Consciousness and Cognition **10,** 451–472 (2001)
doi:10.1006/ccog.2001.0505, available online at http://www.idealibrary.com on IDEAL®

Pro- and Retrospective Memory in Late Adulthood

Bob Uttl

Department of Psychology, Oregon State University, Corvallis, Oregon 97331

Peter Graf[1] and JoAnn Miller

Department of Psychology, University of British Columbia, Vancouver, British Columbia V6T 1Z4, Canada

and

Holly Tuokko

Department of Psychology, University of Victoria, Victoria, British Columbia V8W 2Y2, Canada

Everyday tasks, such as getting groceries en route from work, involve two distinct components, one prospective (i.e., remembering the plan) and the other retrospective (i.e., remembering the grocery list). The present investigation examined the size of the age-related performance declines in these components, as well as the relationship between these components and age-related differences in processing resources. The subjects were 133 community-dwelling adults between 65 and 95 years of age. They completed a large battery of tests, including tests of pro- and retrospective memory as well as tests for indexing processing resources. The results showed similar age-related declines in pro- and retrospective memory. There was only a weak relationship between pro- and retrospective memory, and the age-related decline in processing resources was related more strongly to retro- than prospective memory.

Prospective memory (ProM)[2] and retrospective memory (RetM) are complementary cognitive functions. In a recent article, we described these functions by an analogy with prospectors and miners (Graf & Uttl, 2001). Prospectors are skilled at examining the environment for telltale signs of mineral deposits, whereas minors are trained for recovery operations. RetM is specialized for recovery operations. For RetM tasks, either cues or instructions or both are provided at the time of testing to facilitate and guide retrospective activities, for retrieving target information from

This research was supported by operating grants from the British Columbia Health Research Foundation and by the Natural Sciences and Engineering Research Council of Canada to P. Graf and by a graduate scholarship to B. Uttl from the Natural Sciences and Engineering Research Council of Canada. We thank Arsalan Fatima Ghani, Nadine Bruce, and Jennifer Shapka for assisting with the project and the preparation of this manuscript and Angela R. Birt and Ulrich Olofsson for valuable comments and discussions. Special thanks also go to the staff of the Kerrisdale Community Center and of Science World in Vancouver whose cooperation enabled us to carry out this research.

[1] To whom correspondence and reprint requests should be addressed. Fax: (604)822-6923. E-mail: pgraf@cortex.psych.ubc.ca.

[2] We use the abbreviation ProM, rather than PM, because as noted by Roediger (1996), the latter is too closely associated with primary memory.

1053-8100/01 $35.00

episodic memory. By contrast, ProM is specialized for discovery operations, for realizing at the right place and time that a cue (a particular time, event, place, person, etc.) is appropriate for recollecting information, such as a previously formed plan or intention. Operationally, the critical difference between RetM and ProM tasks is that for the latter, *no instructions about the cues or about using them in a ProM-task-relevant manner are provided at the time of testing* (such instruction are provided only at the time of study), whereas for RetM tasks, instructions about the cues and how to use them are provided at the time of testing.[3]

The complementary link between ProM and RetM is highlighted by an example—getting groceries en route home from work. For this task, the prospective activity is to recollect the plan at the appropriate time (i.e., when driving by the supermarket) in the absence of specific test-phase input that alerts us to the cue and directs us to use it as a memory probe. Once the plan is retrieved, however, the rest of the task is retrospective—it requires recollecting the items from the grocery list and this activity is equivalent to retrieving words for a recall test.

This article focuses on that aspect of ProM that corresponds to explicit episodic memory. James (1890) called the latter ''memory proper,'' and he stipulated that it requires ''the knowledge of an event, or fact, of which meanwhile we have not been thinking, with the additional consciousness that we have thought or experienced it before'' (p. 684). In parallel with this definition, *ProM proper* requires that we are aware of a plan, of which meanwhile we have not been thinking, with the additional consciousness that we had made the plan earlier (see Graf & Uttl, 1999). The primary goals of the present investigation were to identify declines in ProM—for convenience, we use ProM as a shorthand for ProM proper throughout this article—that occur in later life, to compare the size of age-related declines in ProM and RetM and to explore the relationships among these memory functions and various indexes of processing resources.

