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Age Differences in Episodic Memory, Semantic Memory, and Priming: Relationships to Demographic, Intellectual, and Biological Factors

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This study examined age differences in episodic memory, semantic memory, and priming using a random sample of 1,000 men and women from 10 age groups (35, 40, 45, . . . 80 years). The main purpose was to determine whether an age effect existed after differences on various demographic, intellectual, and biological factors had been controlled for. The simple correlations of age with episodic and semantic memory performance were found to be significant, whereas no relationship was found between age and levels of priming. After controlling for differences on the background factors, age predicted episodic but not semantic memory performance. It is proposed that the failure to account for the age effect on episodic memory is because it is caused by age-related neuronal changes.

THERE is ample evidence that advanced age is associated with impaired memory functioning (Kausler, 1991; Salthouse, 1991), but the basis for this impairment is not well understood (Light, 1991). Physical changes in the aging brain (e.g., Creasey & Rapoport, 1985) will likely prove to be one important factor. However, to appreciate the degree to which such changes affect memory functioning, it is important to take into account various differences between young and old persons on factors that are related to cognitive functioning. A striking illustration of this point was recently provided by Lindenberger and Baltes (1994), who showed that differences in sensory functioning accounted for most of the age-related variance in intelligence. Studies of episodic memory functioning have also found that controlling for background factors is critical. In general, controlling for differences on cognitive factors seems to eliminate (Troyer, Graves, & Cullum, 1994) or greatly reduce (Hultsch, Hertzog, & Dixon, 1990) the age-related variance in episodic memory performance, whereas controlling for noncognitive factors seems to have less of an effect (West, Crook, & Barron, 1992). The purpose of the research reported here was to extend these previous studies by examining how age differences in episodic memory, semantic memory, and priming are influenced by differences between young and old subjects on cognitive and noncognitive factors related to memory functioning.

One of the factors we considered was education. In Sweden, as in most other countries, the average educational level is markedly higher for younger than older people, and memory performance has been shown to be related to this factor (Inouye, Albert, Mohs, Sun, & Berkman, 1993; West et al., 1992). A second factor considered was fluid intelligence, as measured by the block design test (Wechsler, 1981). Block design is known to be a very age-sensitive task (e.g., Lezak, 1983), and several studies have shown that performance on this measure is strongly linked to memory functioning (e.g., Wahlin et al., 1993). We also considered two biological factors: blood pressure and vitamin B_{12} status. Aging is associated with increased blood pressure and decreased levels of vitamin B_{12}, conditions that can lead to impaired cognitive performance (e.g., Elias, Robbins, Schultz, & Pierce, 1990; Hector & Burton, 1988). Finally, we considered gender as a factor. Several studies have found that women outperform men on episodic memory tests (e.g., Wahlin et al., 1993; West et al., 1992), although the evidence for an Age by Gender interaction is weak (Larrabee & Crook, 1993).

A variety of memory tests were included. These were selected from a larger battery of 34 different memory tests (see Nilsson et al., in press). Four of the tests included here were episodic memory tests, two were semantic memory tests, and one was a measure of perceptual priming. The latter two types of tests involve *implicit retrieval*, in that subjects are not required to think back to a study event, whereas the episodic tests involve *explicit retrieval*. Many studies have indicated that the age effect is more pronounced on explicit tests than on implicit tests (for reviews, see Light, 1991; Moscovitch & Winocur, 1993). The inclusion of both explicit and implicit tests allowed us to test this finding further. In addition, the inclusion of explicit and implicit tests made it possible to compare the effect of controlling for differences in the background factors on the age effect for different types of tests.

To examine the importance of age differences on the above described background factors for the age effect on the different memory tests, a regression methodology was used (cf., West et al., 1992). First, simple regression analyses were conducted. The results of these analyses show whether or not there is an effect of age on memory performance. Second, hierarchical regression was used to determine whether age predicts performance after variance from the background factors had been removed. The latter type of analysis involved regression of the memory performance on the scores on the background factors (entered simultaneously), after which age was entered into the equation (cf., Hultsch et al., 1990).

