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Is there anything special about the aging of source memory?

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Abstract

A battery of cognitive tests designed to measure the constructs of episodic memory, perceptual speed, fluid ability, executive functioning and vocabulary was administered to 330 adults between the ages of 18 and 89. Each participant also performed four different tasks designed to assess source memory. Structural equation modeling was used to evaluate the validity of a source memory construct, and to explore the relation of the source memory construct to age and to the other cognitive variables. The variance common to the source memory variables was strongly related to other cognitive abilities suggesting that source memory may not have discriminant validity, and there were only small unique age-related effects on the source memory construct after the influence of other abilities was considered.

Source memory refers to memory for information about the conditions or features under which a memory is acquired (Johnson, Hashtroudi & Lindsay, 1993), and in this article the terms source and context are used interchangeably. Source memory has been investigated with a wide variety of paradigms. For example, participants have been asked to remember such varied contexts as the font (e.g. Kausler & Puckett, 1980), color (e.g., Doerkson & Shimamura, 2001; Macken, 2002), origin (e.g., Craik, Morris, Morris, & Loewen, 1990; Shimamura & Squire, 1987), and voice (e.g. Hicks & Marsh, 1999; Dodson, Holland, & Shimamura, 1998) in which a word or fact was presented, as well as the format (i.e., performed, imagined, or watched) in which an action occurred (e.g. Cohen & Faulkner, 1989), or the location of a picture (Cansino, Maquet, Dolan, & Rugg, 2002). At least in part based on these studies, a number of researchers have proposed that source memory is a construct distinct from a construct representing memory for items or content (e.g. Yonelinas, 1999; Batchelder & Riefer, 1990).

There are several reasons to believe that memory for content and memory for context might involve different processes or systems. For example, intuitively it seems apparent that one could remember certain information but not necessarily where or from whom he or she originally acquired it. In addition, formal models of memory often make a distinction between processes associated with content information and processes associated with source or context information (e.g. Batchelder & Riefer, 1990; Bayen, Murnane, & Erdfelder, 1996). Specifically, researchers have proposed that source memory is primarily reliant on recollection, whereas recognition is primarily based on familiarity processes (e.g. Yonelinas, 1999). Some of the most compelling evidence for a content-context distinction can be found in the aging literature where measures of source memory have typically been found to have larger negative age relations than measures of memory for content (e.g., for reviews see Spencer & Raz, 1994; Zacks, Hasher, & Li, 2000). For example, based upon findings from their meta-analysis, Spencer and Raz (1994) suggest that memory for source information is particularly sensitive to increased age. This higher age sensitivity on measures of source memory has been documented under a variety of conditions. For example, significant differences between young and old adults have been found when participants were asked to: determine whether actions have been performed, imagined, or watched (Cohen and Faulkner, 1989), distinguish among words that had been spoken, heard, or thought (Hashtroudi, Chrosniak, and Johnson, 1989), determine the fame of a name (Dywan & Jacoby, 1990), identify whether information was learned in an experiment or from an outside source (Craik, et al., 1990), and identify the speaker of information (Rahhal, May, & Hasher, 2002).

Another type of evidence consistent with a content-context distinction is that context memory performance has been found to be selectively impaired in patient groups with frontal lobe dysfunction (e.g., Shimamura & Squire, 1987; Janowsky, Shimamura, & Squire, 1989; Johnson, O'Connor & Cantor, 1997; Schacter, Harbluk & McLachlan, 1984). In addition, a number of studies have reported stronger relations of context memory measures, compared to content measures, with variables assumed to be sensitive to frontal lobe functioning or executive functioning (e.g. Craik, Morris, Morris, & Loewen, 1990, Glisky, Polster, & Routhieux, 1995; Glisky, Rubin, & Davidson, 2001). In fact, Glisky and colleagues argued for a functional double dissociation between source and content memory, citing as evidence studies in which content memory appears to be more reliant on the medial-temporal region of the brain whereas source memory appears to be more reliant on the frontal lobe region of the brain (Glisky, Polster, & Routhieaux, 1995).

The evidence just cited seems to imply that context and content memory are qualitatively distinct, but an alternative perspective is that memory for source information and memory for content information primarily differ in terms of the relative importance of specific stimulus features for the task (e.g., how differentiated the memory needs to be to meet task requirements), and of the likelihood that automatic versus controlled judgment processes will be recruited (e.g. Johnson, Hashtroudi, & Lindsey, 1993).

Although correlations between measures of context and content are relevant to the potential distinction between the two types of memory, only a few articles have reported these correlations. The studies that have reported the correlations found that they were small (e.g. Shimamura & Squire, 1987; Craik et al., 1990; Johnson, DeLeonardis, Hashtroudi, & Ferguson, 1995), but the results are difficult to interpret because of small sample sizes and the absence of information about reliability. The small sample sizes mean that the power to detect correlations as significant was likely low, and without estimates of reliability it is possible that the correlations between the measures of content and context were weak because the variables did not have much systematic variance available to be associated with other variables.

There also do not appear to be any studies in which two or more source memory tasks were administered to the same individuals to allow an examination of convergent and discriminant aspects of construct validity. In order to establish that source memory is a distinct construct it is important to have empirical evidence that different tasks considered to assess memory for source represent the same dimension of individual differences (i.e., they are moderately correlated with one another, and exhibit convergent validity), and that that dimension is distinct from other individual difference dimensions (i.e., the source memory construct is not highly correlated with other constructs, and exhibits discriminant validity).

Correlation-based procedures to investigate construct validity rest on the assumption that all tasks have multiple determinants (i.e. that no task is “process pure”), but that it should be possible to converge on the critical determinant (or process) by focusing on what different tasks have in common. This is an alternative approach to separating tasks and processes from the isolation or subtraction approach frequently employed within cognitive psychology, but it has the advantage of ensuring that processes identified in this manner are relatively general and not specific to one particular task.

From the perspective of research on aging, once there is evidence that tasks used to assess source memory have construct validity, it should then be determined whether that construct has unique relations with age. This is an important issue because many cognitive variables have been found to be related to age, and nearly all cognitive variables are moderately interrelated with one another (e.g., Carroll, 1993; also see Salthouse & Ferrer-Caja, 2003). However, if the source memory construct is special with respect to age-related influences, those influences should still be evident after taking into consideration influences associated with age on other cognitive abilities that are related to the source memory construct. Two variables are sometimes inferred to have distinct age-related influences when they differ in the magnitude of their relations to age, perhaps as indicated by a significant age-by-variable interaction in an analysis of variance. However, because variables might exhibit interactions for a number of reasons (e.g., Salthouse, 2000; Salthouse & Coon, 1993), a more powerful method of determining whether a variable is special or unique with respect to its age-related influences is to examine the extent to which those influences are statistically independent of influences on other variables or constructs.

There were two primary goals of this report. The first was to investigate the convergent and discriminant validity of variables hypothesized to reflect source memory, and the second was to determine the extent to which age-related influences on source memory were statistically independent of age-related influences on other cognitive abilities.

Four tasks were used to assess source memory. In the first task, participants were asked to remember words and the color of the font in which the words appeared. This task therefore involved intentional memory for both the content (words) and the context (color). The second task required participants to rate the level of interestingness of pictures that were presented in one of four quadrants on the computer screen. After the pictures were displayed the participants were presented with a surprise source identification test in which they had to classify the picture as new, or identify the quadrant in which the picture had appeared. Thus this task involved incidental memory for both the content (pictures) and the context (location). The third task was a variant of a reality monitoring paradigm (Johnson & Raye, 1981) in which participants were asked to perform, watch, or imagine simple actions, and later had to distinguish between internally generated events (i.e., performing and imagining simple actions) and externally generated events (i.e., watching the examiner perform simple actions). The task was described as a following directions exercise to the participants, and therefore it involved incidental memory for both the content (action) and the context (type of action). The fourth task used to assess source memory was based on a task recently described by Rahhal, May, and Hasher (2002) in which participants were instructed to pay attention to trivia statements that were spoken by either a male who was characterized as always truthful or a female who was characterized as always deceitful. A source identification task followed the presentation of the trivia statements during which the participant was to classify each statement as new, true, or false. This task therefore involved intentional memory for both content and context. The four tasks thus differ in the nature of material, the nature of the context, and whether the encoding phase was intentional or incidental.

