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Influence of Processing Speed On Adult Age Differences in Learning

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Two studies were conducted with adults from a wide range of ages to investigate the mechanisms by which a slower processing speed contributes to adult age differences in short-term learning. Although statistical control of measures of perceptual speed substantially reduced the age-related variance in measures of associative learning and of maze learning, there was little evidence that speed exerted its effects through processes of forgetting previously correct responses or perseverating with the same incorrect responses.

Adult age-related differences in learning are well-established in a variety of learning situations. For example, there are reports of slower learning by older adults in maze learning (Baddeley & Brooks, 1976; Husband, 1930; Wright, 1957), mirror tracking (Wright & Payne, 1985), reading degraded or inverted text (Hashtroudi, Johnson & Chrosniak, 1991), identification of stimuli from fragments (Russo & Parkin, 1993), verbal paired associates (Kausler & Puckett, 1980; Monge, 1971; Winn, Elias & Marshall, 1976), and remembering lists of unrelated words (Crook & West, 1990; Macht & Buschke, 1983; Mueller, Rankin & Carlomusto, 1979; Query & Megran, 1983; Rankin & Firnhaber, 1986; Worden & Sherman-Brown, 1983). However, despite the robustness of the phenomenon, the reasons for age differences in learning are not yet understood.

A recent project (Salthouse, 1994) identified two factors that appear to contribute to adult age differences in associative learning; the probability of forgetting previously correct responses, and the speed with which simple operations could be executed. That is, increased age was associated with greater forgetting of responses that were correct on the prior trial, and with slower performance in simple perceptual comparison tasks. Both of these measures were correlated with associative learning accuracy, and when the forgetting and speed measures were statistically controlled, the relation between age and associative learning performance was no longer significantly different from zero. More detailed analyses of the data across successive trials were reported by Salthouse & Dunlosky (in press). These analyses identified forgetting and perseverations, which were operationalized as the continued use of a response already disconfirmed for the current stimulus, as important correlates of adult age differences in trial-by-trial improvement.

The current project consists of two studies designed to replicate and extend the earlier findings. Study 1 examined familiar (digits and letters) and unfamiliar (symbols) stimulus materials in associative learning. The contrast was not pure because the familiar stimuli were presented before the unfamiliar stimuli for all research participants, but the comparison should still prove informative.

Study 2 examined the effects of repeated experiences with the same type of stimuli (but different items) across three blocks of trials. Generalizability was investigated with another learning task designed to be amenable to a similar type of process decomposition in terms of forgetting of previously correct responses and perseveration of previously incorrect responses. In addition, two working memory tests were administered in Study 2 to investigate whether the age-related learning differences, either in the overall percentage correct measure or in the more detailed forgetting and perseveration

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measures, might be mediated by relations with working memory. In both studies, tasks designed to assess the speed of carrying out elementary processing operations were also administered to examine the role of processing speed as a potential mediator of the age differences in these tasks.

Study 1

Method

Subjects. The participants in this study performed the current tasks after a series of memory tasks involving verbal and spatial information (reported in Salthouse, in press). A total of 170 adults completed both tasks in the current study. The subjects were recruited from newspaper ads, community groups, and acquaintances of research assistants, and were categorized in three age groups whose demographic characteristics are summarized in Table 1.

Tasks. The two paper-and-pencil perceptual speed tasks, Letter Comparison and Pattern Comparison, required subjects to decide whether pairs of letters or pairs of line patterns were the same or different. The test forms consisted of pairs of 3, 6, or 9 letters (Letter Comparison) or line segments (Pattern Comparison) with a line between the members of each pair. Subjects were to write an S on the line between the two members of the pair if they were the same, and to write a D on the line if they were different. The measures of performance were the number of correct items minus the number of incorrect items produced in 30 sec.