Our pursuit of these goals was motivated by theory-guided expectations that conflict with the complex data pattern in the literature on age-related declines in ProM (for a review, see Birt, 1999; Brandimonte, Einstein, & McDaniel, 1996). According to a widespread theoretical view, age-related changes in higher cognitive functions (e.g., explicit episodic memory) result from a decline in the availability of processing resources (e.g., Hasher & Zacks, 1979; Jorm, 1986; Kausler, 1991; Salthouse, 1988; Salthouse, Kausler, & Saults, 1988). Craik (1983, 1986) proposed that memory tests can be arranged along a continuum according to the extent to which performance depends on the availability of processing resources. He characterized ProM tests as being the most resource demanding and thus predicted that ProM test performance would show the largest age-related decline. By contrast to this clear expectation, a recent meta-analysis of all empirical investigations on age-related changes in ProM performance revealed that the size of effects due to age ranged from being large and positive (mean $d = .99$; with the older participants scoring lower than the younger

[3] Instructions given at the time of testing also distinguish between explicit and implicit retrospective tests (see Graf & Uttl, 1999). For explicit tests, subjects are instructed to use the cues in order to recollect information related to a specific prior event or experience, whereas for implicit tests, the instructions focus on general knowledge and skills and they make no reference to specific prior events or experiences.

on time-based laboratory tasks) to being significantly negative (mean $d = -.81$; with the older participants scoring higher than the younger on time-based naturalistic tasks) (Birt, 1999).

ProM researchers have exercised ingenuity and achieved considerable success in illuminating this complex pattern of findings (for a comprehensive review, see Brandimonte, Einstein, & McDaniel, 1996). In general, they explain differences in effects by distinguishing among different task types (e.g., event-versus time-based tasks; Einstein & McDaniel, 1990), by pointing to the unique constraints and requirements of each task type, and by identifying between-group differences in the use of reminders and strategies (see Brandimonte, Einstein, & McDaniel, 1996). More important for the present investigation, these explanations highlight potential confounds that must be identified and removed for a valid assessment of the relationship between ProM and RetM performance. Craik's (1983, 1986) view of age-related declines in memory was not intended to explain the complex pattern of existing findings. It does not distinguish explicitly among different types of ProM tasks. However, we propose that Craik's prediction of larger age-related declines in ProM than RetM performance should hold at least under the following conditions: when ProM proper is tested in circumstances that are similar or identical to those used for testing explicit episodic RetM, and when the latter is examined by means of a test that yields evidence of an age-related performance decline.

An additional hurdle must be overcome to make a valid assessment of ProM and RetM performance and of the true relationship between them. It is widely recognized that every ProM task has two components, called the pro- and retrospective components respectively (Einstein & McDaniel, 1996). These components are illustrated by the example given earlier, getting groceries en route from work. We can fail this task either because we do not recollect the plan when driving by the supermarket or because we do not remember the items on the grocery list. Only the first of these components is clearly prospective, in the sense defined earlier as ProM proper. Once the plan is remembered, failing the next step seems not different from failing to recollect upon request a list of previously learned items. Despite the fact that the distinction between these components is widely recognized, relatively little direct knowledge exists about the former component. Instead, what is known about the prospective component is indirect, inferred from the findings of investigations that used various estimation strategies (e.g., varying the RetM load across constant ProM conditions and minimizing the RetM load across different ProM conditions; see Einstein, Holland, McDaniel, & Guynn, 1992; Einstein & McDaniel, 1990). However, the appropriate use of such strategies presupposes an understanding of how the pro- and retrospective components interact with each other, and the absence of this kind of understanding was an additional impetus for the present study.

