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Running head: DEVELOPMENT OF PROSPECTIVE MEMORY

Short Article

A Large-Scale Comparison of Prospective and Retrospective Memory Development from
Childhood to Middle-Age

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Abstract

We present the first large-scale comparison of prospective memory (PM) and retrospective memory (RM) from 8 to 50 years of age ($N = 318,614$). Participants in an Internet study were asked to remember to click on a smiley face (single-trial event-based PM test), and to indicate whether/where a picture had changed from study to test (single-trial RM test), in both cases after retention intervals filled with working memory tests and questionnaires. Both PM and RM improved during childhood; however, whereas maximal PM was reached by teenagers, with approximately linear decline through the 20s-40s, RM continued to improve through the 20s and 30s. On both tests, females outperformed males and achieved maximal success at earlier ages. Strikingly, 10-11-year-old girls performed significantly better than females in their late-20s on the PM test. The presence of the smiley face at encoding and temporal uncertainty (expecting it “later” rather than at the “end” of the test) both benefited PM; these effects decreased and increased, respectively, from childhood to middle-age. The findings demonstrate that in a cross-sectional study (i) developmental trajectories are qualitatively different between PM and RM, and (ii) the relative influence of PM cues differs between younger and older ages.

Keywords: prospective memory, retrospective memory, development, adulthood, middle-age, Internet

A Large-Scale Comparison of Prospective and Retrospective Memory Development from Childhood to Middle-Age

Remembering to do something unprompted at some specified point in the future (prospective memory, PM) is at least as important in children as in adults (McCauley & Levin, 2004), with everyday PM tasks including bringing a letter home from school, returning a library book, feeding a pet, turning off the bath taps, and so on. It is therefore perhaps surprising that according to a recent comprehensive review by Kvavilashvili, Kyle, and Messer (2008) there has been an “almost complete lack of research on the development of prospective memory” (p. 115). They suggest this may be due in part to an (incorrect) assumption that developmental work is unlikely to shed new light on PM, or indeed vice versa. Counter to this, there are several novel findings in the aging-PM literature that have led to interesting practical and theoretical advances (e.g., McDaniel & Einstein, 2007). Another reason for the relative lack of developmental studies may be the difficulty in designing PM tasks suitable for young children, with minimal retrospective memory (RM) requirements (see Kvavilashvili et al. for discussion). PM from young adulthood to middle-age has been similarly neglected (Maylor, 2008), and rare studies that have included this age range have tended to suffer from ceiling effects in younger adults and/or low power (see Logie & Maylor, in press, for examples).

From the few existing studies, the general pattern emerging so far is that PM seems quite well developed in preschoolers, consistent with Meacham’s (1982) early view that it forms an important precursor to RM development. There appears to be modest improvement in PM thereafter, contrasting with stronger developmental trends for RM (Kvavilashvili et al., 2008; see Maylor, 2008, for discussion). However, few studies have directly compared the development of PM and RM in the same children, which was one of the aims of the present study. Also, there has been little research on PM through adolescence, a period

during which considerable improvement in RM and executive function continues to take place (e.g., Gathercole, Pickering, Ambridge, & Wearing, 2004). A recent study by Zimmerman and Meier (2006) observed no difference in PM performance between 13-14 year-olds and adults but performance was near ceiling in both age groups. Another of our aims was therefore to assess PM over as wide a range of children's ages as possible (8-17 years), while avoiding both ceiling and floor effects. Moreover, we wished to compare childhood performance with that of young adulthood and middle-age as an earlier report of a subset of the present data suggested that PM may peak at a relatively young age (Logie & Maylor, in press).

Importantly, our aim was to compare PM and RM trajectories from childhood to middle-age using tasks that were as representative as possible (while recognising that neither PM nor RM may be a unitary dimension) and as equivalent as possible (while recognising that this may be difficult to achieve). The PM task was similar to many laboratory-based PM tasks in the literature (see McDaniel & Einstein, 2007, for examples): participants were required to remember to indicate when they saw a pre-designated visual target event, which occurred after other intervening tasks. In the RM task, participants were shown a picture, which they were shown again later and asked where a change had occurred, if any. Thus, both tasks were pictorial in nature, both were measured by success/failure on a single trial, and both involved retention intervals of several minutes filled with ongoing activity. Crucially, however, they differed in terms of whether participants were required to recognise and respond to a target without being prompted (PM) or were explicitly asked to recognise information from the past (RM).

