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Interrelations of Age, Self-Reported Health, Speed, and Memory

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Contributions of self-reported health to adult age differences in perceptual speed and memory were assessed for 301 adults ages 20–90. Participants were asked 4 health status questions, given 3 perceptual speed tests, 2 working memory tests, and 2 memory tests. Self-reported health was found to predict speed better than it predicted memory. Covariance structural equation modeling was used to assess the relations among age, self-reported health, perceptual speed, working memory, and memory. The results support the hypothesis that any effects of self-reported health on age differences in memory are mediated by perceptual speed.

Many explanations have been offered for why increased age is associated with poorer memory performance (see Salthouse, 1991b, 1992). One variable that mediates a large portion of the age–memory relation is processing efficiency, as measured by perceptual speed tasks (e.g., Park et al., 1996; Salthouse, 1994). Another potential contributing variable to the age–memory relation is health status (e.g., Elias, Robbins, Schultz, & Pierce, 1990). The contributions of these two variables may not be independent. Instead, the poorer health associated with increased age may contribute to slower processing speed, thereby producing poorer memory performance. Thus, the effects of health on the age–memory relation may be indirect rather than direct. Earles and Salthouse (1995) examined the interrelations of age, self-reported health, and speed, using covariance structural equation modeling. Health was found to mediate some, but not all, of the age–speed relation. There was limited evidence that cardiovascular disease may be important to the relation between self-reported health and speed. Because health status has been linked to age differences in memory performance, it is important to examine whether health contributes directly to the age–memory relation or contributes indirectly through contributing to slower processing.

Not surprisingly, increased age has been found to be associated with lower self-reported health status (e.g., Perlmutter & Nyquist, 1990). Self-reported health status may be a reflection of the overall capabilities of the biological system. Although self-reports may not be the best possible measure of health status (Elias, Elias, & Elias, 1990), they have been found to be related to other measures that are considered to be more objective measures of health status, such as physician ratings (e.g., LaRue, Bank, Jarvik, & Hetland, 1979) and longevity (Botwinick, West, & Storandt, 1978). For example, Schulz et al. (1994), in their Cardiovascular Health Study, tested the health status of over 5,000 older adults. They found that self-ratings of health correlated significantly with measures of functional status, health care utilization, diseases, and health habits. They suggested that the self-reported number of medications that a participant is currently taking is an especially useful health status measure. Self-reports do, therefore, appear to be useful measures of health status.

Bazargan and Barbre (1994) found that among older adults, those who report poorer health also report having more memory problems. Thus an age-related decrease in health status may contribute to the age–memory relation (e.g., Elias et al., 1990). The relations among age, health status, and cognition have been studied in several previous studies. Field, Schaie, and Leino (1988) conducted a longitudinal study, using only older adults. They found limited evidence that poorer health was associated with poorer performance on cognitive tests. Performance on the performance subtests of the Wechsler Adult Intelligence Scale (WAIS; Wechsler, 1981) was not found to be related to self-reported health at the first test but was found to be related at the second test. Using a larger age range (i.e., ages 20–90), Perlmutter and Nyquist (1990) found that self-reported health was associated with more of the variance in intellectual performance for younger than for older adults. Hultsch, Hammer, and Small (1993), using only older adults, found that poorer health was associated with poorer performance on memory tests. The age-related variance in memory performance, however, was reduced by only 4%–10% by the statistical control of self-reported health. Finally, Salthouse, Kausler, and Saults (1990) found no significant change in the regression equation predicting memory performance from age after adjusting for self-reported

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health status. Thus, evidence that self-reported health is a mediator of age differences in cognition is limited. In the current study we used a large life span sample and several self-reported health measures to assess the relations among age, self-reported health, and memory.

In addition to poorer self-reported health status, increased age has also been found to be associated with decreases in perceptual speed, an index of processing efficiency (e.g., Salthouse, 1994). There is growing evidence that the speed of mental processing is important to the relation between age and memory performance (e.g., Salthouse, 1991a, 1993). The age-related variance in a wide variety of memory tasks has been found to be greatly reduced by the statistical control of perceptual speed (Earles, 1996; Earles & Coon, 1994; Hultsch, Hertzog, & Dixon, 1990; Lindenberger, Mayr, & Kliegl, 1993; Park et al., 1996; Salthouse, 1993). For example, Lindenberger et al. found no direct effects of age on memory for words, text, and activities. All of their age-related effects were mediated by perceptual speed. Also, Park et al. found that speed mediated the age differences in free and cued recall of words, and Earles and Coon found speed to be associated with a large portion of the age-related variance in memory for performed activities. There is, therefore, strong evidence to support the hypothesis that age differences in speed are related to the age differences in memory performance. The age-related decline in processing efficiency over the life span may contribute to limitations in the use of self-initiated processing in memory tasks, which in turn lead to age differences in memory performance. Limitations in self-initiated processing have been suggested to be important contributors to the age differences in memory performance (e.g., Craik & Jennings, 1992).