Table 1: Demographic characteristics of research participants in Study 1

	Age		
	18–39	*40–59*	*60–88*
n	64	55	51
Age			
Mean	25.3	47.9	70.1
SD	6.5	5.1	6.1
% Female	51.5	60.0	51.0
Years of Education			
Mean	14.3	14.5	13.2
SD	2.0	2.3	2.3
Health			
Mean	2.0	2.3	2.3
SD	0.9	1.0	1.0
Letter Comparison			
Mean	11.59	9.53	7.31
SD	3.02	3.21	3.02
Pattern Comparison			
Mean	18.30	15.69	12.33
SD	4.04	3.40	3.27

Note: Education refers to years of formal education completed, and health is a self-rating on a 5-point scale ranging from 1 for excellent to 5 for poor.

Trials in the associative learning task contained a single stimulus item on the left, and the set of response alternatives in a column on the right. The subject selected the appropriate response by using the arrow keys on the keyboard to position an arrow in front of the designated response item. After the subject selected the response and pressed ENTER, feedback was presented in the form of an auditory tone to indicate correct or incorrect, and visual highlighting of the correct response. The response alternatives were then re-ordered and a new stimulus term was presented. Three practice trials with two stimulus pairs (i.e., I–X, II–Y) were presented, followed by two sets of five pairs each. The first set consisted of pairs of digits and letters (i.e., 1-C, 2-A, 3-D, 4-E, and 5-B), and the second set consisted of pairs of unfamiliar symbols. (See Salthouse, 1994 for an illustration of the symbol stimuli). Trials continued until the subject reached a criterion of three trials with all pairs correct, or until a maximum of 10 trials had been presented.

Results

Percentage correct across successive trials for the three age groups is illustrated in Figure 1. Notice that all age groups begin at the same level, but that the amount of improvement is inversely related to age. It can also be seen that the pattern was very similar with both sets of stimuli.

An Age (18–39, 40–59, 60–88) × Stimuli (Familiar, Unfamiliar) × Trial (1 through 10) ANOVA revealed significant (i.e., $p < .01$) effects of Age, $F(2,167) = 22.24$, $MSe = 0.67$; Trial, $F(9,1503) = 114.04$, Age × Trial, F(18,1503) = 4.91, MSe = .045, and Stimuli × Trial, F(9,1503) = 2,79, MSe = .037. The latter interaction reflected slightly greater improvement with familiar stimuli. Because many subjects reached the criterion in fewer than 10 trials and did not continue in the task, values of 100% were used to replace their missing values in this initial analysis. A similar analysis was conducted with only data from trials 1 to 6 in which no missing observations had to be replaced. The same general pattern was apparent in this analysis as there were significant effects of Age, F(2,167) = 17.73, MSe = .31; Trial, F(5,835) = 82.00, and Age × Trial, F(10,835) = 3.93, MSe = .046. Only the Stimulus × Trial interaction was not significant in the analysis restricted to trials 1 through 6, suggesting that the advantage of familiar stimuli occurred primarily in later trials.

The pattern in Figure 1, and the significant Age × Trials interaction, indicate that there were significant age differences in the rate of learning. The learning data were therefore examined with path analysis techniques to determine where distinct age-related effects occur. Figure 2 illustrates the path model used to guide the analyses. Notice that performance on each trial was assumed to be affected by performance in the immediately preceding trial, and possibly also by age.

Age-related effects were not expected on the first trial because there was no prior opportunity to learn since it was the initial exposure to the materials for all subjects. The interesting question was where in the sequence do unique age-related effects occur. If age-related effects occur only on early trials, then all of the age-related influences on later trials can be presumed to be mediated through the effects on the first few trials. However, if there are independent age-related effects on later trials, then distinct age-related influences can be inferred to be operating on processes at several different stages of learning.

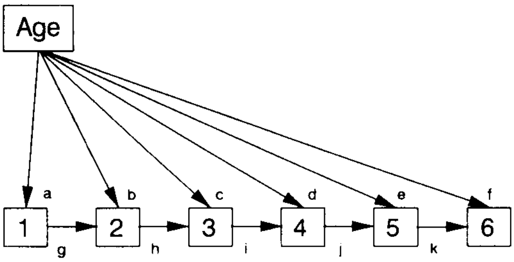

Figure 2: Path diagram illustrating possible relations from age to performance on successive trials.