METHOD

Subjects

The participants were 1,000 adults from 10 different cohorts (100 35-year-olds; 100 40-year-olds; . . . and 100 80-year-olds). They were part of the Betula prospective study of aging, memory, and health. The sample and the sampling procedure of this study have been described in detail elsewhere (Nilsson et al., in press). In brief, the participants were randomly sampled from the population of Umeå, Sweden. Persons suffering from a severe sensory handicap, mentally retarded or demented persons, and persons having a native tongue other than Swedish were not included in the sample.

Procedure

The data were collected during two test sessions scheduled about one week apart. Each session lasted about 90 minutes. The first test session mainly included a medical examination and collection of questionnaire data, and this test session was run by a nurse. The second test session included cognitive testing only and was run by a psychometrician (the majority of the cognitive tests included in this study were administered during this session). All subjects were tested individually. For further procedural details, see Nilsson et al. (in press).

Predictors

Gender. — The subjects within each cohort were sampled such that the gender distribution would approximate that in the population as a whole. In practice, this meant that the sample consisted of more women (n = 530) than men (n = 470).

Education. — This measure was based on self-reports with regard to years of formal education.

Block design. — The subjects completed the Swedish version of the Block-design test (Wechsler, 1981). The raw scores were used in the analyses.

Systolic blood pressure. — The subjects' systolic blood pressure was measured during the first test session by a nurse after they had rested 3 minutes on a bed. Time of testing during the day varied among subjects.

Vitamin B_{12}. — Blood samples used for blood analysis of B_{12} were collected during the first session.

An overview of the individual difference variables is presented in Table 1.

Dependent Measures — Episodic Tests

Free recall of enacted and nonenacted sentences. — These measures consisted of recall of simple sentences (e.g., *roll the ball*). Subjects were presented with two lists of 16 sentences each at a rate of 8 sec/sentence (the sentences were read by the experimenter and shown simultaneously on cards). For one list, the subjects were told to enact according to the sentences and to try to remember as many sentences as possible. If the sentences included external objects, these were handed over by the experimenter. For the other list, subjects were told to try to remember as many sentences as possible (i.e., they were encoded without enactment). Following presentation of each list the subjects were given a free-recall test. Two minutes were allowed for recall. List order and materials were counterbalanced across subjects.

Memory for words studied and retrieved under divided attention conditions. — This measure consisted of immedi-

Table 1. Summary Statistics for Independent Measures Across Age-groups; Means and (*SD*)

Age (Gender:F/M)	Education	Block Design max = 51	Systolic Blood Pressure	Vitamin B_{12}
35 (50/50)	13.93 (2.60)	34.37 (9.42)	119.45 (13.12)	334.41 (120.15)
40 (52/48)	13.54 (3.50)	31.82 (8.18)	121.95 (14.37)	331.62 (104.66)
45 (54/46)	12.74 (4.22)	32.05 (9.22)	126.95 (16.16)	321.29 (103.68)
50 (60/40)	10.42 (3.72)	29.93 (8.52)	130.85 (16.07)	329.23 (119.58)
55 (54/46)	8.94 (3.26)	29.59 (9.19)	137.20 (17.44)	327.81 (106.21)
60 (46/54)	8.82 (3.20)	25.67 (7.81)	147.60 (21.74)	289.61 (98.44)
65 (54/46)	8.16 (2.94)	22.80 (8.85)	152.35 (22.31)	335.59 (201.99)
70 (48/52)	8.22 (3.29)	22.52 (8.82)	153.60 (22.64)	289.87 (142.01)
75 (53/47)	7.48 (2.76)	17.15 (8.15)	157.10 (22.81)	299.05 (187.38)
80 (59/41)	7.35 (3.13)	14.04 (7.62)	159.39 (22.26)	270.35 (146.25)

ate recall of 12 nouns. At study, one word was presented (read by the experimenter) every 2 seconds, and at the same time the subjects were required to sort standard playing cards into two piles according to their color (one card every time a word was read). During the recall phase a beep from a timer was heard every 2 sec. The subjects were instructed to recall one word every time they heard a beep and also to sort a card every time a beep was heard. If they could not come up with a word they were still supposed to sort cards. The test phase lasted 45 sec.