It is still a matter of speculation as to why the relation between age and speed exists. Health status may be one contributor to age differences in speed. Perlmutter (1988) suggested a three-tier model of cognition. The first tier comprises basic mechanisms, such as speed. The second tier comprises knowledge and experience, and the third tier involves higher mental functions, such as memory. She suggested that biological functions, such as health, influence first-tier abilities. Hultsch et al. (1993) did find health to be more predictive of more basic processing resource variables than of higher level processes.

Health status may represent biological conditions associated with age-related slowing (Earles & Salthouse, 1995). Several researchers have reported an association between health status and speed (e.g., Light, 1978; Shapiro, Miller, King, Ginchereau, & Fitzgibbon, 1982; Speith, 1964). Also, Earles and Salthouse found that a portion of the age-related variance in perceptual speed was mediated by self-reported health status. The influence of health on the age–speed relation, however, was small. It is possible that rather than affecting memory directly, health status affects memory indirectly through an effect on some other mediating variable, such as speed (Earles & Salthouse, 1995; Salthouse & Earles, 1995). Age-related declines in health status may contribute to decreases in speed that in turn contribute to age differences in memory performance.

The purpose of the current study was to use covariance structural equation modeling to evaluate the contribution of self-reported health status to adult age differences in memory performance. It was hypothesized that self-reported health influences age differences in memory through an influence on processing efficiency, as measured by perceptual speed.

Method

Participants

Participants were 301 community-dwelling adults ages 20–90 who participated in the Park et al. (1996) study. They were recruited through newspaper advertisements and were paid $50 for their participation. The participant characteristics are shown in Table 1. Increased age was associated with significantly higher vocabulary scores, $r(299) = .26$, $p < .05$, and with significantly more education, $r(299) = .12$, $p < .05$.

Materials

Health measures. Participants were asked four questions about their health. These questions, with some minor alterations, were taken from the Duke University (1978) OARS Multidimensional Functional Assessment Questionnaire. The questions were (a) "How would you rate your health at the present time?" on a scale of 1 (*poor*), 2 (*fair*), 3 (*good*), and 4 (*excellent*). (b) "How much do health troubles stand in the way of your doing things you want to do?" on a scale of 1 (*a great deal*) to 3 (*not at all*). (c) "Do you think your health is better, the same, or worse than most people your age?" on a scale of 1 (*worse*) to 3 (*better*). (d) "How many prescription medications are you presently taking?"

Perceptual speed measures. There were three measures of perceptual-motor speed. For all of these tasks, participants were asked to work as quickly as possible. In the WAIS Digit Symbol Substitution task (Wechsler, 1981), participants were presented with a key containing the digits 1–9, each paired with a simple figure. They were then given a list of digits and were asked to draw the figure associated with each digit. The score was the number correct in 90 s.

In the letter comparison task (Salthouse & Babcock, 1991), participants were presented with pairs of letter strings, each of which consisted of three, six, or nine letters. They were instructed to compare each pair of letter strings and to write an *S* in the blank between them if they were the same and a *D* if they were different. There were three 30-s sections, one at each level (three, six, or nine letters in each string). The score was the sum of the number correctly completed on each of the sections. The pattern comparison task (Salthouse & Babcock, 1991) was identical to the letter comparison task except that participants compared pairs of line drawings composed of three, six, or nine line segments instead of pairs of letter strings.

Working memory measures. There were two measures of working memory. The reading span task was similar to a task used by Salthouse and Babcock (1991). Participants were presented with sentences on a

Table 1
Participant Characteristics

Age range	Age *M*	Age *SD*	*n*	Women (%)	Vocabulary *M*	Vocabulary *SD*	Education *M*	Education *SD*
20–39	29.4	6.3	84	58	31.3	5.2	5.5	0.9
40–59	49.2	5.6	86	66	32.7	6.7	5.5	1.2
60–90	72.2	7.0	131	57	34.8	4.2	5.8	1.0

Note. The Shipley (1986) Vocabulary test has 40 multiple-choice items. The mean education scale level corresponds to some college education: 1 (*less than 7th grade*), 2 (*8th grade*), 3 (*10th grade*), 4 (*high school graduate*), 5 (*some college*), 6 (*college graduate*), and 7 (*graduate degree*).

computer screen. They read aloud each sentence and answered a comprehension question about each one. Participants were instructed to simultaneously remember the last word from each sentence. Participants received a series of one–seven sentences. They received three trials at each series length. The task ended when a participant made three consecutive errors. The score was the total number of trials on which the participant answered the questions correctly and recalled the words.

The computation span task also came from Salthouse and Babcock (1991). Participants were shown simple arithmetic problems on a computer screen. The participant was asked to solve the problem while simultaneously remembering the last digit from each problem. As in the reading span task, they received a series of one–seven items and continued until they made three consecutive errors. The score was the number of trials on which a participant solved the problems correctly and recalled the digits.

Memory measures. There were two memory measures. In the free-recall task, there were two lists of 25 words. Each list was composed of five nouns from each of five categories, randomly distributed. Each word was presented for 5 s by a slide projector onto a screen in the front of the room. Participants were instructed to learn the words for later recall. After all 25 words had been presented, participants were given unlimited time to write down the words from the list. The procedure was then repeated with the second list of words.