The standardized path coefficients from these analyses are presented in Table 2. As expected, there were strong relations between the measures of performance on successive trials, particularly after the first trial (lower half of table). Significant age effects were found on trials 2 and 4 with familiar stimuli, and on trials 2, 3, 5, and 6 with unfamiliar stimuli. The pattern is somewhat variable, but it is clear that the age-related influences are not restricted to the first one or two trials on the task. Instead, there appear to be independent age-related effects at several phases in learning.

The processes involved in the age effects in learning were next investigated by computing measures of forgetting and perseveration. The former is the number of forgets (correct on trial n followed by incorrect on trial n+1 for a given stimulus) divided by the total number of correct responses on the previous trial, and the latter is the number of perseverations (the same incorrect response to a given stimulus on two

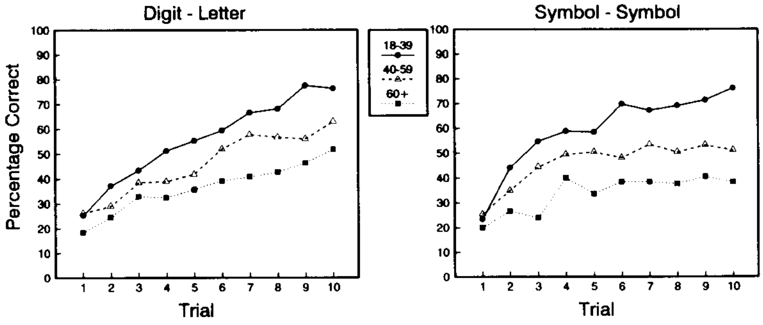

Figure 1: Percentage correct in associative learning with familiar and unfamiliar stimuli across successive trials in three age groups, Study 1.

Table 2: Path coefficients for influences of age on successive trials, Study 1

Path		*Digits-Letters*	*Symbols-Symbols*
a	Age –1	–.14	–.07
b	Age –2	–.24*	–.24*
c	Age –3	–.08	–.29*
d	Age –4	–.21*	–.04
e	Age –5	–.16	–.19*
f	Age –6	–.08	–.26*
g	1–2	.19	.27*
h	2–3	.39*	.48*
i	3–4	.41*	.58*
j	4–5	.56*	.60*
k	5–6	.58*	.55*

* Different from zero by more than 2 standard errors.

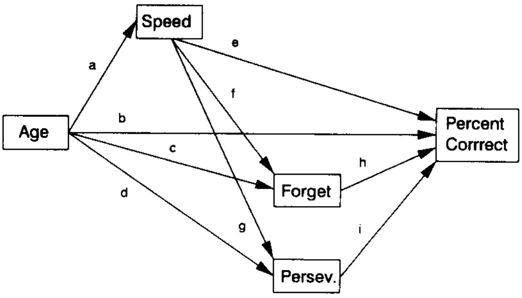

Figure 3: Path diagram illustrating possible relations from age to speed and measures of associative learning performance.

successive trials) divided by the total number of errors on the previous trial. Notice that in each case the relevant value is expressed as a percentage of the possible opportunities for that type of response.

The overall means for the forgetting measure were 38.4% for the familiar stimuli and 36.6% for the unfamiliar stimuli, and those for the perseveration measures were 17.6% for the familiar stimuli and 15.2% for the unfamiliar stimuli. The same type of Age × Stimuli × Trial ANOVA conducted on the percentage correct measure was conducted on the forgetting and perseveration measures except that there were only 5 trials because neither forgetting nor perseveration can occur until there was at least one prior trial. With the forgetting measure, the Age F(2,167) = 5.30, MSe = .28; and Trial, F(5,835) = 3.63, MSe = .15, effects were significant but no other main effects or interactions were significant. With the perseveration measure, only the Age, F(2,167) = 5.64, MSe = .10, and Stimuli, F(1,167) = 13.82, MSe = .07, effects were significant. Both forgetting and perseverations were more frequent with increased age, forgetting decreased across trials, and perseverations occurred more often with familiar stimuli than with unfamiliar stimuli.

