Running head: PROSPECTIVE MEMORY ACROSS ADULTHOOD

An Internet Study of Prospective Memory across Adulthood

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Abstract

In an Internet study, 73,018 18-79-year-olds were asked to "remember to click the smiley face when it appears". A smiley face was present/absent at encoding, and participants were told to expect it "at the end of the test"/"later in the test." In all 4 conditions, it occurred after 20 min of retrospective memory tests. Prospective remembering benefited at all ages from both prior target exposure and temporal uncertainty; moreover, it resembled working memory in its linear decline from young adulthood. The study demonstrates the power of Internet methodology to reveal age-related deficits in a single-trial prospective memory task outside the laboratory.

Keywords: prospective memory; aging; Internet; event-based cueing; temporal uncertainty

An Internet Study of Prospective Memory across Adulthood

The study of human memory has recently broadened to encompass not only retrospective memory (RM) – recognising or recalling information from the past when requested – but also prospective memory (PM) – performing an intended action at an appropriate point in the future without being prompted (Brandimonte, Einstein, & McDaniel, 1996; Kliegel, McDaniel, & Einstein, 2008). Much of the PM literature concerns age-related changes (Maylor, 2008), with results ranging from large age deficits to large age benefits (see reviews by Maylor, 1993, 1996; McDaniel & Einstein, 2007; Uttl, 2005, 2008). The former tend to be associated with laboratory-controlled experiments and the latter with naturalistic studies (Henry, MacLeod, Phillips, & Crawford, 2004), an age-PM paradox that is not entirely explained by older adults' greater use of external reminders outside the laboratory (Maylor, 2008; Phillips, Henry, & Martin, 2008). However, even within the laboratory, age-related effects vary from substantial deficits to age equivalence in performance (Henry et al., 2004; McDaniel, Einstein, & Rendell, 2008; Uttl, 2005, 2008).

Disagreements in the literature highlight difficulties in investigating PM across adulthood. For example, participants could be asked to perform a simple action in response to a particular cue (e.g., Dobbs & Rule, 1987; Huppert, Johnson, & Nickson, 2000), producing a single binary measure of success/failure that can only be a coarse estimate of PM ability. Attempts to increase precision introduce other complications: If several different single-trial PM tasks are administered successively in one session, participants may begin to suspect that PM rather than ongoing task performance is the researcher's primary interest and may alter their strategies accordingly (cf. effects of manipulating PM task importance in Kliegel, Martin, McDaniel, & Einstein, 2004). The number of PM target events may be increased but this similarly risks the task becoming one of vigilance (Uttl, 2005); moreover, multiple observations may not be independent as successfully responding to one PM target event may increase the likelihood of responding to the next (Maylor, 1996). At least two other problems prevalent in the literature concerning aging and PM are that many studies lack sufficient power to detect age-related differences in PM, and studies have failed to avoid ceiling effects that artificially limit group differences (Uttl, 2005, 2008). These problems apply especially to the few studies that have included attempts to compare PM in young adulthood with PM in middle age (e.g., Salthouse, Berish, & Siedlecki, 2004; Zimmermann & Meier, 2006).

The present study avoided the modal approach of administering multiple PM trials to modest-sized groups of young and older adults in favor of a single-trial PM task administered via the Internet to larger numbers of people. Our aim was to explore the trajectory of PM across 60 years of adulthood, and also to compare it with that of RM measures, specifically those for visual short-term memory, digit span and working memory. Participants were instructed to "remember to click the smiley face when it appears." After 20 min of tests and questionnaires, the smiley face was presented on a screen that provided performance feedback. PM was expected to be well below ceiling, and also to decline in old age, because the PM target event was nonfocal, that is, not directly relevant to the particiapnts' ongoing task of processing feedback on their performance (see Einstein & McDaniel, 2005; McDaniel & Einstein, 2000).

However, it could be argued that Internet methodology has at least as much in common with naturalistic studies as with laboratory-based studies, so it is less obvious that PM would show age-related decline in this case. As in laboratory tasks, the interval between PM instructions and test was relatively short and there was some control over the ongoing activities carried out during the retention interval. But as in naturalistic tasks, there was no time limit imposed on viewing either the instruction screen or the feedback screen, the present context was the participants' own familiar environment, and an experimenter was not physically present. Thus, whether or not an age deficit is observed with this paradigm could help to identify the factor(s) responsible for the age-PM paradox.