To our knowledge, only one previous study has attempted a direct assessment of the prospective component and of its relationship with RetM (Dobbs & Rule, 1987). The subjects in this study were required to complete a questionnaire at home, and the ProM task was to write the time and date in the upper right corner of the form. Dobbs and Rule scored performance in two ways. By a strict criterion, both the time and the date had to be written in the correct location, and by a lenient criterion, performance was counted as successful if either the time or the date were in the correct location. According to Dobbs and Rule (1987, p. 216), the ''lenient criterion provides some measure (albeit not perfect) of remembering to do something [i.e., of ProM proper] while placing minimum requirements on remembering the content of the task.'' Dobbs and Rule found that the strict scores showed only a marginal influence due to age, but the lenient scores showed a large and significant age-related decline.

These findings are consistent with expectations based on Craik's proposal about ProM and RetM, but they must be interpreted cautiously for several reasons. One is that lenient scoring, as defined by Dobbs and Rule (1987), does not yield a pure measure of ProM. A second reason is that the strict scores do not provide a pure index of RetM; the strict scores reveal RetM only for subjects who remembered the ProM component, but not for subjects who did not remember this component. A third reason for caution is that overall task performance (i.e., performance based on strict scoring) was close to the floor, especially for the oldest subjects. The present investigation was designed to overcome these limitations of the Dobbs and Rule study and to reveal the true relationship between age-related declines in ProM and RetM.

The third and final goal of the present investigation was to examine the relationship of ProM and RetM with various indexes of processing resources. According to Craik (1983, 1986), age-related differences in memory performance reflect a decline in the availability of processing resources, and he predicts that such declines would be largest on ProM tests because they make the greatest demands on processing resources. *Processing resources* is a construct intended to reflect a system's capacity to perform attention-demanding activities, and this construct is often operationalized by performance on elementary attention, perception, and decision-making tasks (see Cerella, 1985; Cerella, Poon, & Williams, 1980; Cerella, Rybash, Hoyer, & Commons, 1993; Salthouse, 1985, 1988, 1991, 1993). Therefore, consistent with Craik's view, we expected a stronger relationship between performance on such tasks and ProM than RetM.

METHOD

Subjects

The present investigation was carried out as an add-on to the Vancouver Center component of the Canadian Study of Health and Aging (CSHA). The CSHA was a nationwide investigation of the health and cognitive status of persons age 65 years and older in Canada (see Canadian Study of Health and Aging Working Group, 1994).

Community dwelling individuals were identified for participation in the CSHA on the basis of Medical Services Plan records (i.e., universal health care system records), using a stratified random selection procedure. Individuals who consented to participation were administered a screening battery, which included the Modified Mini-Mental State examination (3MS; Teng & Chui, 1987), and a subsample defined on the basis of 3MS scores was invited to participate in the clinical component of the CSHA. For the present study, a smaller subsample ($N = 293$) of those scoring >77 on the 3MS and living in the Vancouver metropolitan area was contacted by letter and invited to participate subsequent to their involvement in the CSHA. On follow-up phone calls, 12 individuals could not be contacted, 31 did not participate for health reasons

TABLE 1
Demographic Data on Participants

	Age group				
	65–69	70–74	75–79	80–95	*F*(1, 131)[a]
n	31	41	38	23	
Sex					
Men	14	21	13	7	
Women	17	20	25	16	
3MS[b]	94.48	93.17	92.37	89.30	23.77*
CVSI[b]	12.64	12.12	13.13	11.74	.04
Vision[c]	1.90	1.88	1.87	2.13	1.40
Hearing[c]	1.84	2.00	1.87	2.09	1.63
Health[c]	1.71	1.85	1.74	2.09	3.13**
Education (years)	12.71	12.63	12.34	12.83	.06
Preretirement occupation					
Not in labor force			1		
Unskilled		1			
Semiskilled	5	8	6	2	
Skilled	6	7	3	5	
Managerial/Official	12	15	16	8	
Professional/Technical	6	10	10	6	
Missing data	2	0	2	2	

[a] Age effects were computed by regression analysis.
[b] Modified Mini-Mental State (Teng & Chui, 1987).
[c] Color Vision Screening Inventory (Coren & Hakstian, 1988).
[d] From CSHA screening questionnaire (Tuokko, Kristjansson, & Miller, 1995).
* $p < .05$.
** $p = .079$.

or because they had moved away, 16 reported being too busy to participate, and 95 were not interested in the study, thus leaving a sample of 139 subjects. Six additional individuals were removed from this sample for the following reasons: Five failed to complete one or more of the ProM tasks and 1 subject did not complete any of the retrospective tests included in the battery. The data reported in this article were collected as an ''add-on'' to the CSHA; they were not derived from the core CSHA data set.