In the cued-recall task, two lists of 22 weakly associated word pairs were used. The pairs were presented by means of slides for 5 s each. One word was presented on the right side of the screen, and the other was presented on the left side. Participants were told that after all of the items had been presented, they would see the words that had been presented on the right and would be asked to write down the word that was previously presented with each of these words. After each list, the right member of each pair was presented for 8 s and the participant listed the word that was previously paired with it.

Procedure

Participants performed a total of 23 tasks across a 3-day period (see Park et al., 1996). Only those tasks that were relevant to the current study are described. The health questions were asked and the computation span task was performed on the first day, the Digit Symbol Substitution (Wechsler, 1981), letter comparison, and reading span tasks were given on Day 2, and the pattern comparison task and the free- and cued-recall tests were given on Day 3.

Results

Missing Data

Ten of the participants were missing data on one of the measures. The data were missing because of failure to follow directions and computer failures. These data were estimated by using the regression procedure used by Lindenberger et al. (1993). A participant's performance on the missing task was estimated by using his or her performance on the other task or tasks from that construct. The results did not change when the data were analyzed by using only those participants with complete data.

Correlational Analyses

Correlations were computed in order to examine the relations among all of the measures. These correlations are presented in Table 2. The age^2 term was computed by calculating the residuals of the regression of age^2 on age. For the self-reported health measures, increased age was associated with significantly lower health ratings, significantly more health-related activity limitations, and with significantly more medications. An exception to this pattern of age differences in self-reported health status was found with the health question that asked participants to compare their health with that of their peers. This measure showed an increase in health ratings with increased age. The self-reported health measures were converted into standard scores for the entire group. The age trends for these health measures are shown in Figure 1. Because the age trend was different for

Table 2
Correlations Among Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Age	—												
2. Age^2	0	—											
3. Rate	−.15	−.03	—										
4. Limit	−.21	.07	.57	—									
5. Compare	.33	.07	.40	.36	—								
6. Medications	.30	−.06	−.40	−.41	−.21	—							
7. Letter comparison	−.63	−.09	.21	.22	−.19	−.19	—						
8. Pattern comparison	−.65	−.11	.21	.19	−.19	−.23	.73	—					
9. Digit symbol	−.63	−.09	.21	.23	−.17	−.20	.71	.68	—				
10. Computation span	−.36	−.09	.12	.11	−.09	−.15	.42	.43	.43	—			
11. Reading span	−.37	−.05	.11	.08	−.12	−.22	.40	.39	.37	.64	—		
12. Free recall	−.41	−.10	.16	.13	−.13	−.24	.54	.52	.52	.44	.51	—	
13. Cued recall	−.34	.01	.09	.09	−.09	−.17	.40	.35	.38	.39	.42	.68	—
M	53.7	0	3.3	2.6	2.6	1.3	35.2	52.2	53.6	7.3	7.1	28.5	22.7
SD	19.0	327.3	0.7	0.6	0.6	2.0	8.6	12.7	15.0	3.4	2.9	8.6	9.1

Note. All correlations equal to or greater than .12 were significant at $p < .05$. Rate = self-rating of health status; limit = self-rating of limitations because of health problems; compare = self-rating of health compared with age mates; free recall = number correct out of 50; cued recall = number correct out of 44.