Construct validity of the proposed source memory construct was evaluated with the four analytical models recently described by Salthouse, Atkinson, and Berish (2003). Model A assesses only convergent validity by determining whether the source memory variables have significant variance in common. Model B investigates discriminant validity in addition to convergent validity by examining the magnitude of correlations of the target construct with constructs representing other cognitive abilities (i.e., fluid ability, processing speed, episodic memory, executive functioning, and vocabulary). Model C extends Model B by allowing individual variables hypothesized to represent the target source memory construct to be related to other ability constructs to determine if that results in improved fit of the model to the data. Model D is the most stringent test of construct validity because all of the target variables are allowed to be related to other ability constructs before examining whether they have significant variance in common. In order for variables to exhibit convergent validity in Model D the residual variance in the variables, after taking into consideration any relations the variables have with other cognitive abilities, must be significantly related to one another.

Salthouse, et al. (2003) applied this series of models to investigate the construct validity of an executive functioning construct defined in terms of frequently used neuropsychological variables, and of constructs of inhibition, updating, and time sharing. The results of the analyses led Salthouse, et al. (2003) to conclude that although inhibition might be a distinct construct, the other hypothesized constructs seemed to represent the same dimension of individual differences as the construct of fluid intelligence. The four analytical models were also applied by Salthouse, Berish, and Siedlecki (in press) to investigate the validity of a prospective memory construct. Although the evidence was somewhat mixed, it was concluded that prospective memory may be distinct from fluid intelligence and episodic memory, and that at least some of the age-related influences on prospective memory were statistically independent of age-related influences on other cognitive abilities.

Figure 1 contains a simplified representation of the issues relevant to the assessment of construct validity in this study. The boxes in the bottom of the figure correspond to the measures of content and context memory for the four tasks, and the circles immediately above them are the latent constructs that represent the variance that those observed variables have in common. The question of convergent validity concerns the degree to which the different observed measures hypothesized to represent the same construct are significantly related to one another, as manifested by significant regression coefficients for the arrows linking the latent construct to its hypothesized indicator variables. The question of discriminant validity concerns the degree to which the target construct is distinct from other constructs, as manifested in weak to moderate correlations between the target construct and the other constructs to which it is linked with a bidirectional arrow.

The second goal of the project is schematically represented in Figure 2. Notice that several cognitive ability constructs are all related to one another, and to the target context memory construct. The variable of age is also postulated to be related to each of the cognitive constructs and to the context memory construct. Of particular interest is the coefficient for the direct relation between age and the context memory construct, portrayed as a dotted arrow in the figure, because that represents the magnitude of the relation between age and source memory that is statistically independent of the age-related influences on other cognitive abilities.

To summarize, the broad aim of the current project was to determine if there is anything special about the aging of source memory. Our approach consisted of first investigating whether it is meaningful to refer to source memory as a distinct construct, and then investigating the degree to which age-related influences on source memory were unique, and statistically independent of the age-related differences on other cognitive abilities.

Method

Participants

The research participants were 330 adults between the ages of 18 and 89 recruited through newspaper advertisements, flyers, or referrals from other participants. This is the same sample of participants described in a recent report on the construct validity of prospective memory (Salthouse, et al., in press). Each participant was paid $120 for coming to the laboratory on three separate occasions, for approximately two hours each occasion. Characteristics of the participants are summarized in Table 1. Based on the participants' scaled scores on the Wechsler Adult Intelligence Scale III (WAIS III; Wechsler, 1997a) subtests of Vocabulary and Digit Symbol (which have a mean of 10 and a standard deviation of 3 in the normative sample), we can infer that the participants were high-functioning relative to the normative sample from the WAIS III. However, it is important to note that this was true in each age group and thus there is no evidence of a confounding between age and selectivity of the participants.

In addition to the tasks designed to assess source memory, all of the participants were administered a battery of tasks intended to represent different cognitive abilities. The source memory tasks described below were intermixed with these tests across the three sessions. Two of the source tasks, Color Word and Picture Location, were presented in the second session, the Action Memory task was presented in the first session, and the Fact Memory task was presented in the third session.

Procedure

Details about the battery of cognitive tests used to assess the reference cognitive abilities are provided in Salthouse, et al. (in press), and thus the tests are only briefly described here. Episodic memory was assessed with a paired associate task (Salthouse, Fristoe, & Rhee, 1996), and with two subtests of the Wechsler Memory Scale (Wechsler, 1997b); logical memory and word recall. A fluid ability construct was based on variables from the following tests: Raven's Progressive Matrices (Raven, 1962), Letter Sets (Ekstrom, French, Harmon & Dermen, 1976), Analytical Reasoning (GRE, 1994), Spatial Relations (Bennett, Seashore & Wesman, 1997), Paper Folding (Ekstrom, et al., 1976) and Form Boards (Ekstrom, et al., 1976). Vocabulary was measured with the WAIS III Vocabulary subtest (Wechsler, 1997a), the Woodcock-Johnson Picture Vocabulary subtest (Woodcock & Johnson, 1990), and the Synonym and Antonym Vocabulary tests (Salthouse, 1993). Perceptual speed was assessed with the Digit Symbol subtest (Wechsler, 1997a), and the Letter Comparison and Pattern Comparison tests (Salthouse & Babcock, 1991). Executive functioning was measured with a Sort Recognition test (Delis, Kaplan & Kramer, 2001), a Multiple Choice Proverb Interpretation test (Delis, et al., 2001), tests of Verbal fluency (Delis, et al., 2001), and a Connections task (Salthouse, Toth, Daniels, Parks, Pak, Wolbrette & Hocking, 2000).

Color Word

In this task participants were presented with a series of words on a computer screen, at a rate of one every 5 sec, that were printed in one of four colors (i.e., blue, green, yellow, and red). The words, which were all five letters in length, were presented in four blocks of ten each, and the ten words in each block had a mean Kucera and Francis (1967) frequency rating of 73. At the start of each block participants were instructed to pay attention to both the word and the color in which it appeared because they would be tested on both attributes. At the end of each block the participant wrote down all the words he or she could recall from the current block on a piece of paper that contained blank lines followed by the names of the four colors, and then circled the color in which each recalled word had originally appeared.

Picture Location

Participants in the Picture Location task, which was modeled after a source memory task described by Cansino, et al. (2002), were initially shown a series of 40 pictures and were asked to rate how interesting the picture was on a scale ranging from 1 (for very interesting) to 4 (for very uninteresting). The pictures were presented for 3 sec each in one of four quadrants of the computer screen (i.e., upper left, upper right, lower left, or lower right). Immediately following the presentation of the 40 pictures a surprise source identification test was administered, which consisted of pictures in the center of the screen accompanied by a list of five choices: new, upper left, upper right, lower left, and lower right. The instructions indicated that the "new" response should be selected if the picture had not been presented in the previous series. If the participant decided that the picture had been presented previously, he or she was to choose in which of the four quadrants it had appeared. Responses were entered with the numeric key pad, and the number choices on the numeric keyboard corresponded to the quadrant on the computer screen (i.e. the "7" key for "upper left", the "9" key for "upper right", the "1" key for "lower left", the "3" key for "lower right" and the "5" key for "new picture".) The source identification test consisted of 40 old pictures and 40 new pictures, and was self-paced.

Action Memory

At the start of this task, which was labeled "Following Directions" during the study, participants were informed that it was a test of their ability to follow directions to perform, view, or imagine simple actions. Actions were created using everyday objects and simple actions (e.g. break the toothpick, wave your hand). The objects required for the actions, including some not used for any of the actions, were always placed in the same locations immediately in front of the participant, and the description of the action was displayed on a computer screen for 7 sec. The actions were presented in blocks of 10 each, with instructions at the beginning of each block indicating whether the actions were to be performed, watched, or imagined. The first block consisted of the participants watching the examiner perform the actions, and this was followed by a performed block, two imagined blocks, another performed block, and a final watched block. During the instruction phase of the task it was emphasized that the participants should make their imagined actions as vivid as possible and to use the displayed objects to assist in enhancing the vividness of their imagined actions.