General descriptive data on the remaining 133 subjects are shown in Table 1. For this table, the data were arranged into four different age groups:[4] 65–69, 70–74, 75–79, and 80–95 years of age. Each of the first three groups spanned 5 years and contained at least 31 subjects, whereas the last group spanned 15 years and contained 23 subjects. The two youngest groups had approximately the same number of men and women, but there were nearly twice as many women than men in the two older groups. Hierarchical regression analyses showed that neither age nor age^2 were significant predictors of years of formal education, *F*s $< .09$ (α was set at .05 for this

[4] Even though this and other tables show the data arranged into age groups, we used regression methods for most statistical analyses with age and age^2 entered as independent variables.

and all other statistical tests). The screening questionnaire used for selecting subjects for the CSHA (described in Tuokko, Kristjansson, & Miller, 1995) required making a self-rating about eyesight (1 = *excellent* to 5 = *unable to see*), hearing (1 = *excellent* to 5 = *unable to hear*), and general health (1 = *very good* to 5 = *very poor*). The means in Table 1 show no significant age differences in eyesight and hearing, and only a small difference in general health. The vast majority (79%) of the subjects in every group were native English speakers, and the groups were comparable on preretirement occupational status. All individuals obtained 3MS scores in the normal range, but there was a decline in the scores that was predicted by age, $F(1, 131) = 23.77$, $r^2 = .15$, and by age^2, $F(1, 130) = 5.19$, $r^2 = .03$.

Assessment Instruments

Table 2 lists all of the instruments that were used as well as the order in which they were administered to subjects. A complete description of the instruments used for the attention battery, the top section of the table, can be found in Graf, Uttl, and Tuokko (1995); the remaining instruments were described in Tuokko et al. (1995). The latter set constitutes the neuropsychological battery that was administered in the core CSHA protocol as part of the clinical component of the study. This battery was also used for the present study to permit comparisons between attention and neuropsychological test performance.

Prospective tasks. ProM was assessed by a series of three brief tasks: the name task, the letter task, and the check task. For the name task, the subjects were instructed that ‘‘when I [the experimenter] say, this is the end of the task, I’d like you to ask for a pen and a piece of paper, then I would like you to write your name on the paper.’’ These instructions were given immediately following screening for color vision and prior to the cancel-H task (see Table 2), and the retrieval cue—‘‘this is the end of the task’’—for the name task was given at the end of the cancel-H task. The cancel-H task required a maximum of about 5 min, thereby fixing the length of the retention interval for the prospective name task. After giving the name task retrieval cue the experimenter paused for about 30 s, for any subject who did not immediately respond to the cue, while preparing for the next task (i.e., dichotic listening). For subjects who proceeded to the name task, they were given a pen and a blank page upon requesting each of these item, and the experimenter paused until subjects finished with the task (i.e., write their name on the page). No other cues were provided.

Immediately prior to the next task—dichotic listening—the subjects were given instructions for the letter task as follows: ‘‘when I say this is the end of the task, I’d like you to ask for a pen, a letter and an envelope. Then I would like you to put the date on top of the letter, sign your name on the bottom of the letter, and write the address on the envelope.’’ The retrieval cue—‘‘this is the end of the task’’—for the letter task was given at the end of the dichotic listening task, which required a maximum of about 5 min. After delivering the letter task cue the experimenter paused for about 30 s for any subject who did not immediately commence with the letter task while preparing for the next task (i.e., the color-word Stroop test). For any subject who proceeded to the letter task, they were given a pen, a letter, and an