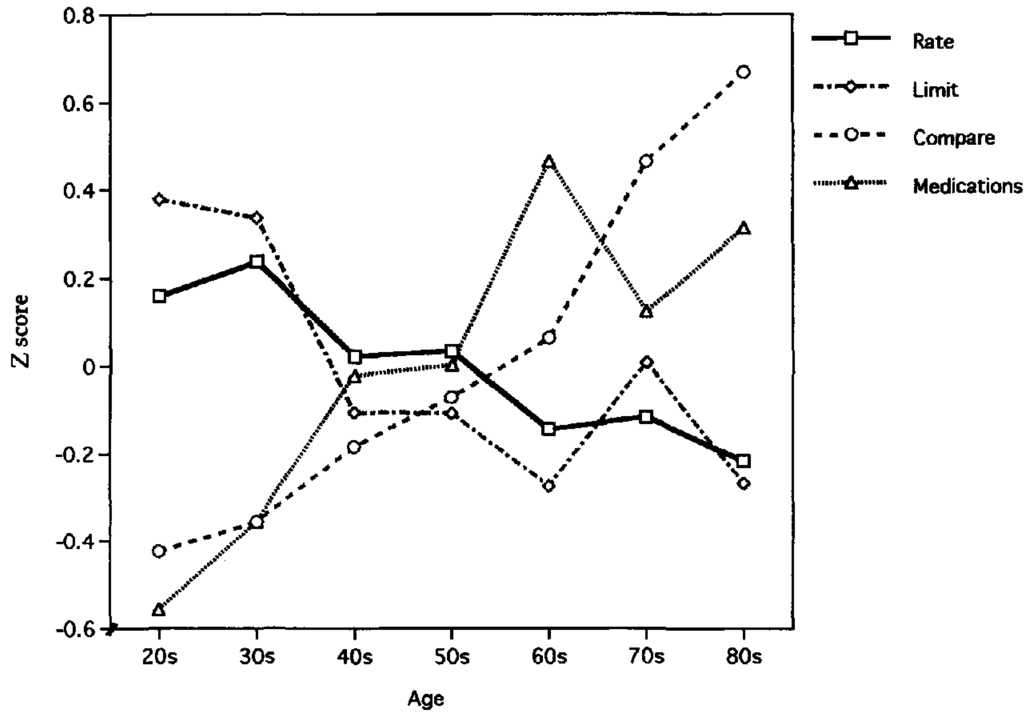

Figure 1. Mean *z* scores by decade for the four health measures. Rate = self-reported health rating on a scale of 1 (*poor*) to 4 (*excellent*); Limit = amount health limitations affect life on a scale of 1 (*a great deal*) to 3 (*not at all*); Compare = rating of health compared with peers on a scale of 1 (*worse*) to 3 (*better*); Medications = number of prescription medications.

the comparison rating question, it was excluded from further analyses. It was not possible from the current data to determine whether this trend in the comparison rating was due to an increasingly selective sample with increased age or to an increase in downward social comparison with increased age.

Increased age was also associated with slower speed on the three perceptual speed tests and with poorer working memory performance on the reading and computation span tasks. Finally, increased age was associated with poorer performance on both memory measures. Better self-reported health was associated with faster speed, and faster speed was associated with better memory performance. The relations among the self-reported health and memory measures, however, were low.

To more clearly examine the associations among constructs, we computed composite scores for the self-reported health, speed, working memory, and memory measures by using the average of the z scores. The health comparison question was not included because of its different pattern of age relations. For the health composite score, the medication measure was inverted before inclusion because of its inverse relations with the health-rating measures. Correlations among age, self-reported health, speed, working memory, and memory were computed. All correlations were significant, $p < .001$, and are presented in Table 3. Increased age was associated with poorer self-reported health, slower speed, poorer working memory, and poorer memory performance. Higher health ratings were associated with faster speed and better memory, and faster speed was associated with better memory performance.

Hierarchical Regression Analyses

Hierarchical regression analyses were used to assess the amount of age-related variance in memory that was associated with self-reported health and speed. It was assumed that if the age-related variance in memory performance was greatly reduced by the statistical control of self-reported health, or speed, then self-reported health or speed is important to the relation between age and memory. The results of these analyses are presented in Table 4. Self-reported health was associated with 4% of the total variance in memory and with 19% (i.e., [.167 − .135]/.167) of the age-related variance in memory. There was no significant quadratic effect of age, and there was no significant interaction of age and self-reported health or age and speed.

Table 3
Correlation Matrix for Composite Scores

Variable	1	2	3	4	5
1. Age	—	−.29	−.76	−.46	−.44
2. Self-reported health	−.28	—	.35	.20	.24
3. Speed	−.71	.29	—	.60	.66
4. Working memory	−.41	.18	.50	—	.64
5. Memory	−.41	.20	.55	.53	—

Note. All correlations were significant at $p < .001$. Correlations among composite measures are below the diagonal, and the standardized covariances among the latent constructs are shown above the diagonal.

Table 4
Hierarchical Regression Analyses

Dependent variable	R^2	$R^2\Delta$	$F\Delta$	p
Memory				
Age	.167		60.00	<.001
Age²	.170	.003	.888	.347
Health	.040		12.50	<.001
Age	.175	.135	48.91	<.001
Speed	.302		129.48	<.001
Age	.303	.001	0.28	.599
Speed				
Age	.506		305.79	<.001
Age²	.517	.012	7.24	.008
Health	.085		27.68	<.001
Age	.515	.431	264.91	<.001

A second set of analyses examined the possibility that self-reported health mediates the age differences in perceptual speed. The results of these analyses are also presented in Table 4. Self-reported health was associated with 9% of the total variance in the speed composite score and with 15% (i.e., [.506 − .431]/ .506) of the age-related variance in speed. There was no significant interaction of age and health. One interesting finding was a significant quadratic effect of age on perceptual speed, suggesting that age-related declines in speed may accelerate in extreme old age.

Covariance Structure Modeling

Covariance structure modeling was used to examine the relations among age and the self-reported health, speed, working memory, and memory constructs. The variance–covariance matrix was analyzed by using the LISREL 8 maximum likelihood estimation procedure (Jöreskog & Sörbom, 1993). The chi-square value, degrees of freedom, p, cumulative fit index (CFI), and standardized root-mean-square residual (RMR) are reported for each model (see Table 5). The CFI is a measure of the overall fit of the model that stresses the fit of the relations among constructs (Bentler, 1990). The standardized RMR is an indicator of the average of the standardized unexplained residuals.

A four-factor model (i.e., self-reported health, speed, working memory, and memory) was fit to the data. Covariances were allowed among all factors. The loading of one indicator of each factor was fixed at one (i.e., rate, letter comparison, computation span, and free recall). Residual variances were estimated, but covariances between residuals were fixed at zero. The fit of the model (i.e., M1 in Table 5) to the data was adequate as can be seen by the high CFI and low chi-square value presented in Table 5.