An additional aim was to explore possible gender differences in the development of PM and RM from childhood through to middle-age. Gender has rarely been considered in studies of PM but where differences have been reported, they seem to favor females (e.g.,

Ceci & Bronfenbrenner, 1985, in children; Huppert, Johnson, & Nickson, 2000, in older adults). For the present RM task, female superiority would be expected on the basis of studies of object identity and location memory (e.g., Voyer, Postma, Brake, & Imperato-McGinley, 2007).

In the PM task, participants were asked to “remember to click the smiley face” which eventually appeared in the corner of the screen that provided performance feedback (see Figure 1). Two additional factors likely to influence PM success were manipulated: (i) a smiley face was either present or absent when the PM instructions were initially presented, and (ii) participants were told to expect the smiley face either “at the end of the test” or “later in the test”. Our earlier report of a subset of data from the present study across adulthood (Logie & Maylor, *in press*) showed that prior target exposure and temporal uncertainty both benefited PM performance, particularly in combination. Here, our question of interest was whether children would benefit to the same or even greater extent from these cues (cf. Passolunghi, Brandimonte, & Cornoldi, 1995).

Finally, a novel feature of our study was that data were collected via the Internet, which is beneficial not least because of the statistical power provided by testing substantial numbers of people who also represent a wider demographic than typically used in laboratory-based studies (see Skitka & Sargis, 2006). There are some obvious disadvantages of this methodology – Internet data are noisy because the conditions under which the experiment is conducted (e.g., at school vs. at home) cannot be controlled. However, participants spontaneously seek out the relevant Web site and choose to undertake the tests online, suggesting that they are highly motivated to perform well on the tests. Moreover, effects emerging from such studies conducted on diverse samples under poorly controlled conditions should be particularly robust and generalizable. There is also accumulating evidence to suggest that Web-based experiments can reliably replicate laboratory findings,

including studies of development over a similar age range as the present study (e.g., Reimers & Maylor, 2005).

Method

Participants

Data were collected from 2006-9 via the Science page of the official Web site of the British Broadcasting Corporation (BBC), which was accessed spontaneously by users of the site and by viewers of a major BBC television programme, expressly aimed at a family audience, on human memory broadcast in the fourth month of data collection. In order for their data to be included in the study, participants were required to provide demographic information, including age and gender, although they could still undertake the tests without filling in these details. To exclude repeated attempts by the same individual, we adopted the usual conservative procedure (cf. Reimers, 2007) of selecting only the first occasion on which a particular computer was used (84.3% of data records). This would have excluded some participants who were encouraged or instructed (e.g., by their school teachers) to undertake the tests in classroom settings on shared computers. Participants who failed to achieve above-zero scores on two of the tests (namely, digit span and visual pattern span) were also excluded (1.5% of the data records), the aim being to remove those who did not take the study seriously and/or understand the task instructions sufficiently. Details of the remaining 318,614 participants aged 8-50 years, divided into 21 age groups, are shown in Table 1. Consistent with a previous BBC Internet study (Reimers & Maylor, 2005), there were more females than males, especially amongst teenagers.

Tests and Questionnaires

The series of eight tests and two questionnaires was programmed in Adobe Flash™. An initial ‘welcome’ screen included the following request: “You should rely only on your memory. Please don’t use other people or a pencil and paper to help.” Below we describe the

two tests relevant to this paper. Tests not reported here examined (in the order in which they were presented): object feature recall, digit span, visual pattern span, memory for everyday objects, verbal working memory, spatial orientation, and questionnaires concerning self-rated memory failures, and lifestyle. Note that four of these tests involved traditional span procedures in which trials were presented at increasing levels of difficulty until two errors were made, whereupon the test terminated.

PM Test. PM instructions appeared on the first screen after completing the demographics form: “At the end of the test/Later in the test, we’ll show you a smiley face. We’d like you to remember to click the smiley face when it appears.” Participants were randomly assigned to the end/late condition and also to whether or not a smiley face cue was present or absent at encoding in a 2 x 2 between-subjects design (Figure 1A shows the present-end condition). In all four conditions, the smiley face target was presented after all the other tests and questionnaires had been completed (~20-30 minutes), and was shown in the top-right of a display summarising the participant’s results headed “Here’s a rundown of how you did” (see Figure 1B). Both the initial instruction screen and the feedback screen remained in view until the participant clicked on a button in the bottom-right marked ‘Next’. (These screen durations were not, however, recorded.) PM performance was scored in terms of whether or not the smiley face was clicked before moving to the next screen (success = 1; failure = 0).