TABLE 2
List of All Instruments, Plus Prospective Tasks (in Italics), Used in the Attention and Neuropsychological Batteries, with Their Order of Administration

Battery/test type	Instrument	Sequence in battery
Attention battery		
Sensation	Hearing Screening Inventory (HSI)[a]	1
	Color Vision Screening Inventory (CVSI)[b]	2
Attention	Cancel H[c] & *Name Task*	4
	Card Sorting[d]	8
	Dichotic Listening[e] & *Letter Task*	5
	Color–Word Stroop	6
	Picture–Word Stroop	3
	Vigilance/Tone Detection[f] & *Check Task*	7
Neuropsychological battery		
Memory	Benton Visual	11
	Buschke Recall	2
	Digit Span	7
	Wechsler Memory Scale-Information	1
	Rey AVL	9
	Working Memory[g]	14
Abstract thinking	WAIS-R Similarities	5
Judgment	WAIS-R Comprehension	8
Verbal fluency	Animal Naming	12
	Verbal Fluency	10
Other tests	Clock Drawing	15
	Token Test	6
	Visual Identification	4
	WAIS-R Block Design	3
	WAIS-R Digit Symbol	13

[a] From Coren and Hakstian (1992).
[b] From Coren and Hakstian (1988).
[c] Adapted from Diller et al. (1974).
[d] Adapted from Rabbitt (1965).
[e] Adapted from Kimura (1967).
[f] Adapted from Strub and Black (1977).
[g] From Dobbs and Rule (1989).

envelope upon requesting each of these items as well as a page with an address on it. This address was to be written on the envelope. No other cues were provided.

Finally, prior to assessing vigilance, subjects were given the check task with the following instructions: ‘‘when I say this is the end of the task, I'd like you to ask for a pen, an envelope and a blank cheque. Then I would like you to write the cheque as you would normally do it, that is, fill in the date, the pay-to blank, the numerical-amount blank, the written-amount blank, and then sign the cheque and put it inside the envelope.’’ The critical cue—‘‘this is the end of the task’’—for the check task was given at the end of assessing vigilance which required a maximum of about 12 min. After delivering the check task cue, the experimenter paused for about 30 s, for any subject who did not immediately commence with the check task, while preparing for the last part of the attention battery (i.e., card sorting). For any subject who proceeded with the check task, they were given a pen, a blank check and an envelope upon requesting each of these items; they were also given a copy of a filled-in check that provided all the information required for carrying out the check task. No other cues were provided.

Procedure

Each subject was tested individually at their residence in two sessions that were scheduled at least a few hours or as much as a few days apart from each other. For about half of the subjects, the first session was used for administering the tests listed in the top part of Table 2 (i.e., the attention battery) and required about 2 h, whereas the tests listed in the bottom part of Table 2 (i.e., the neuropsychological battery) were given in the second session that lasted nearly 3 h. The order of the two sessions was reversed for the remaining subjects. The order of giving the tests within each sessions was fixed as indicated in Table 2. All tests except for the prospective tasks were administered according to published instructions.

The three prospective tasks—name, letter, and check—were interpolated among various items of the attention battery as indicated in Table 2. The order of administering tasks was the same for all subjects. Each prospective tasks was nestled around one of the attention battery items in the sense that the task began with an instruction phase just prior to it, and it ended with a test phase immediately following it. For each prospective task, the experimenter re-presented the instructions until they were clearly understood and until the subject could repeat them correctly. For the test phase, the experimenter made eye contact with the subject and only then delivered the critical retrieval cue for each prospective task. No other cues were provided. The experimenter recorded subjects’ verbal responses to the cues.

