (1999). Brain development during childhood and adolescence: A longitudinal MRI study. *Nature Neuroscience*, 2, 861-863.

Greenberg, D. L., & Rubin, D. C. (2003). The neuropsychology of autobiographical memory. *Cortex*, 39, 687-728.

Howe, M. L., Cicchetti, D., Toth, S. L., & Cerrito, B. M. (2004). True and false memory in maltreated children. *Child Development*, 75, 1402-1417.

Hudson, J. (1990). Constructive processing in children's event memory. *Developmental Psychology*, 26, 180-187.

Kaufman, A. S., & Kaufman, N. L. (1993). *Batterie pour l'examen psychologique de l'enfant (K-ABC)*. Paris: Editions du Centre de Psychologie Appliquée.

Klimkeit, E. I., Mattingley, J. B., Sheppard, D. M., Farrow, M., & Bradshaw J. L. (2004). Examining the development of attention and executive functions in children with a novel paradigm. *Child Neuropsychology*, 10, 201-211.

Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology, 21*, 59-80.

Mäntylä, T. (1993). Knowing but not remembering: Adult age differences in recollective experience. *Memory and Aging, 21*, 379-88.

Mäntylä, T., Carelli, M. G., & Forman, H. (2007). Time monitoring and executive functioning in children and adults. *Journal of Experimental Child Psychology, 96*, 1-19.

McGuigan, F., & Salmon, K. (2004). The time to talk: The influence of the timing of adult-child talk on children's event memory. *Child Development, 75*, 669-686.

Meltzoff, A. N. (1995). What infant memory tells us about infantile amnesia: Long-term recall and deferred imitation. *Journal of Experimental Child Psychology, 59*, 497-515.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49-100.

Morris, G., & Baker-Ward, L. (2007). Fragile but real: Children's capacity to use newly acquired words to convey preverbal memories. *Child Development, 78*, 448-458.

Morris, N., & Jones, D. M. (1990). Memory updating in working memory: The role of the central executive. *British Journal of Psychology, 81*, 111-121.

Murphy, K., McKone, E., & Slee, J. (2003). Dissociations between implicit and explicit memory in children: The role of strategic processing and the knowledge base. *Journal of Experimental Child Psychology, 84*, 124-165.

Nelson, K. (1986). *Event knowledge: Structure and function in development*. Hillsdale, NJ: Erlbaum.

Nelson, K. (1988). The ontogeny of memory for real events. In U. Neisser & E. Winograd (Eds.), *Remembering reconsidered: Ecological and traditional approaches to the study of memory*, pp. 2244-2276. New York: Cambridge University Press.

Nelson, K., & Fivush, R. (2004). The emergence of autobiographical memory: A sociocultural developmental theory. *Psychological Review*, *111*, 486-511.

Newcombe, N. S., Lloyd, M. E., & Ratliff, K. R. (2007). Development of episodic and autobiographical memory: A cognitive neuroscience perspective. *Advances in Child Development and Behavior*, *35*, 37-85.

Ofen, N., Kao, Y., Sokol-Hessner, P., Kim, H., Whitfield-Gabrieli, S., & Gabrieli, J. D. E. (2007). Development of declarative memory system in the human brain. *Nature Neuroscience*, *10*, 1198-1205.

Ornstein, P. A. (1995). Children's long-term retention of salient personal experiences. *Journal of Traumatic Stress*, *8*, 581-605.

Ornstein, P. A., Baker-Ward, L., Gordon, B. N., Pelphrey, K. A., Tyler, C. S., & Gramzow, E. (2006). The influence of prior knowledge and repeated questioning on children's long-term retention of the details of a paediatric examination. *Developmental Psychology*, *42*, 332-344.

Ornstein, P. A., Shapiro, L. R., Clubb, P. A., Follmer, A., & Baker-Ward, L. (1997). The influence of prior knowledge on children's memory for salient medical experiences. In N. Stein, P. A. Ornstein, C. J. Brainerd, & B. Tversky (Eds.), *Memory for everyday and emotional events*, pp. 83-111. Mahwah, NJ: Erlbaum.