Two other factors were manipulated between participants in a 2 x 2 design. First, a smiley face was either present or absent when the PM instructions were presented on the screen. Prior target exposure was predicted to increase the likelihood of PM success on the basis of both the RM literature (e.g., Tulving & Thomson, 1973) and several PM studies (see Hannon & Daneman, 2007) showing enhanced memory performance when there is overlap between the target/context/processes at encoding and retrieval. Second, participants were led to expect the smiley face either “at the end of the test” or “later in the test.” There has been surprisingly little work on how people’s expectations about the future context of an intention can affect PM (Marsh, Hicks, & Cook, 2008). An exception is a time-based PM study by Cook, Marsh, and Hicks (2005) in which PM was more successful when participants were told that the target time-window would occur during a specific phase of the experiment than when no such information was given. We therefore expected temporal certainty (“end” as opposed to “later”) to increase the likelihood of PM success. For both factors, our question of interest was whether older adults would benefit to the same extent as would younger adults, or perhaps to a greater extent in the case of the presence of the smiley face where environmental support is provided (Craik, 1986).

Method

Participants

From May 2006 to March 2007, data were collected via the Science page of the British Broadcasting Corporation (BBC) official news website. There was additional advertising for the study’s Web pages during a series of BBC radio and television programs on memory broadcast in August 2006. In total, 160,405 data records (including partially completed attempts) were collected. For inclusion in the present study, participants had to provide demographic information (although they could still take the tests without doing so). To exclude repeated attempts by the same individual, data records were selected from only the first occasion on which a particular computer was used (cf. Reimers, 2007). Participants who failed to achieve predetermined minimum scores (given below) were also excluded to avoid those who did not take the study seriously and/or did not understand the test requirements. After we applied these criteria, there remained 73,018 data records for participants aged 18-79 years (see Table 1 for demographic information). As expected from previous Internet studies with the BBC (e.g., Maylor et al., 2007; Reimers & Maylor, 2005), the age distribution was positively skewed. Also, not surprisingly, the highest level of education achieved differed significantly across age groups, $F(5, 73{,}012) = 193.86$, $MSE = 1.11$, $p < .001$, $\eta^2 = .013$, initially increasing and then decreasing with age.

Tests and Questionnaires

There were eight cognitive tests and two questionnaires programmed in Adobe Flash™ by BBC computing staff employed to generate Web-based material. An opening screen introducing the study included this 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 tests relevant to this study in the order in which they occurred. (Other tests and questionnaires examined visual recognition memory, memory for everyday objects, spatial orientation, self-rated memory failures and lifestyle.)

PM Test. PM instructions appeared on the first screen after the participants completed 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 or later conditions and also to conditions of the cue being present or absent at encoding (Figure 1 shows the end-present condition). In all four conditions, the smiley-face target was presented after all the other tests and questionnaires had been completed (~20-30 minutes),[1] and was clearly visible in the top-right of a display summarising the participant's results (see Figure 1). Both the initial instruction screen and the feedback screen remained in view until the participant clicked on the 'Next' button. PM performance was scored in terms of whether the smiley face was clicked before moving to the next screen (success = 1; failure = 0).

Feature binding. Participants were presented with colored objects (one object/s), with the task of recalling the color, shape and location of each object immediately after stimulus offset. There were two trials each with 1, 2, 3, then 4 objects, although the test stopped when the participant failed to correctly recall the color, shape and location of all of the objects displayed on two trials at a given object array size. Performance was scored as the total number of objects correctly recalled (minimum for inclusion = 1; maximum = 20).

Digit span. Random digit sequences were presented (one digit/s). At the end of the sequence, participants were requested to type in the digit sequence in the order shown. Sequences started with three digits and increased to a maximum of nine, with two sequences at each length. The test stopped when the participant was unable to correctly recall the digit sequence on two trials at a given sequence length. Performance was scored as the total number of digits recalled in the correct order (minimum = 6; maximum = 84).

Visual pattern span. A rectangular matrix pattern with white and blue squares was presented for 2 s and then replaced with a blank matrix, the task being to click on the squares that were previously blue (cf. Logie & Pearson, 1997). The patterns started with 3 x 3 squares (5 blue squares), then 3 x 4 (6 blue), then 4 x 4 (8 blue), then 4 x 5 (10 blue), up to a maximum of 5 x 5 (12 blue), with two patterns shown at each level. The test stopped when participants failed to recall all of the squares correctly on two trials at a given matrix size. Performance was scored as the number of patterns correctly recalled (minimum = 2; maximum = 10).