RM test. Immediately following the PM task instruction screen, participants were shown a series of three outdoor scenes. They were given a maximum of 20 s to view a scene, and it was then replaced with the same scene but in two cases, a small change had been made, and in the third case, no change was made. Participants were asked to click on the area of the scene in which they thought a change had been made or to indicate that there was no change. As the cursor was moved over the scene, cells of a virtual 3 x 3 grid became

highlighted in red to indicate the area that would be selected when the mouse button was clicked. After the third scene, feedback on performance was provided. There then followed a fourth scene and participants were told that they would see this scene later in the test series and would be asked to specify where a change had been made, if any. This delayed change detection test occurred after four intervening tests, that is, after the test of memory for everyday objects. RM performance was scored in terms of whether or not the area containing the change in this fourth scene was selected (correct area = 1; incorrect area or “no change” = 0).

Results

The overall mean scores for both PM and RM are displayed in Figure 2 as a function of age group and gender. An ANOVA with age group and gender as between-subjects factors and task (PM vs. RM) as the within-subjects factor confirmed what is apparent from Figure 2 (all p 's < .01): Performance varied across age groups (increasing and then decreasing), $F(20, 318,572) = 77.37$, females outperformed males, $F(1, 318,572) = 120.30$, and PM success exceeded RM success, $F(1, 318,572) = 15,314.50$. Gender differences were larger in older children and young adults than in middle-age, $F(20, 318,572) = 4.63$, age trends were quite different between the two tasks, $F(20, 318,572) = 173.20$, and female superiority was greater for PM than for RM, $F(1, 318,572) = 7.73$, but more so in children than in young adults, $F(20, 318,572) = 3.98$. Restricting the ANOVA to the children's age groups (8-17 years) also resulted in the full set of main effects and interactions (all p 's < .001).

Separate ANOVAs on each task produced significant effects of age group, gender, and age x gender (all p 's < .001).¹ Looking at each task separately for females and males, post-hoc comparisons between children and adults (least significant difference test) revealed the pattern summarized in Table 2. To illustrate, 12-13 year-olds girls exceeded all age

groups from 22-50 for PM, but were exceeded by all age groups from 14-50 for RM. In addition to the clear contrast between children exceeding older age groups for PM but being exceeded by older age groups for RM, girls reached young adult levels of PM performance earlier than boys. For example, 10-11 year-old girls outperformed adults in their late-20s whereas 10-11 year-old boys only outperformed those in their 40s. Note also from Figure 2 that for RM, peak performance was achieved earlier by females than by males (28-29 vs. 38-39, respectively).

PM was examined in more detail as a function of the smiley face cue (present vs. absent) and temporal cue (end vs. later). It can be seen from the means in Figure 3 that PM was more successful when the smiley face cue was present than absent (particularly in younger age groups), and less successful for the end than for the later temporal cue (particularly in older age groups). In addition to the effects already discussed of age group, gender, and age group x gender (all p 's < .001), an ANOVA¹ confirmed significant main effects of the smiley cue, $F(1, 318,446) = 1142.06$, and the temporal cue, $F(1, 318,446) = 1144.37$, with interactions between age group and smiley cue, $F(20, 318,446) = 2.32$, and between age group and temporal cue, $F(20, 318,446) = 8.43$. Also, there was an interaction between the two cues, $F(1, 318,446) = 83.54$, such that the difference between the presence and absence of the smiley face cue was smaller for the end temporal cue (.063) than for the later temporal cue (.109). In other words, prior target exposure was more beneficial under temporal uncertainty. No other interactions reached significance.

Finally, binary logistic regressions were conducted on the children's and adults' PM data to assess the independent contributions from age, gender, the two PM cues plus their interaction, and RM (see Table 3 for a summary). In addition to effects already noted (e.g., larger influence of gender in children than in adults; larger influence of the smiley cue in children than in adults but the reverse for the temporal cue; similar influence of the cue

interaction in children and adults), it can be seen that RM was positively (and similarly) related to PM in children and adults (note the overlapping confidence intervals).