Name recognition. — This measure consisted of a multiple forced-choice name-recognition test. First, subjects were presented with 16 photos of children's faces, and below each face a fictitious first and family name was written (one face and name was presented every 8 sec). The subjects were instructed to try to remember the face and the family names for a later test. At test, given approximately 20 min after study, 24 faces were presented (12 old; 12 new). The subjects were instructed to say "yes" when they recognized a face and "no" if they did not recognize a face. For all studied faces, recognized or not, four different combinations of first and family names were presented and the subjects had to select the combination which they believed had been presented earlier along with the face (a set of names was also shown if a subject recognized a nonstudied face, but these "false alarms" were not considered in the analyses). The number of correct responses (responses including the correct first and family name) was used in the regression analyses.

Semantic Tests

Word fluency. — This measure consisted of performance on a word generation task. Subjects were instructed to say as many names of professions that started with the letter B as they could come up with in one minute.

General knowledge retrieval. — This measure consisted of retrieving general information, and it was part of a source memory task in which subjects were asked to recall the source (or setting) of acquired information (cf., Schacter, Harbluk, & McLachlan, 1984). Four different presentation modes were used to present 10 made-up statements of famous people and 10 made-up statements of fictitious people. At test, subjects were given 20 questions related to the previously presented statements and 20 "new" questions. The answers to 10 of the new questions could be answered on the basis of general knowledge, whereas the other 10 were impossible to answer because they were questions about fictitious people. For each answer, the subjects indicated the source of the information by selecting one of 10 alternatives. The number of correct answers to the 10 new questions in the source memory test that could be answered on the basis of general knowledge was used in the analyses.

Priming Test

Stem completion. — This measure involved completion of name stems. The subjects were given 32 two-letter name stems and asked to complete each stem with the first family name they could think of. Half of the stems were possible to complete with the family names presented in the face/name recognition test (Hits), and the other half could only be completed with names not encountered in the experiment (Baseline). Within each age group, the stems served equally often as hits and baseline stems. The number of stems that were completed with studied names, corrected for the baseline probability of completion (Hits-Baseline), was used in the analyses.

An overview of the mean performance on the dependent measures in the different age groups is given in Table 2.

Results

Preliminary Analyses

Simple and age-partialed correlations among the independent and dependent variables are shown in Table 3. As can be seen from the table, age was strongly related to education, block design, and BPs, and weakly related to B_{12} status. All of the background factors were found to be significantly related to at least one memory test (p's $< .01$).

Condition indices were computed to check for multicollinearity. A condition index greater than 15 indicates a possible problem with multicollinearity, and an index greater than 30 may indicate a serious problem (Wilkinson, 1992, p. 180). The largest condition index equaled 21 and the second largest equaled 10. An examination of the proportion of variance accounted for by the principal component associated with the highest index (signaling a possible problem with multicollinearity) showed that this component contributed to the variance in age (.756) and BPs (.685). Thus, no background factor seemed to predict others, suggesting that all factors could be included in the analyses. This impression was further supported by a second check for multicollinearity, in which each independent variable was regressed against the others (cf., West et al., 1992). It was found that no variables predicted others at a problematic level ($R >$ .90), so all background factors were included in the regression analyses.

Reliability was estimated with Spearman-Brown corrected split-half Pearson correlations. Across age groups, the reliability for the episodic tests was .48 (average across the four tests), for the semantic .46 (general knowledge), and for the priming test .26 (computed on hits).

Regression Analyses

The alpha level was set at .01. The use of this conservative level of significance was motivated by the large sample size. The outcome of the regression analyses for each dependent measure is summarized in Table 4.