Working memory span. Short sentences were presented for verification against semantic knowledge. Participants had to click *True* or *False* buttons as quickly as possible and to remember the final word of each sentence (cf. Duff & Logie, 2001). Retrieval was tested by selecting the sentence-final words in the correct order from 20 words displayed in a 4 x 5 array. Sequence length increased from two to six sentences, with two sequences at each length. The test stopped when participantw were unable to recall all of the sentence-final words for two sequences for a given sequence length. Performance was scored as the total number of sentence-final words recalled in the correct serial order (minimum = 2; maximum = 40).

Results

Scores were first standardized with respect to the performance of 18-year-olds by taking each individual's score on a task and subtracting the mean score for the 18-year-olds and then dividing by the *SD* of the 18-year-olds' scores. Next, these were averaged across individuals of the same age and the resulting means are displayed in Figure 2. (The numbers of participants on which each data point is based are shown in Figure 3.) The data from participants in their 70s were obviously noisier than from younger participants, but generally four of the five tests showed an approximately linear decline across the age range from 18 to 79 years, which was steepest for visual pattern span (-.357 correlation with age), less steep for feature binding (-.258), and shallowest (and similar) for PM (-.165) and working memory (-.149). Digit span initially improved in young adulthood and remained stable in middle age before declining somewhat in old age (-.014 correlation with age). All correlations were significant at $p < .001$, and significantly different from each other ($p < .01$ for all comparisons). Partialling out education level had almost no effect on these correlations.[2]

PM scores were examined in more detail by considering the effects of the two experimental manipulations (see Table 1). In addition to declining with increasing age from

.614 in the youngest age group to .258 in the oldest, PM was more successful when the smiley cue was present (.473) than when absent (.403), and less successful under temporal certainty than under uncertainty (.379 vs. .497 for end vs. later conditions, respectively). Age decline was slightly steeper when the smiley cue was present than when absent (at least until the 70-79 age group), and steeper for temporal certainty than uncertainty. Although not apparent in Table 1, the overall difference between the presence and absence of the smiley cue was .060 under temporal certainty (end) but .084 under temporal uncertainty (later).

A binary logistic regression confirmed these observations, with smiley cue (present/absent) and temporal cue (later/end) entered as categorical variables and age centered prior to calculating interaction variables (Aiken & West, 1991). The overall model was significant, 2Log-likelihood = 97,378.14, Nagelkerke $R^2 = 0.058$, with contributions ($p < .001$) to the prediction of PM success from age, Wald's $\chi^2(1) = 1{,}959.66$, Exp(B) = 0.971 (95% CI = 0.970-0.973); smiley cue, Wald's $\chi^2(1) = 399.14$, Exp(B) = 0.738 (0.716-0.760); temporal cue, Wald's $\chi^2(1) = 773.40$, Exp(B) = 0.655 (0.636-0.675); Smiley Cue x Temporal Cue, Wald's $\chi^2(1) = 14.49$, Exp(B) = 0.971 (0.957-0.986); Age x Smiley Cue, Wald's $\chi^2(1) = 12.88$, Exp(B) = 0.998 (0.996-0.999); and Age x Temporal Cue, Wald's $\chi^2(1) = 34.84$, Exp(B) = 0.996 (0.995-0.997). Note that the Exp(B) values indicate that the temporal cue was a stronger manipulation than was the smiley cue and that its interaction with age was also stronger. The three-way interaction did not reach significance, Wald's $\chi^2(1) = 2.99$, $p = .084$, Exp(B) = 1.001 (1.000-1.002), although the trend suggested that the Smiley Cue x Temporal Cue interaction was more evident at younger than at older ages.