Because the only significant trial effect was with the forgetting measure, the values were averaged across the first six trials in an attempt to improve reliability. The correlation of the Letter Comparison and Pattern Comparison paper-and-pencil speed measures was .57, and thus a composite speed measure was created by averaging the two z-scores. Interrelations of the measures were then examined in path analyses with the path model illustrated in Figure 3.

Path coefficients for both sets of stimuli for the model illustrated in Figure 3 are presented in Table 3. The following points should be noted about the results in this table. First, as expected, there were strong negative relations between age and speed. Second, age and percentage correct were negatively related, although with both sets of stimuli the direct effects were smaller than the total age-related effects (i.e., the path coefficients were –.14 and –.21 compared to the correlations of –.34 and –.42, respectively). The reduced age relations

Table 3: Path coefficients for interrelations of age, perceptual speed, percentage forgetting, percentage perseverations, and percentage correct, Study 1

Path	*Digits-Letters*	*Symbols-Symbols*
a Age – Speed	–.59*	–.59*
b Age – Percentage Correct	–.14*	–.21*
c Age – Forget	.04	.14
d Age – Perseveration	.18	.03
e Speed – Percentage Correct	.07	.06
f Speed – Forget	–.12	–.27*
g Speed – Perseveration	–.06	–.09
h Forget – Percentage Correct	–.41*	–.51*
i Perseveration – Percentage Correct	–.54*	–.36*
Correlations		
Age – Percentage Correct	–.34*	–.42*
Age – Forget	.11	.30*
Age – Perseveration	.21*	.08
Forget – Percentage Correct	–.45*	–.65*
Perseveration – Percentage Correct	–.59*	–.47*

* Different from zero by more than 2 standard errors.

Table 4: Demographic and performance characteristics of research participants in Study 2

		Age	
	20–39	*40–59*	*60–79*
n	38	42	37
Age			
Mean	30.8	48.0	68.9
SD	6.0	5.8	5.7
% Female	68.4	42.9	43.2
Years of Education			
Mean	15.1	16.1	15.3
SD	1.5	2.4	2.7
Health			
Mean	1.7	2.3	2.1
SD	0.7	1.2	1.0
Pattern Comparison			
Mean	17.71	16.60	12.59
SD	3.64	2.67	2.88
Letter Comparison			
Mean	10.62	9.89	6.46
SD	3.07	1.43	2.90
Digit Digit RT			
Mean	624	689	836
SD	104	149	207
Digit Symbol RT			
Mean	1243	1425	1917
SD	270	318	531
Reading Span			
Mean	2.68	2.92	1.78
SD	1.28	1.22	1.00
Computation Span			
Mean	4.42	4.64	3.34
SD	1.63	2.11	1.48

for that task. Each task was administered twice with different stimulus items to increase reliability.

The two computer-administered reaction time tasks each involved the presentation of a pair of items in the middle of the screen and a code table with nine pairs of items at the top of the screen. In the Digit Digit task the code table contained identical pairs of digits, and the decision concerned whether the two digits in the middle of the screen were physically identical. In the Digit Symbol task the code table contained pairs of digits and symbols, and the decision concerned whether the digit-symbol pair in the middle of the screen matched according to the code table. Ninety trials were presented in each of two administrations of the tasks, and because accuracy averaged over 95%, median reaction time in milliseconds was used as the measure of reaction time performance.

The associative learning task was very similar to the version with symbols used in Study 1 except that three sets of six trials each were administered, with six different stimulus pairs in each set. The maze learning task also involved six trials on each of three different mazes. In the computer-administered maze task the subjects used the arrow keys on the keyboard to move a cursor through a grid in which obstacles (i.e., the % symbol) blocked many of the possible paths. Only a 3×3 portion of the 10×10 grid was visible at any given time, but the goal was to find the end point (designated by the digit 1) in the minimum number of moves. Each maze contained six choice points with three options each (e.g., if moving down, the options were left, right, and straight or down). The associative learning and maze learning trials were presented in alternating blocks, with six trials of one set of associative learning stimuli, six trials of one maze, six trials of a second set of associative learning stimuli, six trials of a second maze, and finally, six trials of the third set of associative learning stimuli and six trials of the third maze.