Episodic tests. — The simple regression analyses revealed that the amount of age-related variance associated with each episodic test ranged widely (4.3% to 34.8%), and that age was a significant predictor in all of the tests. The impact of age was substantially reduced when it was entered after the individual factors, but for all of the tests, the proportion of variance added by age was still significant (p name-rn $< .02$). Education, gender, and block design were

Table 2. Group Characteristics — Dependent Measures

	Episodic Memory Tests				Semantic Memory Tests		Stem Completion		
Age	Action Memory max = 16	Sentence Memory max = 16	Recall + Div. Att. max = 12	Name-Rn[a] max = 12	Word Fluency	General Knowledge max = 10	Hits max = 16	Base max = 16	Hits-Base (%)
35	10.81	6.46	4.31	5.03	6.33	7.81	4.14	2.28	1.86 (.12)
	(2.57)[b]	(2.72)	(1.49)	(2.94)	(3.10)	(1.78)	(1.89)	(1.31)	(2.19)
40	10.33	5.97	4.15	5.15	6.08	8.17	3.80	2.22	1.58 (.10)
	(2.43)	(2.56)	(1.33)	(2.32)	(2.99)	(1.65)	(1.76)	(1.40)	(2.18)
45	10.31	5.38	4.09	4.62	5.49	8.23	3.67	2.38	1.29 (.08)
	(2.25)	(2.55)	(1.44)	(2.44)	(2.79)	(1.58)	(1.78)	(1.29)	(2.32)
50	9.58	5.29	3.86	4.88	5.65	7.99	3.55	2.68	0.87 (.05)
	(2.68)	(2.89)	(1.32)	(2.10)	(2.88)	(1.53)	(1.75)	(1.26)	(2.29)
55	9.23	4.90	3.66	4.32	5.18	8.04	3.84	2.69	1.15 (.07)
	(2.16)	(2.71)	(1.38)	(2.65)	(3.28)	(1.66)	(1.73)	(1.38)	(2.29)
60	8.24	4.31	3.53	4.61	5.25	8.09	3.31	2.26	1.05 (.07)
	(2.71)	(2.24)	(1.28)	(2.10)	(3.27)	(1.59)	(1.47)	(1.45)	(1.99)
65	7.61	4.05	3.31	4.45	4.68	7.49	3.98	2.12	1.86 (.12)
	(2.44)	(2.29)	(1.19)	(1.97)	(3.06)	(1.81)	(1.89)	(1.24)	(2.06)
70	6.88	3.78	3.11	4.15	4.62	7.46	3.50	2.24	1.26 (.08)
	(2.67)	(2.33)	(1.25)	(2.16)	(2.82)	(1.76)	(1.61)	(1.19)	(1.80)
75	5.93	3.09	2.74	3.82	3.80	6.88	3.11	2.22	0.91 (.06)
	(2.61)	(2.18)	(1.24)	(1.97)	(2.70)	(1.92)	(1.52)	(1.20)	(1.85)
80	5.05	2.53	2.59	3.35	3.86	6.49	3.14	2.12	1.02 (.06)
	(2.75)	(2.01)	(1.16)	(2.05)	(3.09)	(1.73)	(1.56)	(1.30)	(1.95)

[a]Name-Rn = Name recognition.
[b]*SD*'s within parentheses.

Table 3. Simple (Upper) and Age-Partialed (Lower) Correlations Among Independent and Dependent Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
(1) Age	1.0	−.56	−.01	−.58	.59	−.12	−.59	−.43	−.39	−.21	−.26	−.26	−.08
(2) Education	—	1.0	.04	.51	−.40	.08	.44	.44	.40	.19	.37	.32	.11
(3) Gender	—	.04	1.0	.09	.06	−.04	−.09	−.08	−.11	−.06	−.07	.02	−.03
(4) Block design	—	.28	.11	1.0	−.36	.11	.54	.45	.37	.19	.40	.32	.10
(5) Blood pressure	—	−.09	.07	−.02	1.0	−.04	−.32	−.30	−.26	−.12	−.14	−.13	−.06
(6) Vitamin B_{12}	—	.02	−.04	.05	.04	1.0	.10	.13	.08	.02	.04	.01	.03
(7) Action memory	—	.18	−.13	.30	.04	.03	1.0	.54	.40	.21	.38	.38	.07
(8) Sentence memory	—	.26	−.09	.27	−.06	.09	.39	1.0	.43	.26	.34	.27	.08
(9) Recall + div. att.	—	.24	−.12	.19	−.04	.04	.24	.32	1.0	.20	.33	.28	.12
(10) Name–rn	—	.09	−.07	.08	.00	−.01	.12	.19	.13	1.0	.18	.15	.11
(11) Word fluency	—	.28	−.08	.32	.02	.01	.29	.27	.26	.14	1.0	.35	.07
(12) General knowledge	—	.22	.02	.22	.03	−.02	.30	.18	.20	.10	.30	1.0	.04
(13) Stem completion	—	.09	−.03	.06	−.01	.02	.03	−.09	.10	.10	.05	.02	1.0