Age and age^2 were then added to form the second model (i.e., M2 in Table 5). The age^2 term was computed by using the residuals of the regression of age^2 on age. Covariances among factors were again estimated as were the variances of the residuals, and as in the first model, the residual covariances were fixed at zero. This model also had an adequate fit to the data, as can be seen by the high CFI and low chi-square value presented in Table 5. This factor structure was therefore considered to have a satisfactory fit to the data. The standardized covariances among age, self-reported health, speed, and memory are shown in Table 3. Increased age was associated with lower self-reported health status, slower speed, and poorer memory performance. Poorer self-reported health was associated with slower speed and poorer memory performance.

A model was then estimated to evaluate the hypotheses that there is a direct effect of age on self-reported health and that self-reported health-related differences in memory performance are mediated by perceptual speed. No direct effects of age or of self-reported health on memory performance were expected. On the basis of the hierarchical regression analyses, age^2 was expected to account for some additional variance in speed. This model (i.e., S1) is shown in Figure 2. The variances of the factors and of the indicators were estimated. All covariances between factors and indicators were fixed at zero, and the loading of one indicator of each factor was fixed at one (i.e., rate, letter comparison, computation span, and free recall). The model had an adequate fit as shown by the low chi-square value and high CFI shown in Table 5. This model did not differ significantly from M2. The two models were compared by computing the difference in the chi-square value for the models. The difference in chi-square was 4.30 with 7 degrees of freedom, which is not significant at $p < .05$. The fit of the model was not significantly improved by the addition of a direct path from self-reported health to memory (i.e., S2 in Table 5), by the addition of a direct path from age to memory (i.e., S3 in Table 5), by the addition of a direct path from age to working memory (i.e., S4 in Table 5), or by the addition of a direct path from self-reported health to working memory (i.e., S5 in Table 5). Thus, the proposed basic structural model seemed adequate for explaining the data.

Because age, self-reported health, and speed form a saturated preceding block in the basic structural model, a model in which speed predicts health is mathematically equivalent to the proposed basic structural model in which health is hypothesized to predict speed. A model was, therefore, estimated in which speed was hypothesized to predict self-reported health. In this model, the path from age to self-reported health was set to zero. The model had an adequate fit, $\chi^2(49, N = 301) = 64.84, p = .064$, CFI = .99, RMR = .039, and this model was not significantly poorer than the basic structural model (S1) in which the path from age to self-reported health was not set to zero. The difference in chi-square was 1.47 with 1 degree of freedom, which is not significant at $p < .05$.

Thus a model in which age differences in self-reported health predict speed (i.e., S1) and a model in which age differences in self-reported health are mediated by speed are both plausible. As discussed later, the model in which self-reported health is assumed to affect speed is believed to be a more theoretically valid model. However, if speed is assumed to contribute to self-reported health, self-reported health may not be needed to account for age differences in memory and working memory because under this assumption, the path from age to self-reported health was not necessary.

Table 5
Summary of Model Fitting

Model	Description	χ^2 (N = 301)	*df*	*p*	CFI	RMR
M1	Intercorrelated factor structure	31.11	29	.360	1.0	.035
M2	Addition of age and age^2	59.07	41	.034	.99	.037
S1	Basic model (see Figure 2 in text)	63.37	48	.068	.99	.037
	Compare with M2	4.30	7	>.05		
S2	Add direct path from health to memory	63.31	47	.056	.99	.037
	Compare with S1	.06	1	>.05		
S3	Add direct path from age to memory	59.68	47	.10	.99	.037
	Compare with S1	3.69	1	>.05		
S4	Add direct path from age to working memory	63.37	47	.056	.99	.037
	Compare with S1	.00	1	>.05		
S5	Add direct path from health to working memory	63.36	47	.056	.99	.037
	Compare with S1	.01	1	>.05		

Note. CFI = comparative fit index (Bentler, 1990); RMR = standardized root-mean-square residual; M = model; S = structural model.

In all of the above models, age was used as a continuous variable. It was possible, however, that self-reported health had a larger (or smaller) relation with speed and memory for the older than for the younger adults. A two-age-group model was, therefore, estimated. Participants were divided into two age groups by using a median split. The 153 adults under the age of 55 were placed in the younger adult group, and the 148 adults age 55 or above were placed in the older adult group. A five-factor model (age, self-reported health, speed, working memory, and memory) was fit to the data in order to examine the relations among the constructs for younger and older adults. The variances and covariances among factors were estimated and so were the residuals of the indicators. No covariances were allowed among the residuals. The loading of one indicator of each factor was fixed at one, as in the previous models.