With the standardized scores from the four RM tests added to the logistic regression, the contribution from age decreased but remained the strongest predictor of PM success, Wald's $\chi^2(1) = 1{,}107.76$, Exp(B) = 0.977 (0.975-0.978). Of the RM tests, the largest contribution was from working memory span, Wald's $\chi^2(1) = 153.72$, Exp(B) = 1.094 (1.078-

1.109); then feature binding, Wald's $\chi^2(1) = 118.60$, Exp(B) = 1.088 (1.072-1.105); visual pattern span, Wald's $\chi^2(1) = 78.98$, Exp(B) = 1.076 (1.059-1.094); and digit span, Wald's $\chi^2(1) = 20.29$, Exp(B) = 0.964 (0.949-0.980); $p < .001$ in all cases. Note that with the other RM tests included in the regression, higher digit-span scores were associated with poorer PM performance.

Discussion

Before discussing the PM results, we mention that it is reassuring that the RM results were as we expected from the aging literature. For example, digit span showed less marked decline with age than did working memory span (see Verhaeghen, Marcoen, & Goossens, 1993). Also, decline was approximately linear across the adult life span and evident from early adulthood (e.g., Li et al., 2004; Park et al., 2002; Salthouse & Babcock, 1991), demonstrating again that Web-based studies can reliably replicate standard findings in the literature (see Gosling, Vazire, Srivastava, & John, 2004; Maylor & Reimers, 2007; McGraw, Tew, & Williams, 2000). However, although highly significant, the age correlations were weak. Inevitably, there is considerable noise in Internet data because of the lack of control over the conditions under which the experiment is conducted, with many uncontrolled factors such as monitor size, hand positions, distractions, noise, time of day, and participants' honesty. There is also no control over the participants' state – for example, they may be tired, intoxicated, or not wearing their glasses. Nevertheless, effects that emerge from such experiments conducted on diverse samples under poorly controlled conditions should be particularly robust and generalizable (Birnbaum, 2004; Reips, 2002; Skitka & Sargis, 2006).

The present study achieved its main objective of establishing the detailed trajectory of PM across adulthood using a single-trial paradigm equivalent to everyday PM requests such as "Remind me to phone X when this program is over." Both ceiling effects in young adults and floor effects in older adults were avoided, and the Internet methodology provided sufficient power to detect age-related decline even from young adulthood to early middle age (cf. Maylor, 1998). Decline in PM was at least as great as that in working memory span, which is traditionally associated with moderate aging effect sizes (Verhaeghen et al., 1993). This was despite the dichotomous outcome for PM, which tends to reduce the size of age effects (see Uttl, 2008). Note, however, that the present study employed a nonfocal PM target – a less marked age decline would be expected with a focal target (Kliegel, Jäger, & Phillips, 2008; Maylor, Darby, Logie, Della Sala, & Smith, 2002; McDaniel & Einstein, 2000).

It is possible that because we did not check for understanding of the PM instructions at encoding or for their accurate recall (i.e., RM) at the end of the study, age deficits at either stage could instead account for age decline in the PM task. Although such possibilities cannot be entirely discounted, it should be emphasized that the present analyses only included participants who had demonstrated their understanding of all the other tests by achieving performance above minimum levels. Also, there was no time limit for encoding the PM requirements, which were deliberately uncomplicated – for example, it would be difficult to forget the response required to the smiley face as participants were doing little else but "clicking" stimuli for the previous 20-30 minutes. Most importantly, three of the four RM tests each made independent and positive contributions to PM success, as we expected from studies showing the influence of working memory and/or executive functioning on PM (e.g., Marsh & Hicks, 1998; McDaniel, Glisky, Rubin, Guynn, & Routhieaux, 1999). Nonetheless, the contribution from age remained highly significant when we took these RM measures into account (cf. Zeintl, Kliegel, & Hofer, 2007). Note finally that age deficits in laboratory studies of PM usually remain after the removal of the minority of participants who cannot recall the PM instructions (e.g., Maylor, 1998).

With regard to the age-PM paradox, our data suggest that, in order to reverse the age decline associated with laboratory studies of PM, it is clearly insufficient to conduct the task in the participants' own familiar environment, without an experimenter physically present, and with unlimited time for PM encoding and retrieval,. Although these features shared with naturalistic tasks may have played some role in influencing performance, it seems that they were considerably outweighed by features shared with laboratory tasks. These include the requirement to rely on one's own memory and not use additional cues or external memory aids (cf. age-related decline in a naturalistic PM task for participants who relied on their own memories in Maylor, 1990), and the control over tasks carried out during the PM retention interval that may be more demanding for older adults (see McDaniel et al., 2008; Phillips et al., 2008, for discussion).