Pak, R., Czaja, S. J., Sharit, J., Rogers, W. A., & Fisk, A. D. (2006). The role of spatial abilities and age in performance in an auditory computer navigation task. *Computers in Human Behavior, 24*, 3045-3051.

Perner, J., & Ruffman, T. (1995). Episodic memory and autonoetic consciousness: Developmental evidence and the theory of childhood amnesia. *Journal of Experimental Child Psychology, 59*, 516-548.

Peterson, C. (2002). Children's long-term memory for autobiographical events. *Developmental Review, 22*, 370-402.

Peterson, C., & Bell, M. (1996). Children's memory for traumatic injury. *Child Development, 67*, 3045-3070.

Peterson, C., Grant, V. V., & Boland, L. D. (2005). Childhood amnesia in children and adolescents: Their earliest memories. *Memory, 13*, 622-637.

Pillemer, D. B. (1998). What is remembered about early childhood events. *Clinical Psychology Review, 18*, 895-913.

Pillemer, D. B., Picariello, M. L., & Pruett, J. C. (1994). Very long-term memories of a salient preschool event. *Applied Cognitive Psychology, 8*, 95-106.

Pillemer, D. B., & White, S. H. (1989). Childhood events recalled by children and adults. In H. W. Reese (Ed.), *Advances in childhood development and behaviour*, pp. 297-340. San Diego: Academic Press.

Piolino, P., & Eustache, F. (2001). Conceptions neuropsychologiques de l'amnésie infantile. In F. Eustache & M. Wolf (Eds.), *Monographies de Psychopathologie: Affections neurologiques et processus psychiques*, pp. 73-114. Paris: PUF.

Piolino, P., Giffard-Quillon, G., Desgranges, B., Chételat, G., Baron, J-C., & Eustache, F. (2004). Re-experiencing old memories via hippocampus: A PET study of autobiographical memory. *NeuroImage*, 22, 1371-1383.

Piolino, P., Desgranges, B., Clarys, D., Guillery-Girard, B., Taconnat, L., Isingrini M, & Eustache, F. (2006). Autobiographical memory, autothetic consciousness, and self-perspective in aging. *Psychology and Aging*, 21, 510-525.

Piolino, P., Desgranges, B., Manning, L., North, P., Jokic, F., & Eustache, F. (2007). Autobiographical memory, the sense of recollection and executive functions after severe closed head injury. *Cortex*, 43, 176-195.

Piolino, P., Hisland, M., Ruffeveille, I., Matuszewski, V., Jambaque, I., & Eustache, F. (2007). Do school-age children remember or know the personal past? *Consciousness and Cognition*, 16, 84-101.

Piolino, P., Desgranges, B., & Eustache, F. Episodic autobiographical memory over the course of time: Cognitive, neuropsychological and neuroimaging findings. *Neuropsychologia*, in press.

Principe, G. F., Ornstein, P. A., Baker-Ward, L., & Gordon, B. N. (2000). The effects of intervening experiences on children's memory for a physical examination. *Applied Cognitive Psychology*, 14, 59-80.

Reitan, R. M. (1958). Validity of the Trail Making Test as an indication of organic brain damage. *Perceptual and Motor Skills*, 8, 271–286.

Rubin, D. C. (2000). The distribution of early childhood memories. *Memory*, 8, 265-269.

Rubin, D. C., & Kozin, M. (1984). Vivid memories. *Cognition*, 16, 81-95.

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

Sheingold, K., & Tenney, X. J. (1982). Memory for a salient childhood event. In U. Neisser (Ed.), *Memory observed*, pp. 201-212. San Francisco: Freeman.

Souchay, C. & Isingrini, M. (2004). Age related differences in metacognitive control: Role of executive functioning. *Brain and Cognition*, 56, 89-99.

Sowell, E. R., Thompson, P. ., Holmes, C. J., Jernigan, T. L., & Toga, A. W. (1999). In vivo evidence for post-adolescent brain maturation in frontal and striatal regions. *Nature Neuroscience*, 2, 859-961.

Sowell, E. R., Thompson, P. M., Tessner, T. D., & Toga, A. W. (2001). Mapping continued brain growth and gray matter density reduction in dorsal frontal cortex: Inverse relationships during postadolescent brain maturation. *The Journal of Neuroscience*, 21, 8819–8829.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18, 643–662.