In the first analysis, the factor loadings and the covariances among factors were estimated separately for the two age groups. The fit of this model was adequate, $\chi^2(84, N = 301) = 133.84$, $p < .001$, CFI = .95, RMR = .078. When the factor loadings were constrained to be equal in the two groups, there was no significant decrease in fit, $\chi^2(90, N = 301) = 144.16$, $p < .001$, CFI = .95, RMR = .084. The difference in the chi-square value was 10.32 with 6 degrees of freedom, which is not significant at $p < .05$. When the covariances among factors were constrained to be equal in the two groups, there was no significant decrease in fit, $\chi^2(94, N = 301) = 149.08$, $p < .001$, CFI = .95, RMR = .086. The difference in the chi-square value was 15.24 with 10 degrees of freedom, which is not significant at $p < .05$. When both the factor loadings and the covariances among factors were constrained to be equal in the two age groups, there was again no significant decrease in fit, $\chi^2(100, N = 301) = 158.40$, $p < .001$, CFI = .95, RMR = .087. The difference in the chi-square value was 24.56 with 16 degrees of freedom, which is not significant at $p < .05$. Thus, the same model could be used for the older and for the younger adults.

Discussion

Self-reported health was predicted to directly influence age differences in perceptual speed and to only indirectly influence age differences in memory. The results supported this hypothesis. Consistent with previous findings (e.g., Perlmutter & Nyquist, 1990; Shapiro et al., 1982; Speith, 1964), lower self-reports of health status were associated with increased age, slower speed, and poorer memory performance. In the covariance structural model, age had a direct effect on self-reported health, and self-reported health had a direct effect on perceptual speed. Thus, some of the age differences in speed were associated with age differences in self-reported health. Although self-reported health directly influenced age differences in perceptual speed, there was no need for a direct path from age to working memory or memory or for a direct path from self-reported health to working memory or memory. All of the effects of self-reported health on age differences in memory and on age differences in working memory were found to be mediated by perceptual speed.

Park et al. (1996) found that all of the age-related variance in memory performance was mediated by perceptual speed. Thus, they provided further support that processing efficiency is very important to the relation between age and memory (see Salthouse, 1992). Because speed is so prevalent as an explanation of age differences in cognition (e.g., Earles, 1996; Earles & Coon, 1994; Park et al., 1996; Salthouse, 1991a, 1992, 1993, 1994), it is important to begin to examine why there are age differences in speed. It is important to determine what speed represents. The current study extended the findings of Park et al. by providing evidence that self-reported health may be a contributor to differences in speed.

A critical assumption of the model used in this study is that health represents a lower level biological process than does speed. It was assumed that self-reported health contributes to differences in speed. An alternative, and mathematically equivalent, model assumes that differences in speed contribute to age differences in self-reported health. For example, a participant may consider speed when making health ratings. Because the data are correlational, it is impossible to determine the causal directions of the relations among the variables in the model. For example, it is our theory, and not the data, that assumes that age predicts changes in speed rather than that speed predicts