Prior target exposure increased the overall likelihood of PM success as expected (Hannon & Daneman, 2007), but older adults benefited no more (in fact, slightly less) than younger adults. Although contrary to Craik's (1986) framework whereby memory deficits in old age can be reduced with appropriate environmental support, this finding is not unprecedented in the PM literature – thus, younger adults outperform older adults equally on time- and event-based tasks in the laboratory (Henry et al., 2004) even though the latter supposedly provide greater environmental support.

Contrary to findings of previous work by Cook et al. (2005), temporal certainty regarding the PM target's occurrence decreased the likelihood of PM success, particularly in older adults. Thus, it is not always the case that providing a specific future context benefits PM. There may be a number of explanations for this finding that would require further exploration. However, we tentatively suggest that for participants in the 'later' condition (temporal uncertainty), the PM task was represented at a higher level of subthreshold activation during the retention interval (see Goschke & Kuhl's, 1993, 1996, 'intention superiority effect') and/or was associated with more strategic monitoring than for participants in the 'end' condition (temporal certainty). In line with the latter notion, multiple regression analyses on RM scores revealed highly significant contributions to the variance from age and PM in all cases (higher RM scores associated with younger age and PM success), but there were also small but significant contributions ($p < .05$) from the temporal cue condition (higher RM scores for ‘end’ than for ‘later’) for feature binding and visual pattern span (interestingly, the two visuospatial tasks).[3] In other words, there was evidence of greater costs to ongoing task performance under temporal uncertainty (see Cook, Marsh, Clark-Foos, & Meeks, 2007; Marsh, Hicks, & Cook, 2006, for similar findings), consistent with more active monitoring for the target.

Finally, the PM manipulations interacted such that prior exposure was more beneficial under temporal uncertainty, suggesting that they affected PM performance via their influence at the same stage(s) of processing. The qualitatively similar pattern of costs to the ongoing performance of at least one RM task (i.e., feature binding) would point toward the retention interval as one potential common stage of influence. Further investigation would be necessary to identify other possible mechanisms. Nevertheless, the present study clearly indicates that Internet methodology offers a promising new avenue for PM research employing the preferred single-trial approach. In particular, it allows the opportunity to explore PM in volunteers who represent wider demographic and age ranges than those typically used in the past. Importantly, the present study highlights age-related decline (at least cross-sectionally) in PM, which is evident much earlier in adulthood than was previously suspected.

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Footnotes

[1]Note that it would not necessarily be the case that older participants took longer than did younger participants to complete all the tests and questionnaires. This is because some of the RM tests used span procedures whereby trials were presented at increasing levels of difficulty and the test stopped when errors were made.

[2]This was also the case when participants in their teens and 20s, many of whom would not yet have completed their education, were excluded from the correlations.

[3]There were no significant contributions to any of the RM scores from the smiley cue condition although there was a trend (p = .065) for lower feature-binding scores for smiley cue present than absent.

Table 1

Number, Age, Education, and PM Performance of Participants in Each Age Group

	Age group (years)					
Characteristics	18-29	30-39	40-49	50-59	60-69	70-79
N						
Total	34,194	19,226	11,004	6,468	1,786	340
Women	18,539	8,750	4,323	2,829	998	150
Men	15,655	10,476	6,681	3,639	788	190
% Women	54.2	45.5	39.2	43.7	55.9	44.1
Age (years)						
M (SD)	23.5 (3.38)	34.1 (2.83)	44.1 (2.88)	53.8 (2.83)	63.1 (2.70)	73.2 (2.70)
Education[a]						
M (SD)	3.32 (1.02)	3.61 (1.07)	3.44 (1.10)	3.40 (1.10)	3.32 (1.13)	3.22 (1.15)
95% CI	3.31-3.33	3.59-3.62	3.42-3.46	3.37-3.42	3.26-3.37	3.10-3.35
PM[b] *M (SD)*						
Smiley cue present	.654 (.476)	.576 (.494)	.506 (.500)	.431 (.495)	.347 (.476)	.327 (.470)
Smiley cue absent	.574 (.494)	.507 (.500)	.431 (.495)	.385 (.487)	.335 (.473)	.188 (.399)
End temporal cue	.577 (.494)	.484 (.500)	.398 (.490)	.348 (.476)	.276 (.447)	.194 (.404)
Later temporal cue	.651 (.477)	.599 (.490)	.539 (.499)	.467 (.499)	.407 (.492)	.322 (.468)