Because the sessions were limited to 2.5 hours in length, some research participants did not complete all of the tasks. Furthermore, the attrition was not random because the fastest and most efficient subjects were more likely to finish every task. These were disproportionately the young subjects because 35 of 38 young adults completed all three sets in the maze task, but only 16 of 37 older adults completed all three maze sets. Only results from subjects completing all three sets will be emphasized in the discussion, but results are reported from the subjects contributing data to each set.

Results

Two possible measures of performance were available in the maze task, the number of keystrokes and the percentage of correct choices at the three-alternative choice points. The two measures had moderate negative correlations with one another, as the number of keystrokes decreased from 122 on trial 1 to 51 on trial 6, and the percentage correct values increased from 32% on trial 1 to 67% on trial 6. The median correlation between the two measures across trials was –.47, with a range from –.27 to –.63. Neither measure is optimal because the number of keystrokes measure is highly skewed, and there are only six choice points for the percentage correct measure. However, because the percentage correct measure is more comparable to the measure in the associative learning task, and is amenable to decompositions into forgetting and perseverations, it was used in subsequent analyses.

Percentage correct by trial and age group for the three sets of trials in the associative learning and maze learning tasks are illustrated in Figure 4. Notice that the pattern with the associative learning data is very similar across the three successive sets of stimuli, and resembles that observed in Study 1. The data in the maze learning tasks were more variable, but trial-by-trial improvement and age differences are still apparent.

An Age (18-39, 40–59, 60–79) × Set (first, second, third) × Trial (1 through 6) ANOVA was conducted with each learning task for the subjects with complete data. In the associative learning task there were significant main effects of Age, F(2,86) = 6.00, MSe = 0.41; Set, F(2,172) = 63.31, MSe = .09; and Trial, F(5,415) = 82.76, and a significant interaction of Age × Trial, F(10,830) = 3.19, MSe = .04, but no interactions with Set. In the maze learning task there were significant main effects of Set, F(2,166) = 40.36, MSe = .06; Trial, F(5,415) = 92.80, MSe = .03; and a significant Set × Trial interaction, F(10,830) = 2.35, MSe = .02, but no interactions with age. Neither the main effect of Age, F(2,83) = 2.17, nor the Age × Trial interaction, F(10,830) = 2.09), were significant in the maze learning data.

Separate Age × Trial ANOVAs were also conducted on the data from each set to exam-

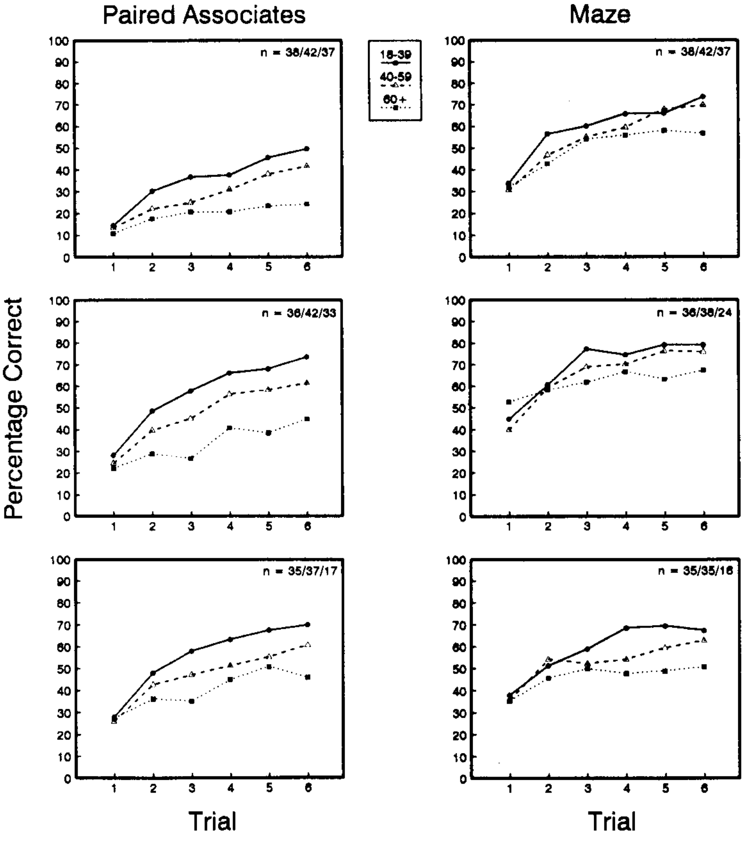

Figure 4: Percentage correct in associative learning and maze learning across three successive trials in three age groups, Study 2. Successive sets of stimuli are represented in the panels from top to bottom.