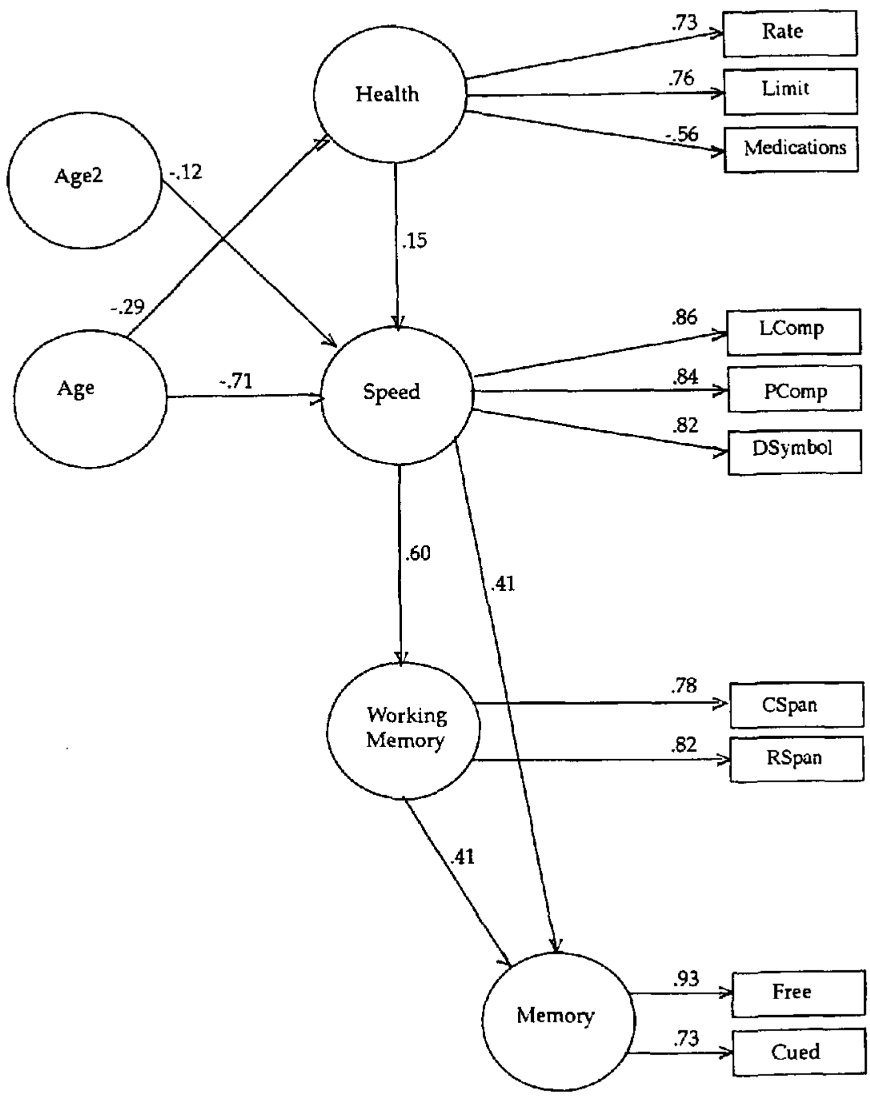

Figure 2. The basic structural model (i.e., S1). Path coefficients are from LISREL's completely standardized solution. All paths were significant at $p < .05$. LComp = letter comparison; PComp = pattern comparison; DSymbol = Digit Symbol; CSpan = computation span; RSpan = reading span.

changes in age. Self-reported health status could reflect feelings of slowing and memory loss. Past work, however, has shown that self-reports of health status do correlate with more objective health measures (e.g., Schulz et al., 1994). In the current study, in fact, the number of prescription medications did correlate significantly with the self-ratings of health status. Many other researchers have made the similar assumption that health predicts changes in speed (e.g., Earles & Salthouse, 1995; Hultsch et al., 1993; Perlmutter & Nyquist, 1990). It is, however, possible that because the composite health measure in the current study contained self-ratings, age differences in self-reported health status did reflect self-perceived slowing. If age differences in self-reported health were assumed to be the result of speed, the self-reported health measure is not needed to predict age differences in memory. It is important to be aware that assumptions about the direction of causality in covariance structure modeling are assumptions that are theory driven rather than data driven (see MacCallum, Wegener, Uchino, & Fabrigar, 1993, for a discussion of this issue). On the basis of the argument that health is at a lower biological level than speed, we argue that the model in which health causes speed is theoretically preferable to a model in which speed causes changes in perceived health.

In the current study, with the assumption that self-reported health is a more basic process than speed, self-reported health status did mediate some of the age-related variance in the speed composite measure. The direct effect of age on speed was, however, much larger than the indirect effect of age on speed through self-reported health. The effects of age and of self-reported health on memory were all indirect, mediated by perceptual speed.

It seems likely that self-reported health is important to the age–speed and age–memory relations, but that it is not the only factor that contributes to these relations. There was no evidence in the current study that relations among age, self-reported health, speed, and memory differ for younger and for older adults. The same covariance structure model can be used for both age groups. One limitation of the current study, however, was that the use of volunteers who were willing to come to the lab for three testing sessions contributed to a very healthy sample of adults, as compared with the general population. The effects of self-reported health on age differences in memory and speed may be larger if participants with a wider range of health status were used. The current study is also limited because we used self-report measures of health and memory measures that consisted only of memory for words. Further researchers should examine the contributions of both self-reported and objective health status to age differences in speed and memory performance.

Because speed is so important to the relation between age and memory performance (e.g., Earles & Coon, 1994; Park et al., 1996; Salthouse, 1992), it is very important to examine both why there are age differences in speed and what causes the relation between speed and memory. For example, limitations in processing speed may contribute to the age-related decrease in the ability to use self-initiated processing (e.g., Craik & Jennings, 1992) when trying to encode information.

The results of the current study replicate and extend the findings of Earles and Salthouse (1995). Earles and Salthouse (1995) found, as in the current study, that age differences in speed were partially mediated by self-reported health status. In both studies, the effect of self-reported health on speed was, however, small. On the basis of the Earles and Salthouse (1995) results, we hypothesized that the relation between age differences in self-reported health and age differences in memory and working memory performance would be mediated by speed. The results of the current study suggest that self-reported health status affects age differences in memory performance through an effect on perceptual speed. Thus, as suggested by Perlmutter (1988) and Hultsch et al. (1993), self-reported health seems to affect first-tier cognitive processes, such as speed. Increased age may result in poorer health, which may lead to slower mental processing that leads to poorer memory performance.

References

Bazargan, M., & Barbre, A. R. (1994). The effects of depression, health status, and stressful life-events on self-reported memory problems among aged blacks. *International Journal of Aging and Human Development, 38,* 351–362.

Bentler, P. M. (1990). Comparative fit indices in structural models. *Psychological Bulletin, 107,* 238–246.

Botwinick, J., West, R., & Storandt, M. (1978). Predicting death from behavioral test performance. *Journal of Gerontology, 33,* 755–762.

Craik, F. I. M., & Jennings, J. M. (1992). Human memory. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 51–110). Hillsdale, NJ: Erlbaum.

Duke University Center for the Study of Aging and Human Development. (1978). *Multidimensional Functional Assessment: The OARS methodology.* Durham, NC: Duke University Press.

Earles, J. L. (1996). Adult age differences in recall of performed and nonperformed items. *Psychology and Aging, 11,* 638–648.