Approximately 75 minutes after the presentation of the stimuli, during which time participants performed a variety of other cognitive tasks, a surprise source identification test was administered. The source identification test was presented on a computer screen and consisted of a list of 60 old actions intermixed with 25 new actions. For each action the participant was to choose whether the action was new (not previously presented), or whether he or she had performed the action, watched the examiner performing the action, or imagined performing the action. The source identification test was self-paced.

Fact Memory

This task was adapted slightly from a task recently described by Rahhal, et al. (2002). There were two phases in the task, which was described to participants as a new fact learning task. In the first phase 56 trivia facts (obtained from Rahhal, et al., 2002) were displayed on the computer and simultaneously spoken by a computer-generated voice. The voices were distinctly male or female, and were described as coming from John and Mary, respectively. The participants were told that John always spoke the truth and thus every statement read by John was true, and that Mary always said false things and hence every statement read by Mary was false. Participants were instructed to pay attention to all the information because they would be tested on it later.

The second phase of the task occurred 10 min later, after the participants had performed another cognitive task. In this phase the 56 old facts intermixed with 16 new facts were presented on the computer screen and the participants were to classify each as “New”, “True”, or “False”.

Results[1]

Table 2 contains the means, standard deviations, estimated reliabilities, and correlations with linear and quadratic age terms for the measures of content and context memory. The values of the content variables are the proportions of correct old/new judgments in the source identification task, except for the color word task in which it was the mean number of words (out of 10) correctly recalled across the four blocks. The values of the context variables are the proportions of correct source memory judgments, given that the participant categorized the stimulus as old. For example, in the Fact Memory task the context memory score was the sum of correct "true" responses and correct "false" responses divided by the total number of "true and "false" (i.e., not "new") responses. Note that the context memory variables are all conditional values because in order for a participant to make a source judgment he or she had to first categorize the stimulus as old, or in the color word task, have already recalled the word.

Because the tasks varied in the number of source options, the chance level of accuracy for the source judgments varied across tasks. In the Color Word and Picture Location tasks there were four source choices, and thus the chance level was 25%. In the Action Memory task there were three source choices, such that chance performance was 33%, and in the Fact Memory task there were two source choices, with chance performance equal to 50%. Inspection of Table 2 indicates that average performance was well above chance with each variable, and was close to 100% in the content component of the Picture Location task.

Reliability estimates were calculated for each variable by using the Spearman-Brown generalized formula[2] to boost the correlations between scores for each type of source assignment. It can be seen that the reliability of each variable was greater than .71 except for the variable representing memory for the color of words, which had an estimated reliability of .62.

Also presented in Table 2 are the correlations of the linear and quadratic age trends for each measure of content and context. The linear relation of age was significantly negative for all measures. The age-squared term, representing the quadratic relation after controlling for the linear relation, was significantly correlated with the content measures in the Color Word and Picture Location tasks, and with the context measures in the Action memory and Fact memory tasks. In order to portray the age trends each variable was converted to a z-score, and the means and standard errors plotted as a function of decade in Figure 3. Inspection of this figure indicates that the quadratic trends in the variables are attributable to a more pronounced decrease in performance at older ages. It is also apparent on this figure that the age trends for the content measures (top panel) are very similar to those for the context measures (bottom panel).

The remainder of the results is organized into three sections. The first section describes performance on each of the four source memory tasks. The second section describes the results of the analyses designed to investigate the convergent and discriminant validity of the source memory construct. Finally, the third section reports the age-related effects on source memory in the context of age-related effects on other cognitive abilities.

Source Memory Performance

Color Word

In the Color Word task participants viewed a series of words in four different colors and then attempted to recall the words and indicate the color in which each word had appeared. Table 3 contains the means and age correlations for the word recall and color identification measures across four successive blocks in this task. It is worth noting that, contrary to the assumption that age-related effects are invariably greater on measures of context than on content, in this task the age correlation is more negative for the content measure (word recall) than for the context measure (color identification). Although the values in Table 2 indicate that both content and context measures were moderately reliable, the correlation between the two was only .12.

The mean recall of between 3.9 and 4.3 words per block is relatively low compared to other measures of free recall. For example, the average number of words recalled on the first trial of the12-word free recall task performed by these same participants was 6.8. The lower level of recall in this task may be attributable to the participants trying to remember both the word and the color in which it appeared. It is also noteworthy that although there was no systematic trend in level of word recall accuracy across blocks, source memory (i.e., color recognition) performance became progressively lower on successive blocks.

Picture Location

In the Picture Location task participants had to decide whether pictures displayed on the computer screen were new, or select the quadrant in which the picture had previously appeared. The correlation between the measures of content (picture) and context (location) in this task was .33, which may be an underestimate of the true correlation because of the near ceiling level of accuracy (i.e., .95) in the old/new recognition measure.

Table 4 contains the proportions of each type of response for the different stimuli, and the correlation between age and the proportion of responses in each stimulus-response combination. The values in the cells are proportions corresponding to the number of times the response in that column was made to the stimulus in that row divided by the total number of stimuli of that type, or by the total number of responses of that type (in parentheses). The cells along the diagonal of the table from upper left to lower right represent correct responses, and all other cells represent errors. Several points should be noted about the values in this table. First, although participants were highly accurate in classifying pictures as old or new as reflected in the smaller error rates in the last column, accuracy in categorizing the source was lower. (Because there were different numbers for each type of response, the average proportion correct for the four source judgments in parentheses in Table 4 is not exactly equivalent to the overall average reported in Table 2.) Second, all of the age correlations for correct responses were negative, whereas all but one of the age correlations for incorrect responses were positive. This indicates that increased age was associated with a lower percentage of accurate responses and a higher percentage of inaccurate responses. And third, the proportions of incorrect responses appear to be smallest for the quadrants in the opposite corner of the display from which the picture had been presented.

Additional analyses were conducted to examine the incorrect responses more systematically. First, all the incorrect responses for each quadrant were summed for each of the stimulus locations, and then the proportion of errors that were in the opposite quadrant of the display and the proportion of errors not in the opposite quadrant[3] were computed for each person. Note that if the errors were randomly distributed among the other three quadrants the proportions should be .33 in each quadrant. However, the mean proportion in the opposite quadrant was .23 and the mean proportion of errors not in the opposite quadrant was .38, which indicates that there was a tendency for the least number of confusions to be in the opposite quadrant. That is, if a participant made an error of location he or she was least likely to say, for example, that a picture in the lower right quadrant was presented in the upper left quadrant (i.e. the opposite quadrant). Rather, he or she was more likely to say that the picture appeared in either the lower left quadrant (row preservation) or the upper right (column preservation). The proportion of errors in the opposite quadrant was positively related to age ($r = 0.28$, $p<.01$), which indicates that increased age was associated not only with less exact, but also less partial, information about the stimulus context.

<u>Action Memory</u>

In the Action Memory task participants were instructed to decide whether an action was new, or had previously been performed, watched, or imagined. The measures of memory for content (old/new action recognition) and context (action type) in this task were moderately highly correlated ($r = .68$), implying that the ordering of individuals was similar in both measures. The proportions of responses to each stimulus-response combination in the Action Memory task are presented in Table 5. As in Table 4, the cells in the diagonal from upper left to lower right represent correct responses, whereas all the other cells represent incorrect responses. Also as was the case in Table 4, the age correlations are negative for the correct responses, and positive for the incorrect responses.

The relatively low error rates in the last column of Table 5 indicate that discrimination between old and new items was quite good. However, imagined actions were misclassified as new about 33% of the time, and this may be attributable to participants not encoding imagined actions to the same degree as performed or watched action. Although participants were similar in their accuracy of classifying performed (i.e., 81%) and watched (i.e., 78%) actions, they were less accurate at identifying imagined actions (i.e., 56%).

Fact Memory

The Fact Memory task required participants to decide whether a displayed fact was new, true (i.e., previously spoken by the truthful male voice), or false (i.e., previously spoken by the deceitful female voice). There was a moderate correlation of .40 between the measures of content (old vs. new classification of the trivia statement) and context (truth of statement).