[a]1 = None or Primary School; 2 = Secondary or High School; 3 = Technical, Vocational or Other College; 4 = Graduate; 5 = Postgraduate or Professional Degree

[b]PM success = 1; PM failure = 0

Figure Captions

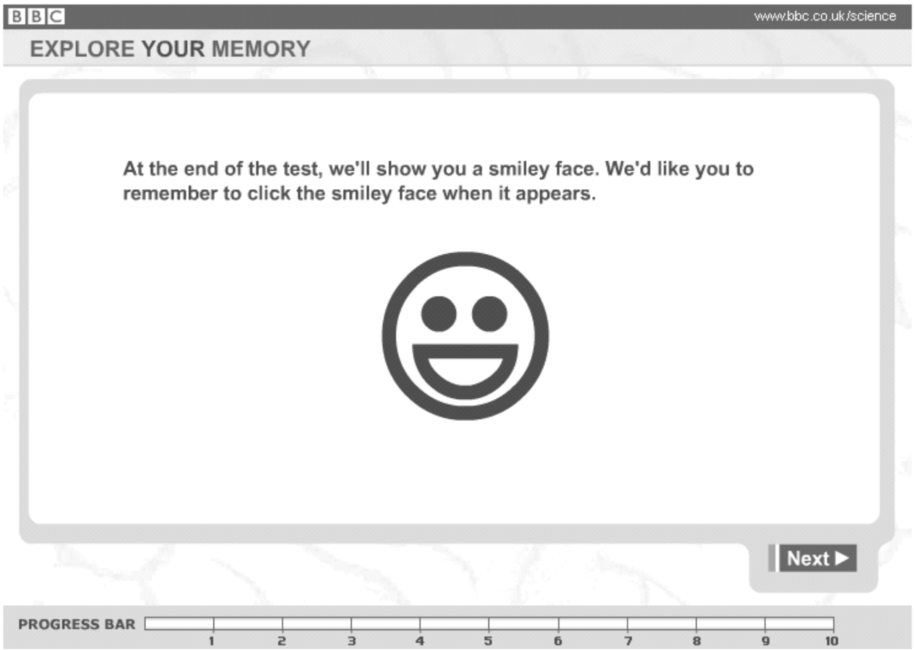
Figure 1. Grayscale screenshots of the BBC Internet experiment showing one of the four versions of the PM instructions (smiley face present; “end” temporal cue) that appeared at the start of the tests (A), and the feedback screen at the end containing the PM target (B).

Figure 2. Means (± 1 *SE*) of scores standardized with respect to the performance of 18-year-olds for the PM task and four RM tasks (feature binding, digit span, visual pattern span, and working memory span).

Figure 3. Frequency distribution of participants from 18 to 79 years of age.

Figure 1.

A


BBC
www.bbc.co.uk/science
EXPLORE YOUR MEMORY
At the end of the test, we'll show you a smiley face. We'd like you to remember to click the smiley face when it appears.
Next ▶
PROGRESS BAR
1 2 3 4 5 6 7 8 9 10