Tulving, E. (1985). How many memory systems are there? *American Psychologist*, 40, 385-398.

Tulving, E. (2001). Episodic memory and common sense: How far apart? *Philosophical Transactions of the Royal Society*, 356, 1505-1515.

Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology*, 53, 1-25.

Tulving, E., Schacter, D. L., McLachlan, D. R., & Moscovitch, M. (1988). Priming of semantic autobiographical knowledge: A case study of retrograde amnesia. *Brain and Cognition*, 8, 3-20.

Uehara, I. (2000). Differences in episodic memory between four- and five-year-olds: False information versus real experiences. *Psychological Reports*, 86, 745-755.

Usher, J. A., & Neisser, U. (1993). Childhood amnesia and the beginnings of memory for four early life events. *Journal of Experimental Psychology: General*, 122, 155-165.

Van Abbema, D. L., & Bauer, P. J. (2005). Autobiographical memory in middle childhood: Recollections of the recent and distant past. *Memory*, 13, 829-845.

Viard, A., Piolino, P., Desgranges, B., Chételat, G., Lebreton, K., Landeau, B. et al. (2007). Hippocampal activation for autobiographical memories over the entire lifetime in healthy aged subjects: An fMRI study. *Cerebral Cortex*, 17, 2453-2467.

Wechsler, D. (1991). *Wechsler Intelligence Scale for Children - Third Edition*. French version. Paris: Editions du Centre de Psychologie Appliquée.

Wetzler, S. E., & Sweeney, J. A. (1986). Childhood amnesia: An empirical demonstration. In D. C. Rubin (Ed.), *Autobiographical memory*, pp. 191-201. Cambridge, UK: Cambridge University Press.

Wheeler, M. A. (1999). Varieties of consciousness and memory in the developing child. In E. Tulving (Ed.), *Memory, consciousness, and the brain: The Tallinn conference*, (pp. 188-199. Philadelphia: Psychology Press.

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

Table 1. Means scores on the TEMPau test expressed in percentages (and standard deviations). Results of the t-tests that allowed recent and remote periods to be compared are shown in the right-hand columns.

	Recent period	Remote period	t	ddl	<i>p</i>
Mean number of events recalled (maximum = 3)	2.77 (0.43)	1.77 (0.86)	5.78	29	< 10 <sup>-5</sup>
Overall spontaneity	61.94 (16.03)	45.56 (28.25)	2.81	29	< .01
Specific spontaneity	67.92 (16.85)	72.92 (24.96)	-.92	27	ns
Episodicity	51.11 (22.48)	29.96 (22.65)	5.33	27	< 10 <sup>-4</sup>
Rehearsal	36.85 (25.41)	28.86 (25.14)	1.61	27	ns
Emotion	71.38 (22.44)	64.70 (28.89)	1.43	27	ns
Visual mental imagery	55.25 (26.81)	45.38 (28.32)	3.23	27	< .01

Table 2. Relations between age, the three indices of the TEMP Au test and the analogue scales for each encoding period (N = 30).

	Recent period				Remote period			
	Age	Rehearsal	Emotion	Imagery	Age	Rehearsal	Emotion	Imagery
Age	-	.18	.19	<b>.32*</b>	-	.23	.02	<b>.30<sup>&amp;</sup></b>
Overall spontaneity	.28	-	-	-	<b>.39*</b>	-	-	-
Specific spontaneity	<b>.32*</b>	.19	.18	<b>.31<sup>&amp;</sup></b>	.26	.12	.01	.05
Episodicity	<b>.55***</b>	.07	<b>.38*</b>	<b>.51**</b>	.05	.07	<b>.36*</b>	.17

<sup>&</sup>  $p = .05$ , \*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$

Note: correlations between prompting and analogue measures were not calculated, as the analogue scores took into account the number of memories recalled, whereas the overall spontaneity index was based on the number of memory requests (3 per period).

Table 3. Relations between age, the three indices on the TEMP Au test and the general cognitive assessment.