Discussion

It is important first to note that other tests in the present battery not reported here successfully replicated standard laboratory findings such as highly significant improvement across childhood on all the working memory measures (cf. Gathercole et al., 2004). For example, digit span increased from around five to seven items from 8-17 years and visual pattern span also increased by around two items. This provides a further demonstration that Internet studies can successfully reproduce laboratory findings in the literature,² including developmental effects (cf. Reimers & Maylor, 2005). Thus while it is possible that children who watch television programmes about memory and access the BBC's Web site may not be typical, their performance on standard tests was as expected from the developmental literature.

Internet methodology does not readily allow checking either for understanding of the PM instructions at encoding or for their accurate recall at the end of the study. However, it seems unlikely that failure to understand and/or retain the PM instructions would play an important role in the interpretation of the present study for at least the following reasons: (i) the PM instructions were encoded at the participant's own pace and were as straightforward as possible, (ii) participants who clearly did not understand or comply with other task instructions were already excluded (see *Participants*), and (iii) even the number of young children who cannot recall PM instructions at the end of laboratory experiments is "usually very small" (p. 121, Kvavilashvili et al., 2008) or zero (e.g., Rendell, Vella, Kliegel, & Terrett, 2009).

For our PM and RM tasks that were equivalent in most respects, performance on both improved during childhood (8-17 years). After that, however, the trajectories diverged, with

PM declining steadily throughout young adulthood and middle-age but RM continuing to improve throughout young adulthood. Thus, whereas children outperformed most adults on PM, most adults outperformed children on RM. These findings therefore provide support for early claims (Meacham, 1982) and more recent reviews (Kvavilashvili et al., 2008) suggesting that PM can develop faster than RM, at least in terms of reaching adult levels of performance at younger ages.

In line with our predictions, females consistently outperformed males on both tasks; females also seemed to reach their peak performance relatively earlier than males. The rate of PM development was particularly rapid for girls, who achieved near-adult levels of success by 10-11 years of age. Female superiority on both the current tasks raises the obvious possibility that females simply took the study more seriously than did males. However, this can easily be discounted by the fact that males significantly outperformed females on at least some other tests in the battery, such as digit span and visual pattern span.

Not surprisingly, the presence of the smiley face cue at encoding led to better PM performance (see Hannon & Daneman, 2007), and children benefited slightly more from this cue than did adults. One might have expected adults (particularly middle-aged) to benefit more from the presence of the smiley cue at encoding because they would be generally less familiar with the concept of a “smiley face” and would therefore gain more from initially experiencing the target stimulus; instead, however, children showed a slightly greater effect of environmental support (see also Passolunghi et al., 1995). Temporal uncertainty enhanced PM performance, which Logie and Maylor (in press) attributed to more active monitoring for the PM target event in the “later” than in the “end” condition. This benefit from temporal uncertainty was less evident in children than in adults, perhaps indicating that the former were relatively more reliant on automatic rather than strategic processes in the PM task (see McDaniel & Einstein’s, 2000, multiprocess framework). Further work is clearly required

into how both younger and older people's expectations about the future context of an intention can affect PM (see Marsh, Hicks, & Cook, 2008, for discussion of this neglected question). However, regardless of age, the combination of the smiley face cue at encoding and uncertainty as to when it would appear was especially helpful to PM success. Moreover, the influence of RM on PM was similar in children and adults, again suggesting that qualitatively similar processes were involved in achieving PM success across different age groups.

Having successfully avoided the ceiling effects that have complicated interpretation of previous lifespan studies of PM, we have shown that PM success in children (especially in girls) can reach adult levels relatively early in comparison with the development of RM. However, it should be acknowledged that although the tasks were matched in many important respects, they did result in somewhat different overall levels of performance (see Figure 2), highlighting the difficulty in designing equivalent PM and RM tasks. Moreover, our conclusion derives from one particular PM task and one particular RM task and may not necessarily extend to comparisons between other PM and RM tasks. For example, although time- and event-based PM tasks seem to result in similar effects of aging (Henry, MacLeod, Phillips, & Crawford, 2004), a different developmental pattern to that of the present event-based study may emerge with a time-based PM task. Also, the present PM target event, although clearly visible (see Figure 1), was outside the focus of attention and irrelevant to the ongoing activity of processing performance feedback (see Maylor, Darby, Logie, Della Sala, & Smith, 2002; McDaniel & Einstein, 2007, for discussion of focal vs. nonfocal targets with respect to both developmental and aging effects). Despite these limitations, the present study demonstrates that Internet methodology may be a useful additional approach for investigating at least some of these issues in the future.