ine patterns with the greatest possible number of subjects in each comparison. All Age × Trial interactions were significant in these analyses except the Age × Trial interaction F(10,570) = 1.44, for the first maze. These results therefore indicate that, as expected, age differences were evident in the measures of learning in both tasks.

Path analyses were next conducted based on the path diagram illustrated in Figure 2. The path coefficients are presented in Table 5, where it can be seen that the pattern was similar to that in Study 1. That is, there were moderate to large relations between percentage correct on successive trials, and several significant age effects on later trials. As mentioned earlier, these latter results suggest that there are distinct age-related influences on learning that are independent of the effects on early trials.

Age × Set × Trials ANOVAs were also conducted on the percentage forgetting and percentage perseveration measures. With the forgetting measure in the associative learning task the following effects were significant: Set, F(2,166) = 19.34, MSe = .01; Trial, F(5,415) = 8.49, MSe = .13, but not Age, F(2,86) = 3.34, MSe = .21, nor any interactions involving age. Forgetting percentages decreased across successive sets (i.e., 42.8, 31.3, and 28.1), and across successive trials (i.e., 45.9, 35.1, 31.9, 30.5, and 26.8). With the associative learning perseveration measure the significant effects were Age, F(2,86) = 6.12, MSe = .07, and Age × Set, F(4,166) = 3.66, MSe = .04. Perseverations were more frequent with increased age (i.e., 10.6, 12.6, and 17.6), but this trend was less pronounced in the third set. The only significant effects on the forgetting measure in the maze learning task were Set, F(2,166) = 25.67, MSe = .08; and Trial, F(5,415) = 4.07, MSe = .05; but not age (F < 1) or any interactions. These effects were attributable to lower levels of forgetting in set 2 (i.e., 19.7, 8.1, 19.6), and a slight decrease in forgetting percentage across successive trials (i.e., 19.0, 18.0, 14.9, 12.4, and 14.8). No significant effects were evident in the maze learning perseveration measures.

Correlations between similar speed and memory measures were .63 between the two paper-and-pencil speed measures, .69 between the two reaction time speed measures, and .39 between the two working memory measures. The correlation for the working memory measures was not very high, but it increased to .53 after adjusting for the reliability of the measures. Composite measures were formed for use in subsequent analyses by averaging z-scores for the relevant measures.

The age-related variance in the average percentage correct measures across all 6 trials was computed before and after control of the speed and working memory composite measures. Results of these analyses are presented in Table 6, where it can be seen that there was large attenuation of the age-related effects after statistical control of the speed measures. For example, control of the perceptual speed composite reduced the age-related variance in set 1 accura-

Table 5: Path coefficients for influences of age on successive trials, Study 2

Path		*Paired Associates* Set				*Maze Learning* Set			
	(n)	*1* (117)	*2* (111)	*3* (89)	*All* (89)	*1* (117)	*2* (98)	*3* (86)	*All* (86)
a	Age –1	–.15	–.15	–.03	–.04	–.05	.15	–.05	.05
b	Age –2	–.30*	–.32*	–.24*	–.33*	–.20*	–.16	–.14	–.19
c	Age –3	–.18*	–.24*	–.18*	–.14	.02	–.29*	–.16	–.15
d	Age –4	–.21*	–.04	–.07	–.03	–.13	.08	–.21*	–.04
e	Age –5	–.32*	–.16*	–.11	–.10	–.07	–.28*	–.10	–.07
f	Age –6	–.24*	–.15*	–.10	–.11*	–.21*	–.01	–.10	–.05
g	1–2	.07	.20*	.12	.30*	.21*	.19	.16	.24*
h	2–3	.35*	.59*	.61*	.69*	.57*	.45*	.36*	.65*
i	3–4	.38*	.69*	.64*	.78*	.51*	.71*	.60*	.77*
j	4–5	.30*	.68*	.64*	.84*	.61*	.54*	.68*	.78*
k	5–6	.49*	.69*	.73*	.84*	.50*	.71*	.69*	.83*