The proportion of correct responses for each stimulus type is presented in Table 6. As in the previous tables, the cells in the diagonal from upper left to lower right represent correct responses and all other cells represent incorrect responses. Once again the age correlations for all the correct responses were negative, whereas the age correlations for all the incorrect responses were positive.

It can also been seen that errors associated with categorizing a new item as old (i.e. either true or false) were relatively rare, but that errors corresponding to categorizing old items as new were more frequent. However, the overall level of source judgment accuracy was nearly the same for true and false statements, suggesting that participants were not biased in their selection of truthfulness.

Correlational Analyses

To test the feasibility of the proposed analytical models, they were first applied to the four cognitive ability constructs of vocabulary, processing speed, fluid ability and episodic memory. As expected, and consistent with the results of Salthouse, et al. (2003), the cognitive ability constructs all exhibited construct validity. For example, in Model D, the most stringent test of construct validity, all of the target variables had significant loadings on their respective ability constructs after allowing the variables to be related to all other constructs.

The initial correlational analysis focusing the source memory construct included only the content variables and context variables from the four source memory tasks in a two-factor confirmatory factor analysis. However, the estimated correlation between the content and the context constructs was greater than 1, and thus the solution was not admissible. This result implies that it is not possible to identify distinct content and context constructs in terms of their patterns of individual differences. It is important to emphasize that this does not mean that individuals performed equivalently on the content and context variables, but rather that the ranking of individuals on the variance common to the content variables was nearly identical to their ranking on the variance common to the context variables.

Although the results from the initial analyses suggest that a context memory construct cannot be distinguished from a content memory construct, we nevertheless felt it would be informative to conduct separate sets of analyses for each hypothesized construct. Confirmatory factor analyses were therefore conducted with a six-factor model including the constructs representing episodic memory, fluid ability (gF), perceptual speed, vocabulary, executive functioning, and either the content memory construct or the context memory construct. The standardized coefficients of each cognitive variable on its respective ability construct and correlations among the reference cognitive abilities are reported in Tables 6 and 7 in Salthouse, et al. (in press).

It should be noted that Salthouse, et al. (in press) found that there was only weak evidence for the construct validity of an executive functioning construct because the variables designed to measure executive functioning were not significantly related to one another when they were allowed to be related to other cognitive abilities (in Models C and D). Nonetheless, the executive functioning construct was included in these analyses because of the interest in the relationship between executive functioning and source memory.

Content

Table 7 contains the fit indices for each of the four construct validity models described in the introduction. Also included in the table for each model are the loadings of the content memory tasks on the content construct, and the correlations of the content construct to the other cognitive constructs. The moderate loadings of the variables on the content memory construct in Models A and B indicate that the variables were significantly correlated with one another, and can be considered to exhibit convergent validity. However, of greatest interest in these analyses is the correlation of 1.0 between the content memory construct and the episodic memory construct in Model B. Even when two of the variables were allowed to have significant loadings on the episodic memory construct in Model C the correlation between the content memory and episodic memory constructs was .91. These results indicate that the two constructs were nearly identical in terms of their patterns of individual differences. That is, on the basis of these analyses the content memory construct cannot be distinguished from the episodic memory construct, and thus it lacks discriminant validity. The results from the Model D analysis are also consistent with the lack of discriminant validity because the variables all have significant relations with the episodic memory construct, and no longer have strong relations to one another. As noted later, this finding of nearly complete overlap between memory for content and episodic memory is not surprising because the constructs are theoretically equivalent.

Context

Table 8 contains the results of the four construct validity models applied to the variables designed to assess source memory. It can be seen that the four source memory variables were significantly related to the source memory construct in three of the four models, providing evidence of convergent validity. However, in the most stringent test of convergent validity (Model D), the source memory variables were not significantly related to the source memory construct after allowing them to be related to other abilities. Two of the four variables had significant relations to the episodic memory construct, but three were also significantly related to the fluid ability construct.

In Model B the context memory construct had moderate relations to both the executive functioning (r =.77) and speed (r =.76) constructs, and sizable correlations with the episodic memory (r = .85), and fluid ability (r =.85) constructs. The considerable overlap of the source memory construct with other cognitive abilities therefore suggests that it does not have high discriminant validity.

Although the correlational analyses of the source memory construct did not provide strong evidence for discriminant validity, there was evidence of convergent validity, suggesting that an examination of the age-related effects might be warranted.

Mediation of age-related effects

The final set of analyses examined the extent to which age-related effects on source memory were unique to that construct, and statistically independent of age-related effects on other cognitive abilities. The results of these statistical mediation analyses are presented in Table 9. Entries in the second row correspond to the values for the model portrayed in Figure 2 when all the cognitive abilities were examined simultaneously. Values in the other rows are from analyses in which each ability was considered separately. The first column lists the cognitive ability serving as a mediator in that particular analysis. The second column contains the standardized coefficient from age to the hypothetical mediator, which indicates the strength of the relation between age and the cognitive ability. Values in the third column are the standardized coefficients for the path from the mediator to the source memory construct, which indicate the relative influence of that cognitive ability on the source memory construct. The fourth column contains the standardized coefficients for the direct relations from age to the source memory construct after controlling for the age-related effects through the cognitive ability. In order to provide an indication of the amount of statistical mediation associated with each cognitive ability, column five contains the percentage by which the direct age-related variance in the source memory construct was attenuated relative to the total age-related variance. These values were computed by subtracting the square of the unique age correlation from the square of the total age correlation, dividing this difference by the latter value, and multiplying by 100 to convert to a percentage. To illustrate, the value for the executive functioning construct as a mediator was equal to: $\{[(-.74)^2-(-.60)^2]/(-.74)^2\}$ x100 = 34.3%.

Inspection of the values in Table 9 indicates that there was a substantial attenuation of the age-related effect on the source memory construct when the variance in each cognitive ability, except vocabulary, was controlled. It can also be seen that after controlling the age-related influences through all of the other cognitive abilities the unique age-related effect on source memory was a non-significant -.21.

The results of these analyses must be considered somewhat tentative in light of the evidence that the construct of source memory may not be distinct from other cognitive constructs. However, it should be noted that the pattern was similar when the analyses were conducted with individual source memory variables replacing the source memory construct. To illustrate, the total and direct age relations corresponding to the model in Figure 2 were, respectively, -.56 and -.19 for Action Memory, -.24 and .18 for Color Word, -.50 and -.11 for Picture Location, and -.27 and -.19 for Fact Memory.

Discussion

The primary aims of the current project were to investigate whether it is meaningful to refer to source memory as a construct distinct from memory for content, and to determine if there is anything special about the aging of source memory. However, before addressing these questions it is important to first consider the results from each source memory task.

Unlike many reports in the source memory literature, the Color Word task had stronger negative age relations with the measure of memory for content (r = -.51) than with the measure of memory for context (r = -.24). A possible explanation for this pattern is that content information was assessed with a relatively demanding free recall task whereas context was assessed with a traditionally easier recognition task. The low correlation in this task between content and context (r = .12) is also anomalous compared to other tasks in this study, and may be attributable to the source judgment following the content memory component. That is, in this task participants were first required to generate all the words they could recall, and then select the color of each word when it had appeared on the computer screen. In the three other source memory tasks, the old/new judgment was embedded in the source identification test and did not require a sequential evaluation. The division of the context and content assessments may therefore have contributed to the low correlation between the two measures in this task.

Although there was no systematic trend in level of word recall accuracy across blocks, source memory performance in the Color Word task was progressively lower on successive blocks of trials. Because the same colors (sources) were associated with progressively more items (different words) across successive blocks, this decrease is likely a consequence of proactive interference. This raises the possibility that many assessments of source memory have large age differences because they involve difficult many-to-one association tasks, and are thus accompanied by considerable proactive interference because multiple items are mapped to the same source.