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Footnotes

¹Binary logistic regressions rather than ANOVAs produced similar findings.

²In addition, note that Logie and Duff (2007) reported a subset of data from the present Internet study and showed that the overall mean scores and split-half reliabilities, together with the pattern of intertask correlations, were all largely consistent with laboratory findings from the same tasks.

Table 1

Total Number of Participants, Numbers of Females and Males, and Percentage of Females in Each Age Group (8-50 Years) and Overall

Age (years)	Total	Females	Males	Females (%)
8-9	936	518	418	55.3
10-11	3,525	2,304	1,221	65.4
12-13	10,728	7,585	3,143	70.7
14-15	25,523	17,928	7,595	70.2
16-17	41,267	28,476	12,791	69.0
18-19	29,882	18,812	11,070	63.0
20-21	25,207	14,956	10,251	59.3
22-23	23,357	13,356	10,001	57.2
24-25	22,402	12,697	9,705	56.7
26-27	19,734	11,180	8,554	56.7
28-29	16,776	9,360	7,416	55.8
30-31	14,580	8,024	6,556	55.0
32-33	12,398	6,918	5,480	55.8
34-35	11,643	6,358	5,285	54.6
36-37	10,368	5,748	4,620	55.4
38-39	9,213	5,281	3,932	57.3
40-41	8,686	5,121	3,565	59.0
42-43	8,048	4,885	3,163	60.7
44-45	7,542	4,523	3,019	60.0
46-47	6,932	4,394	2,538	63.4
48-50	9,867	6,387	3,480	64.7
Overall	318,614	194,811	123,803	61.1

Table 2

Results of Post-Hoc Comparisons Between Each Children's Age Group (8-17 Years) and Older Age Groups for PM and RM, Separately for Females and Males

Age group (years)	PM		RM	
	Significantly better ($p < .05$) than		Significantly worse ($p < .05$) than	
	Females	Males	Females	Males
8-9	42-50	48-50	12-50	26-50
10-11	28-50	40-50	12-50	14-50
12-13	22-50	34-50	14-50	16-50
14-15	20-50	24-50	16-47	18-50
16-17	18-50	22-50	18-45	20-50

Table 3

Summary of Binary Logistic Regression Analyses on PM for Children (8-17 Years) and Adults (18-50 Years)

Predictor	Children ($N = 81,979$) ^a		Adults ($N = 236,635$) ^b	
	Wald's $\chi^2(1)$	Exp(B) (95% CI)	Wald's $\chi^2(1)$	Exp(B) (95% CI)
Age (years)	98.22	1.039 (1.031-1.047)	3,293.07	0.974 (0.973-0.974)
Gender ¹	169.19	1.224 (1.188-1.262)	49.05	1.061 (1.044-1.079)
Smiley cue ²	830.03	1.232 (1.215-1.250)	1,681.98	1.188 (1.178-1.197)
Temporal cue ³	436.11	1.163 (1.147-1.180)	1,743.08	1.191 (1.181-1.201)
Cue interaction	56.44	1.056 (1.041-1.071)	96.46	1.042 (1.033-1.051)
RM ⁴	176.59	1.239 (1.201-1.279)	732.98	1.276 (1.254-1.299)

Note. All p 's < .001; Exp(B) indicates the change in odds of PM success for a one-unit change in the predictor, with 95% confidence intervals