B

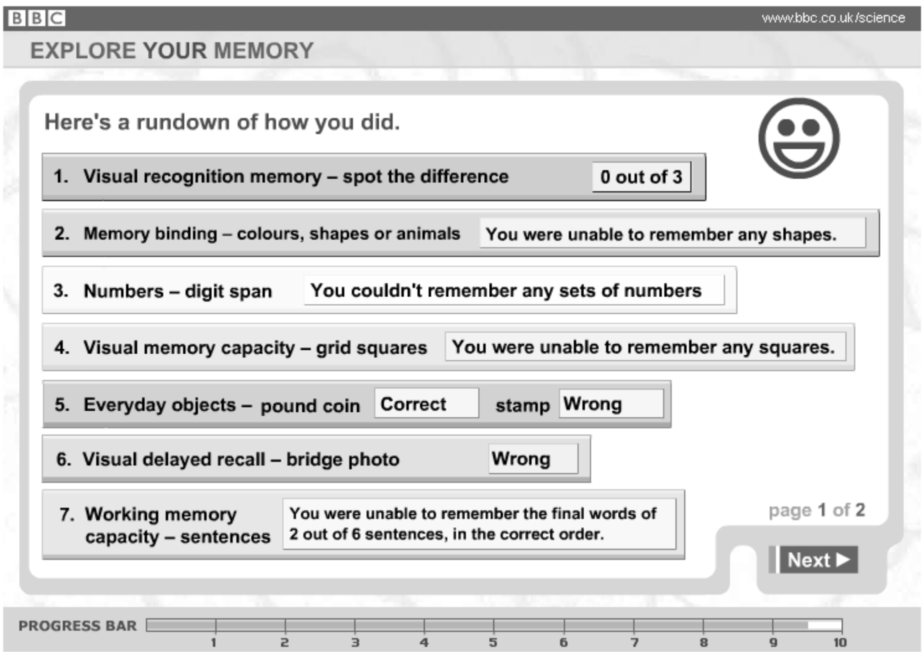

BBC
www.bbc.co.uk/science
EXPLORE YOUR MEMORY
Here's a rundown of how you did.
1. Visual recognition memory – spot the difference
0 out of 3
2. Memory binding – colours, shapes or animals
You were unable to remember any shapes.
3. Numbers – digit span
You couldn't remember any sets of numbers
4. Visual memory capacity – grid squares
You were unable to remember any squares.
5. Everyday objects – pound coin
Correct
stamp
Wrong
6. Visual delayed recall – bridge photo
Wrong
7. Working memory capacity – sentences
You were unable to remember the final words of 2 out of 6 sentences, in the correct order.
page 1 of 2
Next ▶
PROGRESS BAR
1 2 3 4 5 6 7 8 9 10

Figure 2.