The correlation between the context and content measures in the Picture Location task was relatively low (r = .33), but in this case it may have been suppressed by the near ceiling level of accuracy (i.e., .95) in the old/new recognition measure. When making judgments about location there was a tendency for individuals to preserve partial information (i.e. row or column information) about location such that they the fewest errors were in the opposite quadrant. This result is similar to Dodson, et al.'s (1998) findings in which participants retained partial information about the gender of the speaker, even when they were unable to identify the specific speaker. Because this tendency was weaker with increased age, it can be inferred that increased age was not only associated with a lower level of correct source identification, but also with less preservation of partial information.

In the Action Memory task the correlation between content and context was .68. This indicates that the ordering of individuals according to their ability to determine whether an action was old or new was fairly similar to the ordering of individuals according to their ability to remember whether an action was performed, watched, or imagined.

Participants in the Action Memory task were slightly more accurate at correctly identifying performed actions than watched actions, and were much more accurate at both of these judgments than identifying imagined actions. This finding is consistent with earlier research that has reported that performed actions are remembered better than actions that are not performed (e.g., Earles, 1996; Ronnlund, Nyberg, Backman, Nilsson, 2003) or imagined actions (e.g., Anderson, 1984).

Although the Fact Memory task was modeled after Rahhal et al.'s (2002) study, we failed to replicate their findings of no age differences when source decisions were based on truth status. The differences between the two sets of results are unlikely to be due to procedural variations because the same materials were used with a very similar procedure[4]. It is possible that Rahhal, et al.'s (2002) finding was an anomaly because not only did the researchers find no age differences in source memory, but there were also no age differences in a measure of memory for content.

In summary, the results of the separate source memory tasks indicate that all the measures of performance had good reliability, and that increased age was associated with lower levels for all content and context memory variables.

Two criteria need to be met to establish that there is something special about the aging of source memory. First, variables hypothesized to assess source memory should exhibit construct validity, and second, there should be unique age-related effects on the source memory construct after considering the age-related effects on other cognitive abilities.

In order for source memory to demonstrate construct validity it should exhibit both convergent validity and discriminant validity. The original intent was to examine source memory with the structural model presented in Figure 1. However, when source memory was examined in a two-factor model with the content memory construct the estimated correlation between the content and source constructs was actually greater than 1.0, indicating that the ordering of individuals on the two constructs was identical. This finding does not rule out the possibility that information about content and context might reflect different systems or processes, but it does imply that in this sample of healthy adults, performance on what is common among the content tasks almost perfectly predicts performance on what is common among the context tasks, and vice versa.

Because the two constructs were so highly correlated, their relations to other cognitive abilities and to age were next investigated in separate analyses with a series of four models. The results with the content memory variables indicated that there was some evidence for convergent validity, but the very high correlation with the episodic memory construct indicated that it did not have discriminant validity. The substantial correlation between the content memory and episodic memory constructs is not surprising because both sets of variables involve the assessment of memory for episodic information.

The major results with respect to the construct validity of source memory are summarized in Table 8. The moderate loadings of the context memory variables on a context memory construct indicate that this construct can be considered to have convergent validity. However, the critical issue is whether context memory is a construct distinct from constructs representing other cognitive abilities. The evidence here is somewhat equivocal because the context memory construct had substantial correlations of .70 or greater with four of the five cognitive ability constructs. Moreover, when a prospective memory construct based on the variables described in Salthouse, et al. (in press) was included in the analysis, the correlation between the context memory construct and the prospective memory construct was 1.0. Examination of the raw correlations revealed that the median correlation among the context memory variables was .25, the median correlation among the prospective memory variables was .28, and the median correlation between the context memory and prospective memory variables was .30. All of the correlations were therefore relatively weak, and they were actually larger across constructs, than within constructs. This pattern suggests that both sets of common variance – that corresponding to the four context memory variables and that corresponding to the four prospective memory variables – were very broad, and not distinguishable in terms of their patterns of individual differences.

The second criterion needed to establish that there was something special about the aging of source memory was investigated by conducting a series of analyses to examine the degree to which age-related influences on context memory were unique, and statistically independent of the age-related effects on other cognitive abilities. The results of these analyses, summarized in Table 9, indicate that after controlling for the age-related effects on all the other constructs there were no statistically significant unique age-related effects on context memory. The degree of mediation (or statistical dependence) varied across cognitive ability constructs, but it was substantial for all constructs except vocabulary and executive functioning.

The finding of no statistically independent age effects on source memory may appear inconsistent with reports that source memory is particularly sensitive to increased age. However, it is important to distinguish between total age-related effects and unique age-related effects. At the construct level the total age effect on source memory is -.74, which is clearly substantial. However age-related effects are evident on many cognitive variables, and in order to determine whether there are unique age-related effects on source memory, that construct needs to be examined simultaneously with other cognitive abilities. When this is done in the context of the model portrayed in Figure 2, the coefficient for the unique age-related effects on source memory, that are independent of age-related effects on the other constructs, was much smaller, and not significantly different from zero.

In light of the apparent discrepancy between the results of this study and those from certain other studies it may be instructive to consider why results or conclusions might differ across studies conducted from experimental and individual differences approaches. We suspect that there are at least five possible reasons. One is that the primary focus of researchers working within the experimental perspective is to decompose the task variance into portions attributable to different theoretical processes, whereas the major goal for individual difference researchers is to decompose the across-individual variance into portions that are and are not reliable, and that are and are not shared with other variables (Salthouse, 2004). A second possible reason is that many experimental researchers tend to focus on a variable from a single task or from a few closely related tasks and thus tend to ignore potential relations with other variables, whereas most individual difference researchers adopt a multivariate approach in which the target variable is examined in the context of other variables. A third reason why the two approaches might yield what appear to be different results is that experimental researchers are frequently interested in variations in the absolute magnitude of performance differences across task conditions, whereas many individual difference researchers are interested in the extent to which the differences in one condition are statistically independent of the differences in another condition (Salthouse & Coon, 1994). As noted in the introduction, the two approaches also differ in the method used to attempt to distinguish processes from tasks as the experimental approach often relies on some type of subtraction or isolation strategy, whereas the individual difference approach frequently attempts to converge on the process that is assumed to be common across multiple tasks, often by means of latent constructs in structural equation modeling. Finally, the approaches even differ in what would be considered a strong outcome as in the experimental approach an effect would be viewed as robust when nearly everyone exhibits it to nearly the same degree, but in the individual difference approach an outcome of this type would not be very interesting because the lack of variation across individuals would mean that the estimated reliability was quite low, which in turn would make it impossible for the effect to be related to any other variable.

Both experimental and individual difference perspectives should continue to be pursued in research on cognitive aging. However, it is important to note that the individual difference perspective is better suited to investigate construct validity and the degree to which issues of age-related influences on a variable or construct are statistically independent of age-related influences on other variables or constructs.

In conclusion, the results of this study suggest that it may not be meaningful to refer to source memory as a construct distinct from episodic memory and other cognitive ability constructs, at least in the context of individual differences. There was strong evidence for convergent validity of a source memory construct, but the evidence for discriminant validity was less definitive. Furthermore, the failure to find significant unique age-related effects on the source memory construct lead us to suggest, in response to the title of this manuscript, that there may be nothing special about the aging of source memory.

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Footnotes

[1] Because of the large number of statistical comparisons and the moderately large sample size, a significance level of .01 was used in all statistical tests.

[2] The Spearman- Brown generalized formula for calculating reliability is:
α = (n) (average r)/ [1 + (n-1) (average r)] where n is the number of measures and average r is the mean correlation between the measures.

[3] That is, the proportion of errors in the same row or same column of the stimulus display was summed and divided by two to obtain the proportion of errors not in the opposite quadrant.

[4] Rahhal, et al. (2002) used eight buffer items in their memory task, in which four statements were used to control for the recency effect and four statements used to control for the primacy effect. After removing eight buffer facts from our analysis the correlation between the context and content measures was 0.79. The correlation between the old-new accuracy measures with and without the buffers included was .99 ($p<.01$) and the correlation between the source accuracy measures with and without the buffer facts included was .99 ($p<.01$). Because the results were nearly identical before and after deleting buffer items, only the results based on all trials are reported.