	Executive functions	Episodic memory	Personal semantic memory
Age	<b>.70***</b>	<b>.52**</b>	<b>.41*</b>
Overall spontaneity(recent period)	<b>.40*</b>	.29	.23
Specific spontaneity (recent period)	<b>.40**</b>	.27	.07
Episodicity (recent period)	<b>.42**</b>	<b>.48**</b>	<b>.47**</b>
Overall spontaneity (remote period)	.25	.24	<b>.39*</b>
Specific spontaneity (remote period)	.00	.02	.16
Episodicity (remote period)	.05	.06	.22

\*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$

Table 4. Final results of the regression analysis conducted with the age-sensitive indices of AM as dependent variables. Two regression analyses were conducted for each dependent variable.

1<sup>st</sup>: the results correspond to the forward stepwise regression using the 3 cognitive measures (episodic memory, executive functions, and personal semantic memory) as independent variables.

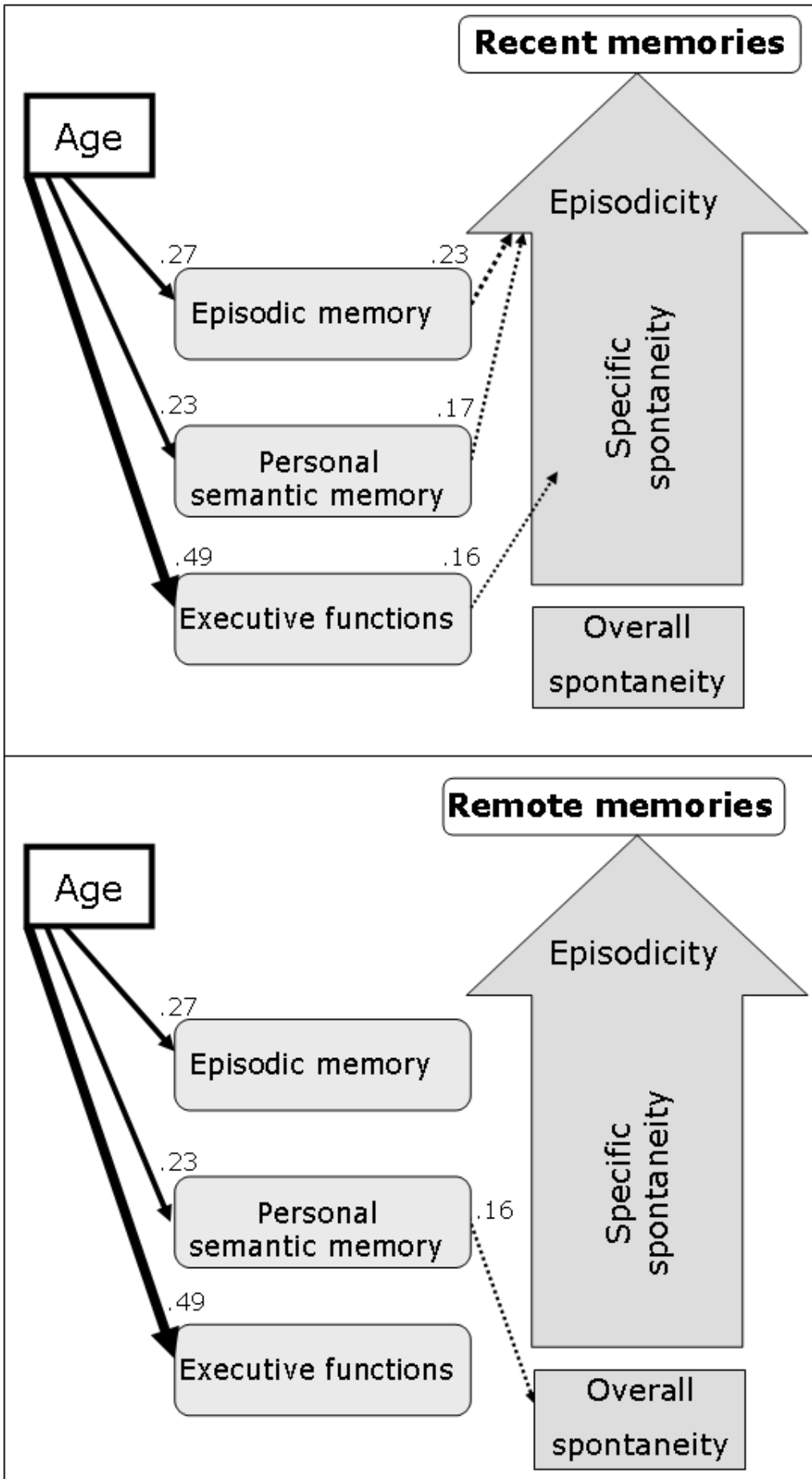
2<sup>nd</sup>: the results correspond to the regression analyses where the significant predictors of the 1<sup>st</sup> analysis were entered into the regression first, followed by age.