found to be significant predictors for three of the four tests, whereas neither of the biological factors significantly predicted performance on any of the tests.

Semantic tests. — The simple regression analyses showed that, although the amount of explained variance was lower than for most of the episodic tests, age was still a significant predictor of performance on both semantic tests. However, after controlling for differences in the background factors, age did not explain any variance in the semantic tasks. It was found that education and block design predicted performance on both tests, and that gender was a significant predictor of word-fluency performance (with women outperforming men).

Priming test. — The number of stems that were completed with target names was in all age groups significantly higher for stems that could be completed with studied names than for stems that could only be completed with nonstudied names ($p < .01$). As measured by the simple regression analysis, age was not a significant predictor of priming on the stem-completion test. There was a trend toward a significant effect of age ($.05 > p > .01$) but age did only account for 0.6% of the variance, and after controlling for differences in the background factors age did not explain any additional variance. None of the background factors were significant predictors of the amount of priming. There was a tendency to a significant effect of education ($p < .05$), but the total amount of explained variance was less than 2%.

Table 4. Summary of Simple and Hierarchical Regression Analyses

Predictor	B	Cum. R^2	ΔR^2	F (total block)	Predictor	B	Cum. R^2	ΔR^2	F (total block)
Action Memory					Word Fluency				
First analysis					First analysis				
Age	−.590	.348		531.89*	Age	−.255	.065		69.44*
Second analysis[a]					Second analysis[a]				
Education	.107*				Education	.250*			
Gender[b]	−.133*				Gender[b]	−.119*			
Block design	.287*				Block design	.332*			
BPs	.066				BPs	.061			
B_{12}	.007	.359		111.20*	B_{12}	−.016	.215		54.33*
Age	−.401*	.431	.072*	125.10*	Age	.040	.216	.001	45.42*
Sentence Memory					General Knowledge Retrieval				
First analysis					First analysis				
Age	−.434	.188		231.06*	Age	−.256	.065		69.75*
Second analysis[a]					Second analysis[a]				
Education	.220*				Education	.208*			
Gender[b]	−.106*				Gender[b]	−.014			
Block design	.250*				Block design	.214*			
BPs	−.038				BPs	.065			
B_{12}	.063	.289		80.65*	B_{12}	−.036	.140		32.23*
Age	−.136*	.298	.009*	69.88*	Age	−.055	.141	.001	27.14*
Recall + Divided Attention					Stem Completion:Hits-Base				
First analysis					First analysis				
Age	−.393	.154		181.88*	Age	−.079	.006		6.35
Second analysis[a]					Second analysis[a]				
Education	.224*				Education	.090			
Gender[b]	−.131*				Gender[b]	−.036			
Block design	.168*				Block design	.056			
BPs	−.005				BPs	−.006			
B_{12}	.020	.222		56.41*	B_{12}	.019	.017		3.28*
Age	−.164*	.234	.012*	50.29*	Age	.010	.017	.000	2.83*
Name-Rn									
First analysis									
Age	−.207	.043		44.59*					
Second analysis[a]									
Education	.083								
Gender[b]	−.077								
Block design	.090								
BPs	.019								
B_{12}	−.016	.053		11.07*					
Age	−.120*	.059	.006	10.42*					

[a]The *B* coefficients are from the equation including age as a predictor.
[b]A negative coefficient indicates that women scored higher than men.
*$p < .01$.