Author Identification Notes

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Table 1
Participant Characteristics

	18-39	40-59	60-89	All	Age r
N	110	145	75	330	-
Age	28.0 (6.6)	49.4 (5.2)	71.8 (8.8)	47.4 (17.5)	-
Proportion Female	.68	.68	.59	.66	-.05
Self-Rated Health	1.9 (0.7)	2.0 (0.9)	2.2 (0.9)	2.0 (0.8)	.23*
CES-D	11.5 (8.2)	12.3 (8.5)	12.0 (8.8)	12.0 (8.5)	.02
Years of Education	15.4 (2.4)	15.8 (2.7)	15.9 (2.8)	15.7 (2.6)	.10
Vocab. Scaled Score	12.6 (3.2)	12.2 (2.8)	13.4 (2.6)	12.6 (2.9)	.05
DigSym. Scaled Score	12.3 (2.9)	11.7 (2.9)	11.7 (2.9)	11.9 (2.9)	-.05

*p<.01

Note: Health was rated on a scale ranging from 1 for Excellent to 5 for Poor. CES-D is the Center for Epidemiological Studies – Depression Scale (Radloff, 1977). Vocab. Scaled Score and DigSym. Scaled scores are the age-adjusted scaled scores from the Wechsler Adult Intelligence Scale III (Wechsler, 1997a).

Table 2
Means, standard deviations, estimated reliabilities, and linear and quadratic correlations with age for the four content and four context memory variables.

	Mean	SD	Est. Rel.	Age Corr.	Age^2 Corr.
Content					
Color Word	4.1	1.34	.78	-.51*	-.17*
Picture Location	.95	.05	.80	-.32*	-.28*
Action Memory	.85	.08	.86	-.55*	-.11
Fact Memory	.87	.09	.84	-.15*	-.13
Context					
Color Word	.67	.22	.62	-.24*	-.00
Picture Location	.47	.15	.78	-.50*	-.06
Action Memory	.81	.12	.71	-.56*	-.16*
Fact Memory	.85	.14	.85	-.27*	-.22*

*p<.01

Note: The age^2 correlation is the semi-partial correlation after controlling the linear relation of age.

Table 3
Means, standard deviations (SD), and correlations across successive blocks of trials in the Color Word task

	1	2	3	4
Word Recall				
Mean	4.31	3.85	4.19	3.99
SD	1.72	1.68	1.77	1.75
Age correlation	-.38*	-.48*	-.43*	-.30*
Color Identification				
Mean	.79	.65	.64	.57
SD	.26	.34	.33	.35
Age correlation	-.19*	-.23*	-.17*	-.12

*p<.01

Table 4
Proportion of responses, standard deviations, and correlations with age in each combination of stimulus type and response in the Picture Location task.

	Response				
	UL	UR	LL	LR	New
Stimulus Location					
UL	.53 (.50)	.16 (.18)	.18 (.16)	.10 (.10)	.03 (.01)
SD	.22 (.18)	.14 (.16)	.15 (.11)	.12 (.11)	.08 (.02)
Age r	-.33* (-.23*)	.15* (.13*)	.07 (.14*)	.20* (.16*)	.22* (.22*)
UR	.20 (.17)	.39 (.44)	.13 (.11)	.22 (.24)	.05 (.01)
SD	.16 (.12)	.23 (.23)	.15 (.12)	.16 (.16)	.09 (.02)
Age r	.02 (.02)	-.31* (-.45*)	.16* (.27*)	.11 (.18*)	.26* (.26*)
LL	.21 (.18)	.11 (.12)	.50 (.50)	.12 (.12)	.05 (.01)
SD	.16 (.11)	.14 (.14)	.22 (.20)	.13 (.12)	.09 (.02)
Age r	.02 (-.01)	.26* (.22*)	-.40* (-.41*)	.17* (.18*)	.32* (.32*)
LR	.13 (.12)	.20 (.23)	.19 (.17)	.41 (.49)	.06 (.01)
SD	.13 (.10)	.16 (.17)	.15 (.11)	.22 (.23)	.08 (.02)
Age r	.21* (.25*)	.17* (.22*)	.10 (.14*)	-.39* (-.33*)	.15* (.13*)
New	.01 (.04)	.01 (.03)	.01 (.06)	.01 (.05)	.95 (.95)
SD	.03 (.07)	.02 (.07)	.02 (.10)	.02 (.09)	.11 (.06)
Age r	.17 * (.22*)	.25* (.24*)	.16* (.18*)	.11 (.11)	-.18* (-.34*)

*p<.01

Note: UL refers to upper left, UR refers to upper right, LL refers to lower left, and LR refers to lower right. Values in each cell are the proportions of responses for that cell relative to the total number of trials with that stimulus type. Entries in parentheses are proportions for that cell relative to the total number of responses in that column.

Table 5
Proportions of responses, standard deviations, and correlations with age in each combination of stimulus type and response in the Action Memory task.

	Source Judgment			
	Perform	Watch	Imagine	New
Stimulus Type				
Perform	.81 (.86)	.05 (.05)	.08 (.11)	.06 (.03)
SD	.13 (.11)	.07 (.06)	.07 (.09)	.08 (.04)
Age r	-.30* (-.50*)	.22* (.23*)	.02 (.15*)	.34* (.30*)
Watch	.08 (.08)	.78 (.80)	.03 (.04)	.10 (.06)
SD	.10 (.06)	.17 (.15)	.06 (.06)	.12 (.06)
Age r	.29* (.29*)	-.40* (-.51*)	.10 (.12)	.33* (.33*)
Imagine	.04 (.04)	.07 (.07)	.56 (.79)	.33 (.20)
SD	.06 (.06)	.08 (.07)	.28 (.16)	.18 (.09)
Age r	.43* (.41*)	.36* (.43*)	-.50* (-.30*)	.34* (.34*)
New	.02 (.02)	.07 (.08)	.04 (.06)	.88 (.71)
SD	.05 (.04)	.06 (.09)	.08 (.09)	.14 (.13)
Age r	.37* (.37*)	.35* (.38*)	.17* (.30*)	-.35* (-.48*)

*p<.01

Note: Values in each cell are the proportions of responses for that cell relative to the total number of trials with that stimulus type. Entries in parentheses are proportions for that cell relative to the total number of responses in that column.

Table 6
Proportion of responses, standard deviations, and correlations with age in each combination of stimulus type and response in the Fact Memory task.

	Response		
	True	False	New
Stimulus Type			
True	.75 (.86)	.10 (.13)	.14 (.16)
SD	.16 (.15)	.10 (.12)	.11 (.09)
Age r	-.11 (-.25*)	.14 (.21*)	.08 (.07)
False	.13 (.13)	.70 (.85)	.16 (.18)
SD	.15 (.13)	.20 (.15)	.12 (.11)
Age r	.26* (.24*)	-.28* (-.24*)	.13 (.13)
New	.02 (.01)	.03 (.03)	.94 (.67)
SD	.06 (.03)	.06 (.06)	.13 (.15)
Age r	.17* (.16*)	.12 (.19*)	-.12 (-.14)

*p<.01

Note: Values in each cell are the proportions of responses for that cell relative to the total number of trials with that stimulus type. Entries in parentheses are proportions for that cell relative to the total number of responses in that column.

Table 7
Statistics for Construct Validity Models for the content memory variables

	Model A	Model B	Model C	Model D
Fit Statistics				
X^2	1	851	813	771
df	2	284	282	269
CFI	1.00	.88	.89	.89
RMSEA	.00	.08	.08	.08
Loadings on Content Memory Construct				
Content → ActionMem	.75*	.65*	.68*	.30*
Content → ColorWord	.60*	.74*	.31*	-.26
Content → PictLocat	.56*	.45*	.47*	.16
Content → FactMem	.46*	.46*	-.33	.34*
Correlations with other Constructs				
Content ←→ Exec		.80*	.77*	
Content ←→ gF		.74*	.72*	
Content ←→ Memory		1.0*	.91*	
Content ←→ Speed		.72*	.76*	
Content ←→ Vocab		.25*	.05	

Loadings on other Constructs

Model C

	Exec	gF	Memory	Speed	Vocab
ActionMem					
ColorWord			.46*		
PictLocat					
FactMem			.81*		

Model D

	Exec	gF	Memory	Speed	Vocab
ActionMem	.06	.29	.54*	-.05	-.32*
ColorWord	-.01	.05	.79*	.03	-.14
PictLocat	.30	-.02	.54*	.00	-.23
FactMem	-.29	.21	.54*	-.06	.19

*p<.01

Note: X^2 is chi-square, df is degrees of freedom, CFI is the comparative fit index, and RMSEA is the root mean square error of approximation.