* p < .01

Table 6: Proportions of age-related variance in average percentage correct before and after control of speed and working memory, Study 2

		After Control of:					
Set	*Age Alone*	*PSpd*	*RTSpd*	*WMem*	*PSpd WMem*	*RTSpd WMem*	*PSpd RTSpd WMem*
		Associative Learning					
1 (n=117)	.238*	.049*	.095*	.153*	.037	.076*	.038
2 (n=111)	.204*	.043	.081*	.169*	.042	.078*	.038
3 (n=89)	.107*	.021	.024	.068	.014	.019	.006
All (n=89)	.152*	.035	.064	.111*	.029	.057	.024
		Maze Learning					
1 (n=117)	.058*	.000	.008	.017	.000	.002	.000
2 (n=98)	.070*	.010	.003	.019	.003	.001	.001
3 (n=86)	.110*	.055	.075*	.069	.042	.064	.051
All (n=86)	.067	.011	.021	.030	.005	.015	.007

* $p < .01$

Note: PSpd refers to the perceptual speed (Letter Comparison, Pattern Comparison) composite, RTSpd refers to the reaction time speed (Digit Digit, Digit Symbol) composite, and WMem refers to the working memory (Reading Span, Listening Span) composite.

cy by 79.4% for associative learning, and by 100% for maze learning. It is also apparent in Table 6 that the reduction of the age-related variance was only slightly greater when both speed and working memory were controlled than when only the speed measures were controlled.

The age-related variance in the composite working memory measure was also examined after control of the composite speed measures. The R^2 associated with age was reduced from .141 to .031 (78.0%) after control of the perceptual speed composite, and to .029 (79.4%) after control of the reaction time speed composite. The initial values were clearly significantly greater than zero, but neither of the residual values differed significantly from zero. Furthermore, when the order of the variables was reversed, there was a much smaller percentage reduction of the age-related variance in the composite speed measure after control of the composite working memory measure. These results are consistent with the results of several earlier studies (e.g., Salthouse & Babcock, 1991; Salthouse, 1991; 1992), and help explain why there is little additional reduction of the age-related variance in the learning measures when working memory was controlled after speed. That is, most of the age-related variance in the working memory measures appears to be shared with the speed measures.

Path analyses were next conducted to examine interrelations among the variables according to the path model in Figure 5. Coefficients with the perceptual speed composite are presented in Table 7. The pattern with the RT speed composite was very similar, and thus only results with the perceptual speed measure are presented.

The following points should be noted about the data in Table 7. First, the relations of age to the measures of speed, working memory, and percentage correct are weaker in successive blocks, which may partly be a consequence of selective attrition in which progressively more lower-ability older adults fail to continue in successive sets. Second, as in Study 1, there were moderate to large paths between age and

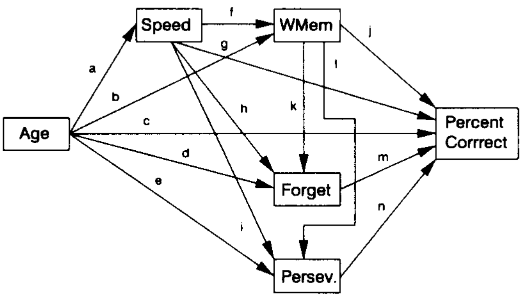

Figure 5: Path diagram illustrating possible relations from age to speed, working memory, and measures of associative learning performance.