Discussion

The main purpose of this study was to examine the age effect on episodic memory tests, semantic memory tests, and a priming test after controlling for age differences on biological, demographic, and intellectual factors. The simple correlation between age and memory performance was significant for all episodic and semantic memory tests, but not for priming. Reliable age differences have previously been demonstrated on stem completion (e.g., Hultsch, Masson, & Small, 1991), and it has been suggested that stem completion has a strategic search component that may make this priming test especially age sensitive (Winocur, Moscovitch, & Stuss, 1996). Procedural differences and/or a lower reliability of the priming test in the present study compared with studies in which age differences have been found (Hultsch et al., 1991) may explain the present lack of age effect. At any rate, there was a tendency to an age effect, so rather than showing a lack of age effect, our results may best be characterized as showing a *smaller* age effect on priming than on episodic and semantic test performance (cf., LaVoie & Light, 1994).

Level of education and performance on the block design test were found to be powerful mediators of the age effect on semantic and episodic memory. Both of these factors were negatively correlated with age, and they accounted for significant portions of variance on both semantic tests and on three episodic tests. Block design is a speeded test, and response speed was of some importance in all semantic and episodic tests. It is thus possible that the relationship between block design performance and performance on these tests reflects age-related cognitive slowing (cf., Salthouse, 1985). Education may be an indirect marker of many different factors (cf., Hill, Wahlin, Winblad, & Bäckman, 1995), ranging from strategy use to socioeconomic status. It is therefore difficult to come up with a specific explanation as to why higher level of education is associated with higher memory performance. With respect to the other factors, women generally performed better than men on the semantic and episodic tests, and neither of the biological variables predicted test performance. The finding that women outperformed men is consistent with the results of previous studies (e.g., West et al., 1992). The lack of effect of the biological factors may be related to the fact that both were within normal ranges (cf., Wahlin et al., 1993).

After controlling for differences on the background factors, age was unrelated to semantic memory performance (cf., Kausler, 1991). Together with the lack of correlation between age and level of priming, this adds to previous findings that age differences on implicit tests (semantic as well as priming tests) are minimal (e.g., Mitchell, 1989). In contrast, even after controlling for differences on relevant background factors, age remained a significant predictor of episodic memory performance (cf., West et al., 1992). Next, we will turn to possible explanations of why controlling for these background factors accounted for the age effect on semantic memory but not on episodic memory.

Given the selective residual effect of age on episodic memory, it is unlikely that the effect is caused by some general factor such as reduced perceptual speed (such a factor should be critical also for the fluency test; Lindenberger, Mayr, & Kliegl, 1993). Instead, it is more likely that factors specific to episodic remembering are underlying the observed residual effect of age on episodic test performance. Major differences between the semantic and episodic tests included (a) that well-learned materials had to be retrieved in the former class of tests whereas information acquired in the experimental setting had to be retrieved in the episodic tests, and (b) that subjects had to retrieve information from a specific study event in the episodic tests. It has been proposed that aging-related neuronal changes affect both of these factors. Using positron emission tomography study, Grady et al. (1995) obtained evidence that one basis for an age-related episodic-memory impairment is that, due to age-related changes in critical brain regions, old people fail to encode new stimuli adequately (i.e., in a way that allows normal performance on episodic tests). Turning to the second difference, Parkin and Walter (1992) suggested that elderly people have problems with initiating retrieval operations necessary to evoke episodic information, possibly due to frontal dysfunction. Taken together, in the light of these previous studies, a plausible explanation of the residual effect of age on episodic memory is in terms of aging-related neuronal changes. Additional work is needed to assess the validity of this account.

In conclusion, the present results underscore the importance of taking into account age differences in relevant background factors in comparisons of age differences in memory performance. Importantly, by including different classes of tests (episodic tests, semantic tests, and a priming test), we were able to show that controlling for differences on background factors is more critical for some forms of memory than others. Also, it was found that age remained an important predictor of episodic but not semantic memory after differences on the background factors had been taken into account. This finding is suggestive of a "true" age-related memory impairment for episodic memory, likely caused by neuronal changes that accompany aging.

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