Table 8
Statistics for Construct Validity Models for the context memory variables

	Model A	Model B	Model C	Model D
Fit Statistics				
X^2	2	816	790	761
df	2	284	283	269
CFI	1.00	.88	.89	.89
RMSEA	.02	.08	.07	.07
Loadings on Context Memory Construct				
Context → ActionMem.	.81*	.72*	.71*	-.25
Context → ColorWord	.33*	.36*	.36*	.06
Context → PictLocat	.52*	.58*	.59*	-.06
Context → FactMem	.52*	.53*	.01	-.37
Correlations with other Constructs				
Context ←→ Exec		.77*	.72*	
Context ←→ gF		.85*	.85*	
Context ←→ Memory		.85*	.83*	
Context ←→ Speed		.76*	.78*	
Context ←→ Vocab		.20	.10	

Loadings on other Constructs

Model C

	Exec	ProsMem	gF	Memory	Speed	Vocab
ActionMem						
ColorWord						
PictLocat						
FactMem				.58*		

Model D

	Exec	gF	Memory	Speed	Vocab
ActionMem	-.05	.35*	.49*	-.05	-.22
ColorWord	-.40	.38*	.45*	-.02	-.07
PictLocat	-.19	.41*	.24	.23	-.14
FactMem	.26	.12	.32	-.14	.05

*p<.01

Note: X^2 is chi-square, df is degrees of freedom, CFI is the comparative fit index, and RMSEA is the root mean square error of approximation.

Table 9

Mediation of age-related effects on context memory

Mediator	Age → Mediator	Mediator → Context	Age → Context.Mediator	% Attenuation
None			-.74*	
All			-.21	91.9
Exec. Funct.	-.33*	.43*	-.60*	34.3
gF	-.60*	.61*	-.38*	73.6
Memory	-.48*	.63*	-.44*	64.6
Speed	-.69*	.46*	-.43*	66.2
Vocabulary	.31*	.46*	-.88*	-

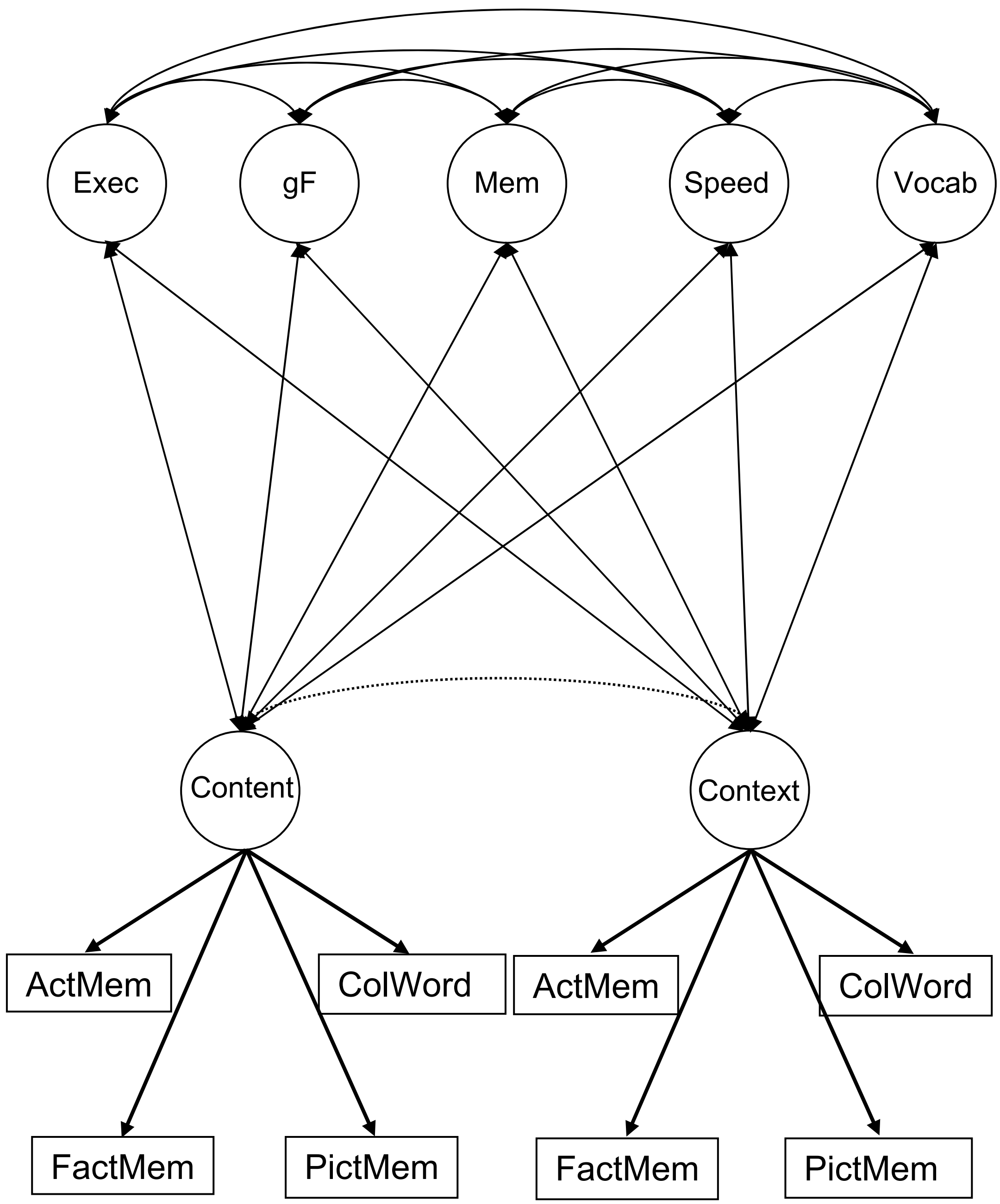
*p<.01

Figure Captions

Figure 1- Structural model to illustrate the assessment of construct validity.

Figure 2- Structural model to examine the role of other cognitive abilities as potential mediators of age-related effects on the context memory construct.