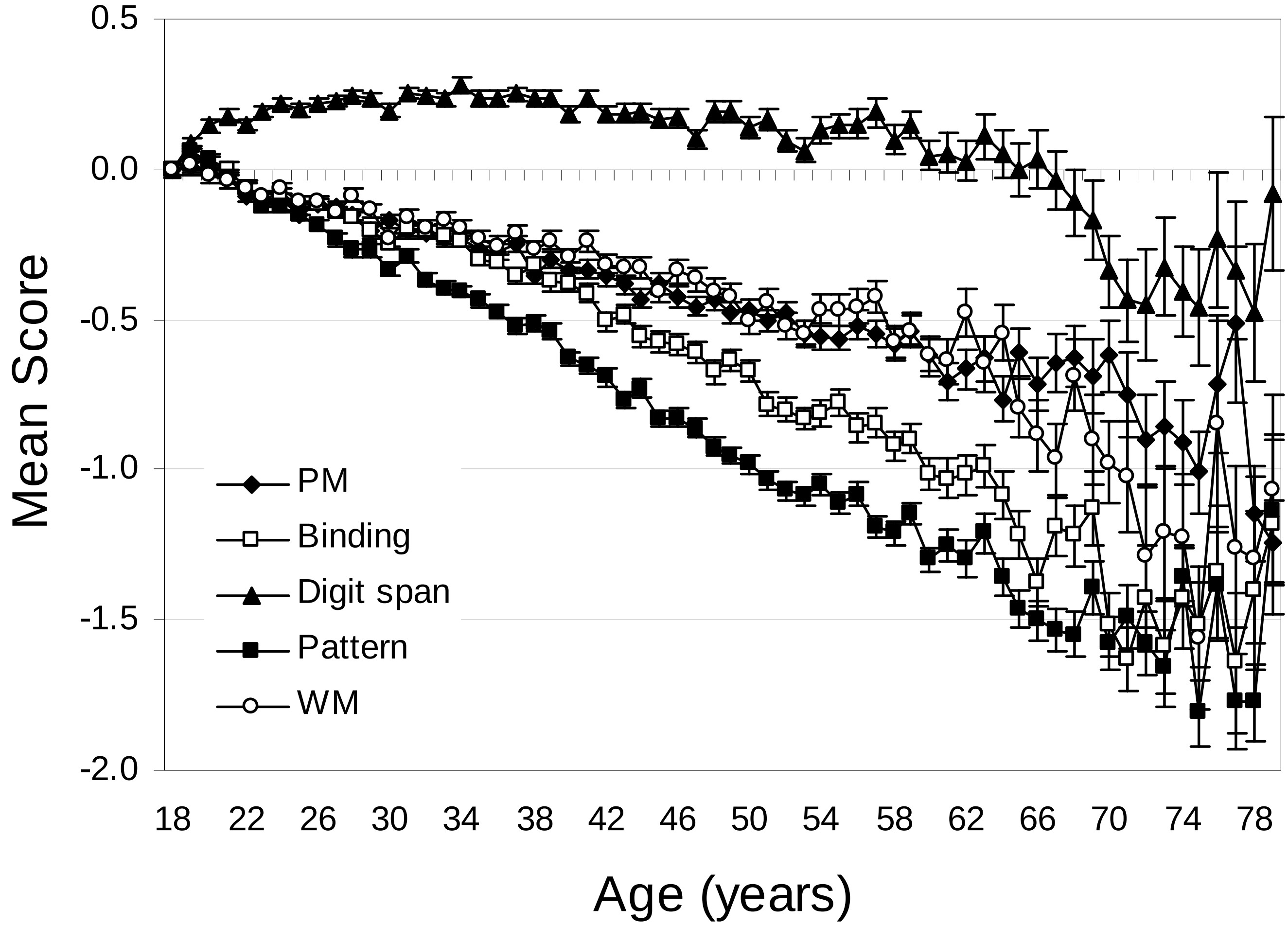
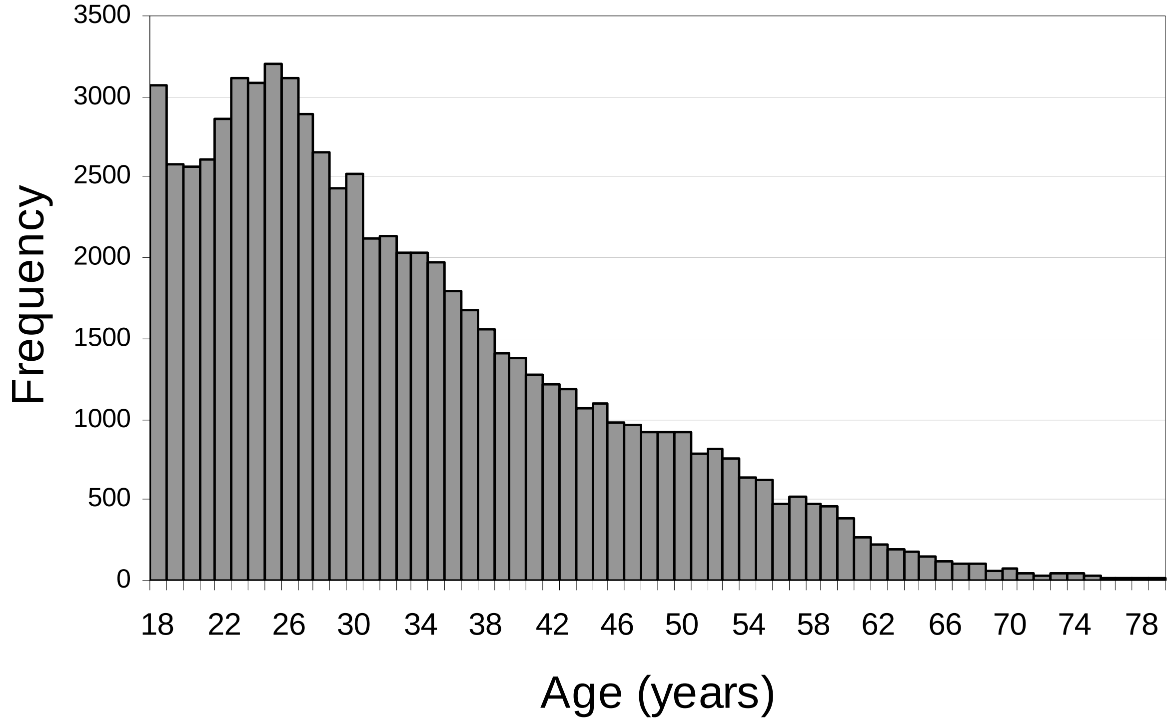

0.5
0.0
-0.5
-1.0
-1.5
-2.0
Mean Score
18
22
26
30
34
38
42
46
50
54
58
62
66
70
74
78
Age (years)
PM
Binding
Digit span
Pattern
WM

Figure 3.



3500
3000
2500
2000
1500
1000
500
0
Frequency
18 22 26 30 34 38 42 46 50 54 58 62 66 70 74 78
Age (years)