^a2Log-likelihood = 108,128.85, Nagelkerke $R^2 = 0.029$

^b2Log-likelihood = 319,251.25, Nagelkerke $R^2 = 0.042$

¹Male = 0; Female = 1

²Absent = -1; Present = 1

³End = -1; Later = 1

⁴Failure = 0; Success = 1

Figure Captions

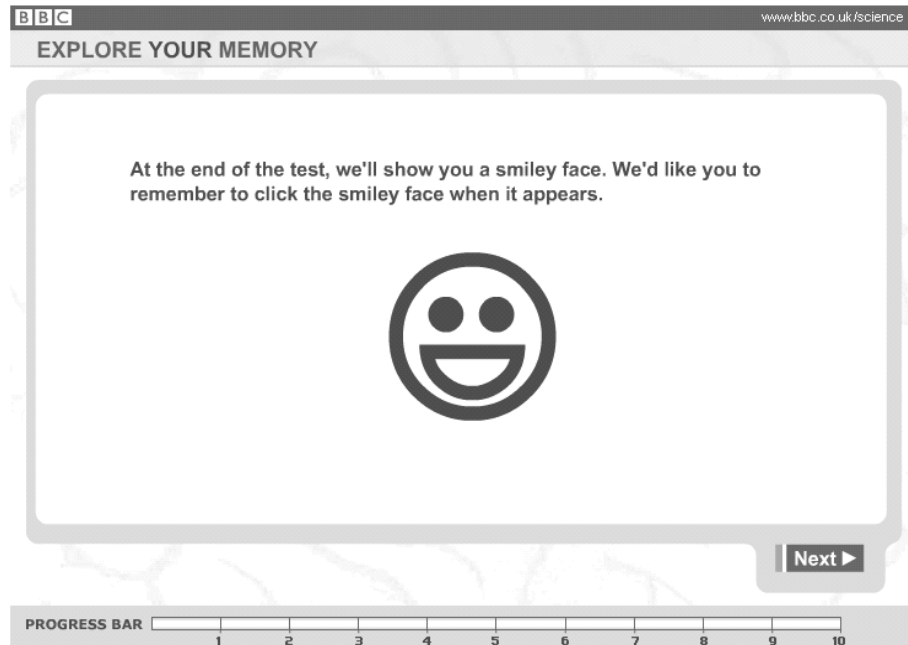
Figure 1. Grayscale screenshots of the BBC Internet experiment showing one of the four versions of the PM instructions (smiley cue present; “end” temporal cue) that appeared at the start of the tests (A), and the feedback screen at the end containing the PM target (B).

Figure 2. Memory performance (proportion correct) for PM and RM tasks as a function of age for females and males.

Figure 3. PM performance as a function of age for smiley present vs. absent (A), and end vs. later temporal cue (B), averaged across females and males.

Figure 1.

A



B

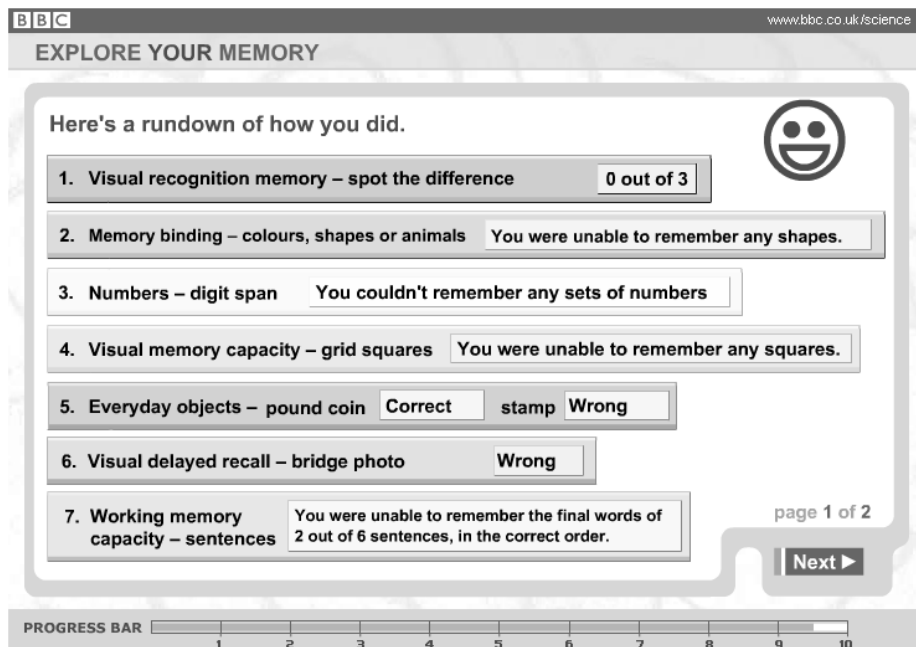


Figure 2.