Figure 3- Means and standard errors by decade of performance on the four content memory variables and the four context memory variables.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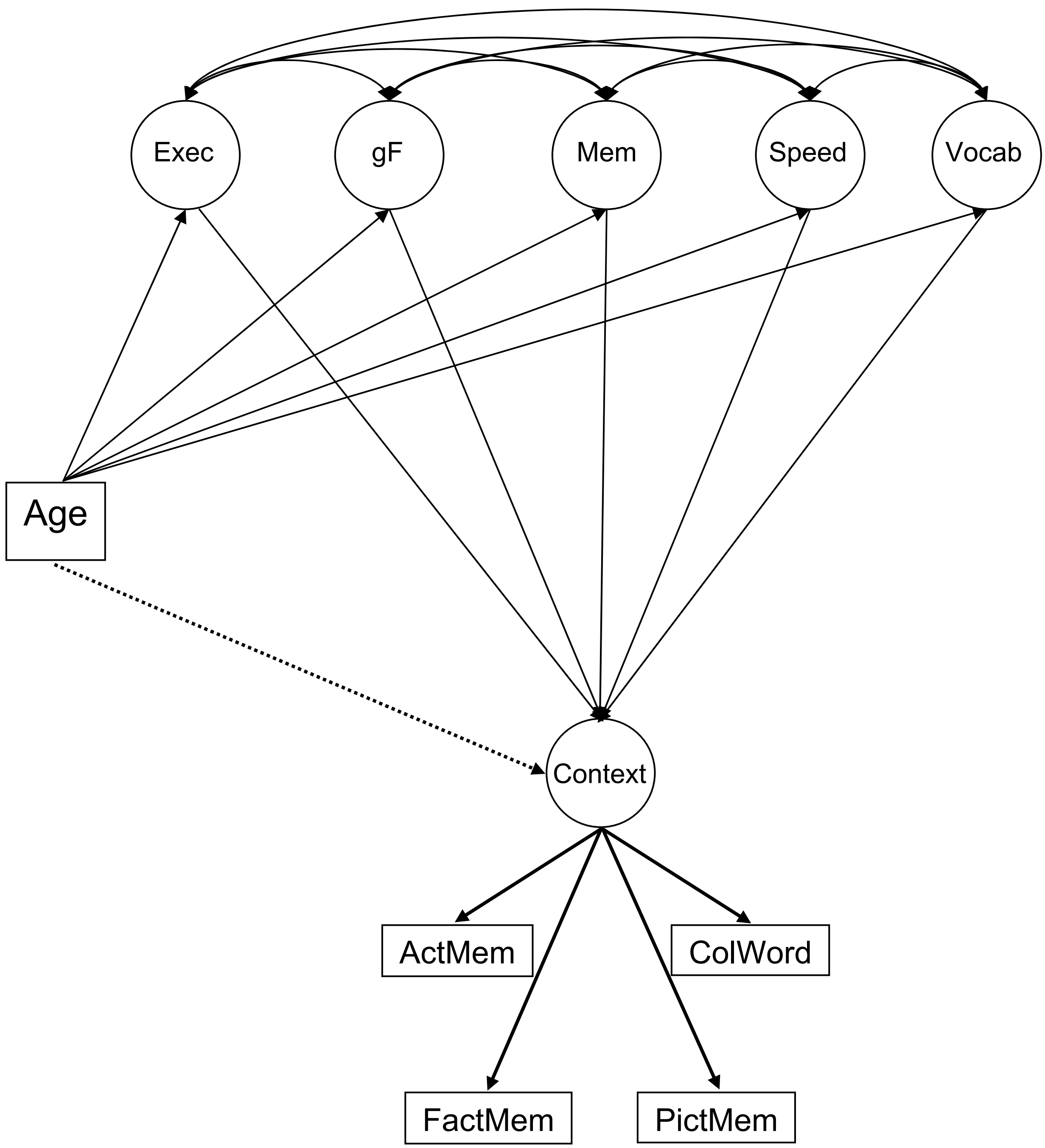
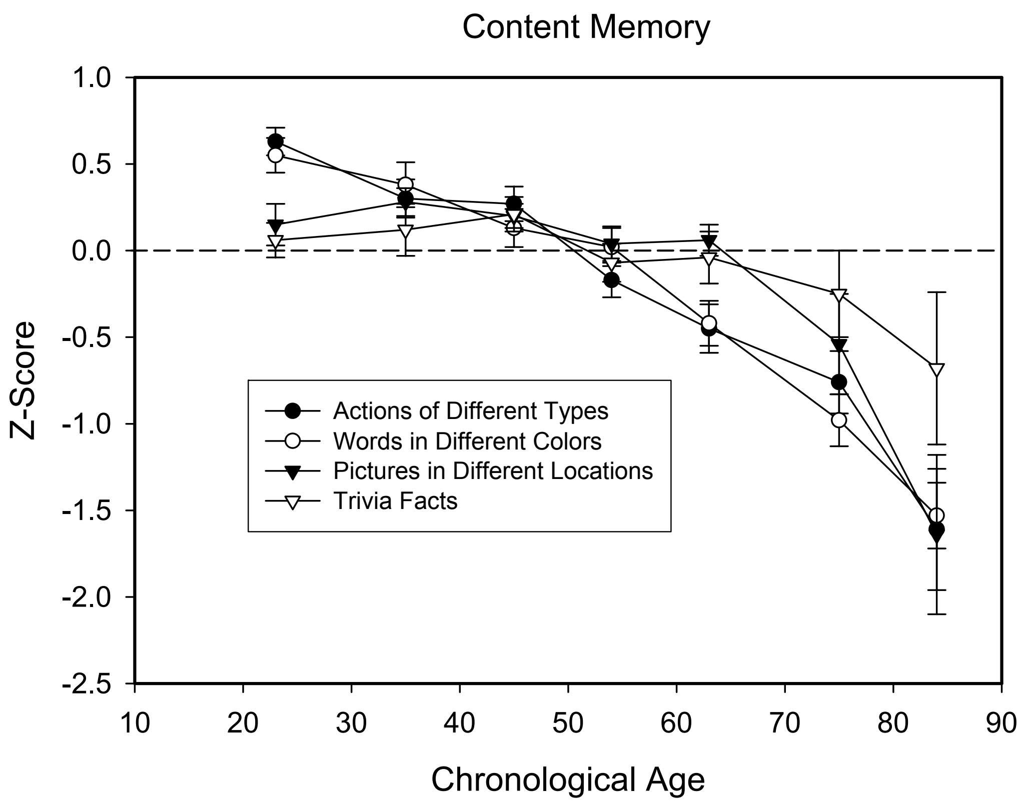
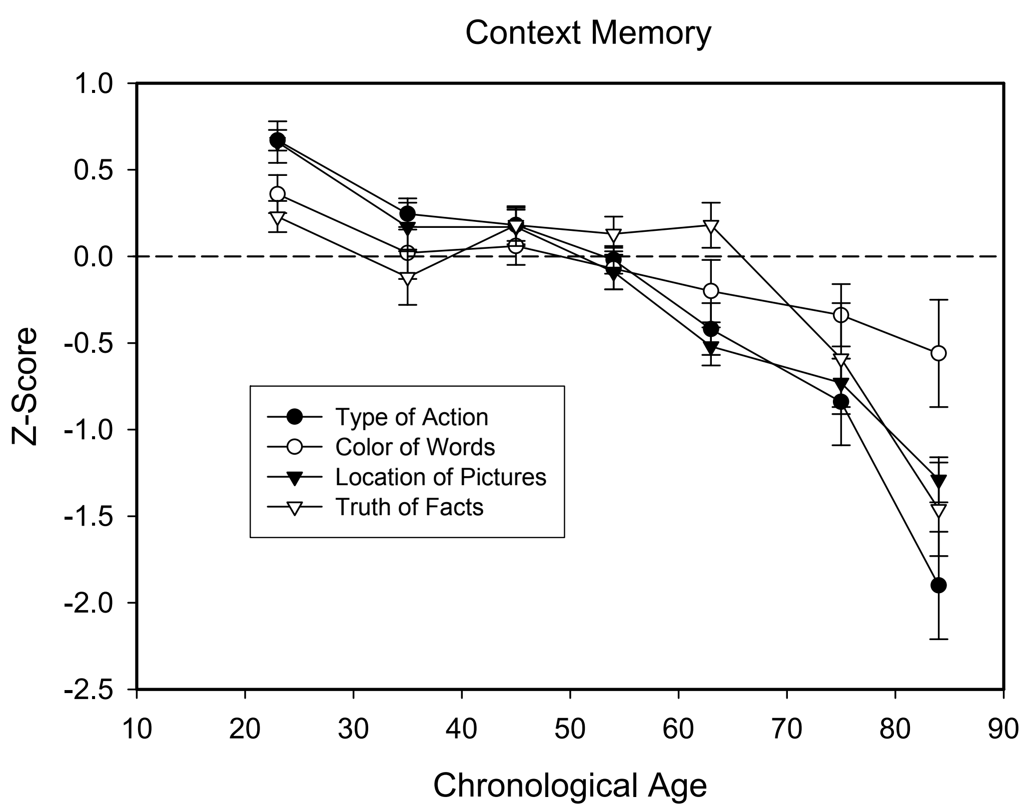
gF
Mem
Speed
Vocab
Content
Context
ActMem
ColWord
FactMem
PictMem
ActMem
ColWord
FactMem
PictMem


Exec
gF
Mem
Speed
Vocab
Age
Context
ActMem
ColWord
FactMem
PictMem


Content Memory
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
Z-Score
Actions of Different Types
Words in Different Colors
Pictures in Different Locations
Trivia Facts
10
20
30
40
50
60
70
80
90
Chronological Age


Context Memory
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
Z-Score
Type of Action
Color of Words
Location of Pictures
Truth of Facts
10
20
30
40
50
60
70
80
90
Chronological Age