Earles, J. L., & Coon, V. E. (1994). Adult age differences in long-term memory for performed activities. *Journal of Gerontology: Psychological Sciences, 49,* P32–P34.

Earles, J. L., & Salthouse, T. A. (1995). Interrelations of age, health, and speed. *Journal of Gerontology: Psychological Sciences, 50B,* P33–P41.

Elias, M. F., Elias, J. W., & Elias, P. K. (1990). Biological health influences on behavior. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (pp. 79–102). San Diego, CA: Academic Press.

Elias, M. F., Robbins, M. A., Schultz, N. R., & Pierce, T. W. (1990). Is blood pressure an important variable in research on aging and neuropsychological test performance? *Journal of Gerontology: Psychological Sciences, 45,* P128–P135.

Field, D., Schaie, K. W., & Leino, E. V. (1988). Continuity in intellectual functioning: The role of self-reported health. *Psychology and Aging, 4,* 385–392.

Hultsch, D. F., Hammer, M., & Small, B. J. (1993). Age differences in cognitive performance in later life: Relationships to self-reported health and activity life style. *Journal of Gerontology: Psychological Sciences, 48,* P1–P11.

Hultsch, D. F., Hertzog, C., & Dixon, R. A. (1990). Ability correlates of memory performance in adulthood and aging. *Psychology and Aging, 5,* 356–368.

Jöreskog, K. G., & Sörbom, D. (1993). *LISREL 8: Structural equation modeling with the SIMPLIS command language.* Hillsdale, NJ: Erlbaum.

LaRue, A., Bank, L., Jarvik, L., & Hetland, M. (1979). Health in old age: How do physicians' ratings and self-ratings compare? *Journal of Gerontology, 34,* 687–691.

Light, K. C. (1978). Effects of mild hypertension and cerebrovascular disorders on serial reaction time performance. *Experimental Aging Research, 4,* 3–22.

Lindenberger, U., Mayr, U., & Kliegl, R. (1993). Speed and intelligence in old age. *Psychology and Aging, 8,* 207–220.

MacCallum, R. C., Wegener, D. T., Uchino, B. N., & Fabrigar, L. R. (1993). The problem of equivalent models in applications of covariance structure analysis. *Psychological Bulletin, 114,* 185–199.

Park, D. C., Smith, A. D., Lautenschlager, G., Earles, J. L., Frieske, D., Zwahr, M. D., & Gaines, C. (1996). Mediators of long-term memory performance across the life span. *Psychology and Aging, 11,* 621–637.

Perlmutter, M. (1988). Cognitive potential throughout life. In J. E. Birren & V. L. Bengtson (Eds.), *Emergent theories of aging* (pp. 247–268). New York: Springer.

Perlmutter, M., & Nyquist, L. (1990). Relationships between self-reported physical and mental health and intelligence performance across adulthood. *Journal of Gerontology: Psychological Sciences, 45,* P145–P155.

Salthouse, T. A. (1991a). Mediation of adult age differences in cognition by reductions in working memory and speed of processing. *Psychological Science, 2,* 179–183.

Salthouse, T. A. (1991b). *Theoretical perspectives on cognitive aging.* Hillsdale, NJ: Erlbaum.

Salthouse, T. A. (1992). *Mechanisms of age–cognition relations in adulthood.* Hillsdale, NJ: Erlbaum.

Salthouse, T. A. (1993). Speed mediation of adult age differences in cognition. *Developmental Psychology, 29,* 722–738.

Salthouse, T. A. (1994). The nature of the influence of speed on adult age differences in cognition. *Developmental Psychology, 30,* 240–259.

Salthouse, T. A., & Babcock, R. L. (1991). Decomposing adult age differences in working memory. *Developmental Psychology, 27,* 763–776.

Salthouse, T. A., & Earles, J. L. (1995). Age, perceived health, and specific and nonspecific measures of processing speed. In A. M. Ferrandez & N. Teasdale (Eds.), *Changes in sensory-motor behavior in aging* (pp. 315–337). New York: Elsevier Science.

Salthouse, T. A., Kausler, D. H., & Saults, J. S. (1990). Age, self-assessed health status, and cognition. *Journal of Gerontology: Psychological Sciences, 45,* P156–P160.

Schulz, R., Mittelmark, M., Kronmal, R., Polak, J. F., Hirsch, C. H., German, P., & Bookwala, J. (1994). Predictors of perceived health status in elderly men and women. *Journal of Aging and Health, 6,* 419–447.

Shapiro, A. P., Miller, R. E., King, E., Ginchereau, E. H., & Fitzgibbon, K. (1982). Behavioral consequences of mild hypertension. *Hypertension, 4,* 355–360.

Shipley, W. C. (1986). *Shipley Institute of Living Scale.* Los Angeles: Western Psychological Services.

Speith, W. (1964). Cardiovascular health status, age, and psychological performance. *Journal of Gerontology, 19,* 277–284.

Wechsler, D. (1981). *Manual for the Wechsler Adult Intelligence Scale—Revised.* New York: Psychological Corporation.

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