<b>Dependent variable</b>		<b>Predictor</b>	<b>R<sup>2</sup></b>	<b>Total R<sup>2</sup></b>	<b>Bêta</b>	<b>F</b>
Specific spontaneity (recent period)	1 <sup>st</sup>	Executive functions	.16*		.40	5.45*
	2 <sup>nd</sup>	Age	.01			0.1, ns
Episodicity (recent period)	1 <sup>st</sup>	Episodic memory	.23**		.48	8.39**
		Semantic memory	.17*	.40***	.42	7.84**
	2 <sup>nd</sup>	Age	.05			1.9, ns
Overall spontaneity (remote period)	1 <sup>st</sup>	Semantic memory	.16*		.37	5.18*
	2 <sup>nd</sup>	Age	.08			2.27, ns

The first R<sup>2</sup> indicates the proportion of variance mediated by each predictor; total R<sup>2</sup> indicates the cumulative percentage of variance mediated by all significant predictors, when the predictors accounted for a significant proportion of variance; The *F* ratios show the significance of the R<sup>2</sup> for each predictor.

\*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$

Figure 1. Schematic representation of the mechanisms of age-related improvements in recent and remote autobiographical memories. The proportion of variance shared between age and the three cognitive functions are indicated above the full lines, and the proportion of variance shared between the cognitive functions and AM indices are indicated above the dotted lines.



## Appendix A

### Instructions for the analogue scales

**Frequency of rehearsal:** “Use this line to indicate how often you think about the memories you have just recalled. This side of the line (*i.e. left side*) means that you have never thought or talked about this event since it happened to you. By contrast, the other side (*i.e. right side*) means that you never stop thinking about this event. The further you go on this side of the line (*the experimenter points to the right side*), the more often you think about this event. I would like you to draw a mark on the line to indicate how often you think about the memory you have just recalled.”

**Emotion at encoding:** “Now, I would like to know about the emotion you felt during the initial event. The left side of the line means that you felt no emotion, whereas the other side means that you got very emotional, for example very happy or very sad. You must draw a mark on the line to indicate the intensity of emotion caused by the event you have just recalled.”

**Visual mental imagery:** “Finally, I would like to know about the amount of visual mental imagery associated with your recall of this event. When we remember a previous experience, we often have the feeling that we are “reliving” the past, accompanied by mental imagery. The left side of the line means that no images are associated with this memory, whereas the other side means that you have lots of images; it is like a film in your mind. You must draw a mark on the line to indicate the amount of visual mental imagery you have when recalling this event.”

Appendix B. Examples of autobiographical memories evoked for each period.

### **Recent period (last year)**

“Last summer, I went to an aqua park called “Maryland” in Antibes. At 11 pm, the night show begun. It was a show with dolphins. A killer whale splashed people in the audience and they got soaked. I was very happy because it was the first time I had seen anything like it. I didn’t know that the killer whale was such a big animal. I hoped the show would last for a very long time. I had watched a lot of other shows during the day. It was really fun. After that, I went back to the hotel with my dad to sleep. Our room was on the second floor. It was in 2003, when I was 9 year old.”

→ **Unique, specific and detailed memory recalled with spatiotemporal information (EAM)**

### **Remote period (preschool years)**

“I was 4 or 5 years old. A woman was standing in for the person who usually supervised our nap. She said something and all the children, including me, fell asleep. The whole class was there, except for the younger children. We had the nap after lunch, and went back to the classroom after the nap.”

→ **Unique, specific memory recalled without details and with no precise spatiotemporal information (AM)**