Table 7: Path coefficients for interrelations of age, perceptual speed, working memory, percentage forgetting, percentage perseverations, and percentage correct, Study 2

		Paired Associates Set				*Maze Learning* Set			
Path		*1*	2	*3*	*All*	*1*	2	*3*	*All*
	(n)	(117)	(111)	(89)	(89)	(117)	(98)	(86)	(86)
a	Age – Speed	–.65*	–.68*	–.54*	–.54*	–.65*	–.65*	–.53*	–.52*
b	Age – WMem.	–.23*	–.13	–.15	–.15	–.23*	–.18	–.15	–.15
c	Age – Per.Cor.	–.25*	–.11	–.08	–.05	.02	.03	–.07	.02
d	Age – Forget	.10	.12	.20	.23	.02	.07	.12	.07
e	Age – Persev.	–.05	.31*	–.12	.07	–.03	.15	.23	.12
f	Speed – WMem.	.22*	.31*	.20	.20	.22*	.28*	.21	.21
g	Speed – Per.Cor.	.18	.15	.06	.06	.02	.09	.08	.05
h	Speed – Forget	–.09	–.06	–.07	–.07	–.30*	–.06	.03	–.17
i	Speed – Persev.	–.35*	–.17	–.37*	–.48*	–.22	–.00	.01	–.13
j	WMem. – Per.Cor.	.13	–.05	–.01	–.02	.14*	.12	.05	.10
k	WMem. – Forget	.10	–.17	–.26*	–.22*	–.03	–.18	–.10	–.08
l	WMem. – Persev.	–.12	.14	–.12	–.08	–.13	–.18	–.26*	–.22*
m	Forget – Per.Cor.	–.21*	–.53*	–.59*	–.58*	–.51*	–.53*	–.50*	–.47*
n	Persev. – Per.Cor.	–.21*	–.35*	–.40*	–.37*	–.51*	–.47*	–.47*	–.59*
Correlations									
Age – Per.Cor.		–.49*	–.45*	–.33*	–.39*	–.24*	–.26*	–.33*	–.26
Age – WMem.		–.38*	–.35*	–.26	–.26	–.38*	–.36*	–.26	–.26
Age – Forget		.12	.23	.30*	.33*	.23	.17	.14	.18
Age – Persev.		.22	.38*	.11	.35*	.16	.22	.30*	.25

* p < .01

speed (a), between percentage forgetting and percentage correct (m), and between percentage perseverations and percentage correct (n). However, there was little or no direct relation between age and percentage correct (c), between age and percentage forgetting (d), or between age and percentage of perseverations (e). This pattern suggests that the age-related effects may be mediated through small speed and working memory influences on the forgetting and perseveration measures. As in Study 1, however, few paths from either speed or working memory to the percentage correct, forgetting, or perseveration measures are significantly different from zero.

General Discussion

The results of these studies confirm the existence of adult age differences in learning, both with different kinds of stimuli in associative learning, and in a new maze learning task. Furthermore, the age-related influences were not simply restricted to the initial learning trials, and thus they represent genuine effects on learning rather than merely effects on processes involved in the first one or two exposures to the stimuli. Speed, and to a lesser extent, working memory, appears to be involved in the age difference in learning because the age-related variance in the percentage correct measures was considerably reduced after statistical control of measures of speed and working memory.

Findings by Salthouse & Dunlosky (in press) were also replicated in the discovery that learning is poor when the subjects fail to retain feedback as reflected by forgetting (i.e., not repeating correct responses), and perseverations (i.e., continuing to repeat incorrect responses). However, it is not simply the case that the age effects in learning occur because of a greater proportion of forgetting and perseveration responses because the relations between age and these measures were relatively small. Moreover, the weak and inconsistent relations between the speed measures and the presumably more detailed measures of associative learning performance indicate that the mechanisms responsible for the speed influences have not yet been identified.

In summary, adult age differences in learning have been confirmed by the existence of significant influences of age on measures of performance from later trials after performance on the immediately preceding trial were taken into consideration. Furthermore, analyses revealed that the speed with which simple comparison operations could be executed, the probability of forgetting previously correct responses, and the probability of perseverating on previously incorrect responses, all contributed to trial-by-trial improvement in these tasks. What is not yet clear, and which should be a goal for future research, is exactly how these measures are interrelated with one another and with increased age in adulthood.

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