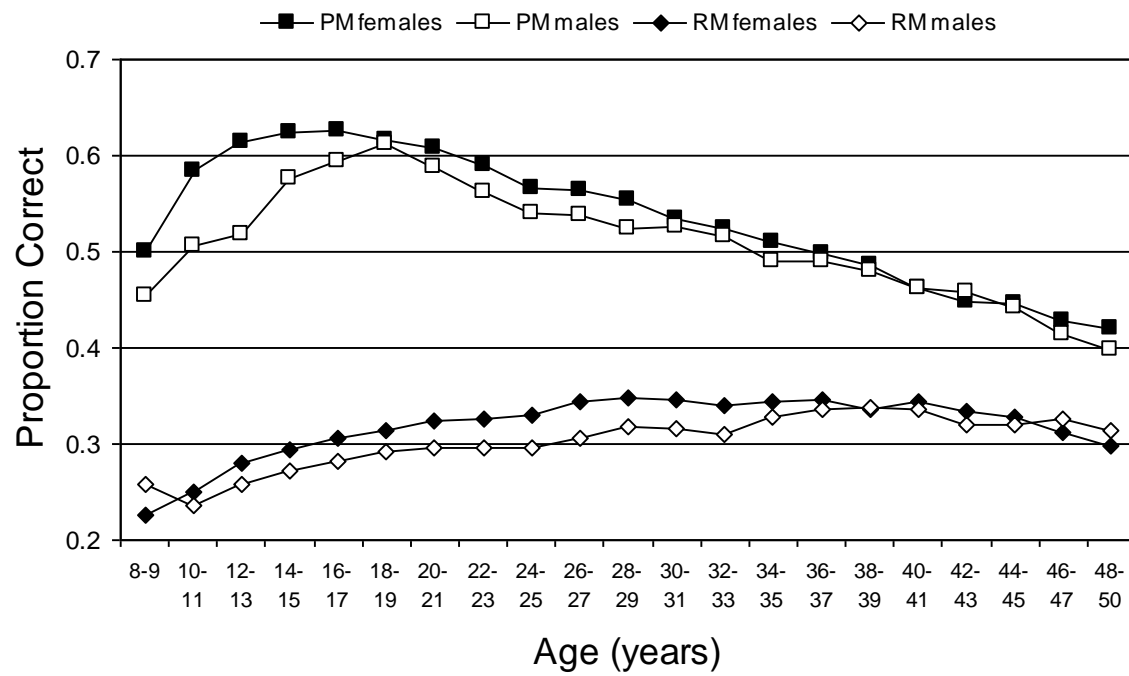
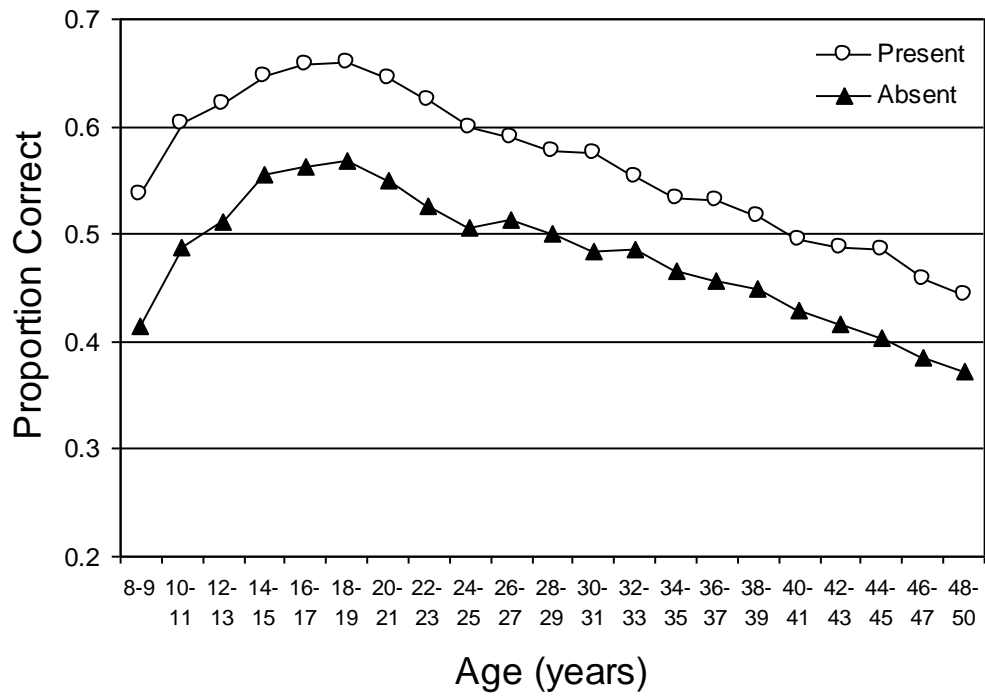


Figure 3.

A



B