RESULTS

ProM Tasks

Scoring. Several different scores were obtained for each of the three prospective tasks. The first, which we call the task score, is an index of ProM proper—of remembering that something had to be done for each task. Subjects received 1 point for remembering at the right time (i.e., within a few seconds of hearing the task relevant cue) that something had to be done; they received only ½ of a point for remembering later (i.e., during the pause inserted before the next task) but prior to the next task, and no points were awarded otherwise. Less than 2% of all scores were ½-point scores, and thus, for all statistical analyses, they were changed to 1-point scores. A second score, which we call the items score, was awarded for recollecting correctly the items to-be-requested for each task (e.g., pen and letter). A score of 1 was awarded for correctly recollecting each to-be-requested item. Finally, a third score, called the activities score, was obtained for correctly carrying out the activities that were specified for each task (e.g., date the letter and sign the letter).

The difference between these scores is important for understanding the results of the present study. As outlined in the introduction, we assume that only the task scores index something that is unambiguously prospective. Task score credit was given for realizing that something had to be done, for remembering an earlier plan. Some subjects expressed this realization directly by means of comments like ‘‘oh yeah, there is something I have to do here,’’ whereas other subjects showed it by their actions by asking for the items to-be-requested for the task.

By contrast to the task scores, the *overall* items and activities scores are difficult to classify as reflecting either pro- or retrospective memory processing. This difficulty is underscored by the experience of arriving someplace (i.e., a room or a store) fully aware that we have come for a particular purpose (i.e., ProM has functioning properly) but without recollecting any specifics related to it (i.e., the retrospective component has failed). In such a situation, we may systematically search memory as we would for a typical recall test, and therefore, performance should be classified as reflecting retrospective memory processing. In other situations, we may fail to recollect the items required for a task for no other reason than that we failed to recollect the task itself. In this case, a zero item score cannot be viewed as evidence of poor retrospective memory processing.

Task scores. The tasks scores appear in Table 3. The majority of subjects (>98%) who remembered each of the tasks did so immediately and thus were awarded full credit (i.e., 1 point). For all statistical analyses, the few ½-point scores were changed to 1-point scores, and for this reason, the means in Table 3 represent the proportion of subjects from each age group who succeeded on each task. The tabled values indicate, first and most important, that performance declined with age on all tasks. A second clear finding was that performance increased significantly across tasks, Cochran’s Q (2; N = 133) = 53.13 (for all statistical tests, α was set at .05); it was lowest on the name task, intermediate on the letter task, and highest on the check task for all subject groups. The means also seem to point to an interaction between tasks and age groups, reflecting the fact that the age group difference in performance was largest on the name task and smallest on the check task, but this interaction is

TABLE 3
Task Scores: Remembering That Something Needs to Be Done on Three Different Prospective Tasks by Adults from Various Age Groups

	Subject age groups (in years)				Age effects[a]	
Task	65–69 (n = 31)	70–74 (n = 41)	75–79 (n = 38)	80–95 (n = 23)	χ^2 (1, 133)	p
Name						
M	.84	.76	.45	.43	14.0	.001
SD	.37	.43	.50	.51		
Letter						
M	.94	.85	.79	.70	3.39	.066
SD	.25	.36	.41	.47		
Check						
M	.97	.98	.84	.78	5.55	.019
SD	.18	.16	.37	.42		

[a] Age effects were computed by logistic regression analysis.

difficult to interpret because it is confounded by ceiling effects on the last task. Logistic regression analyses showed a significant age effect on the name and check task and a marginal effect on the letter task (see Table 3 for statistics).

Items scores. The items scores are summarized in Table 4. We give two entries for each item. The first shows overall performance and represents the total proportion of subjects from each group who requested each item. The second entry is a contingent score; it shows recall of items by only those subjects who had successfully recollected each planned task (i.e., remembered that something had to be done). For a concrete illustration, 26 of 31 (.84) of the youngest subjects recollected the name task (see Table 3), and of these 26 subjects, .88 (23 of 26) recollected the pen and .96 (25 of 26) recollected the paper—the two items required for carrying out the name task. Consistent with our preceding analysis, the overall scores confound prospective requirements (i.e., remembering that something had to be done) and retrospective requirements (i.e., recollecting items required for a task). By contrast, the contingent scores may be viewed as a purer index of explicit retrieval from episodic memory. Only the latter scores are directly relevant to the goals of our investigation, and only they are discussed further.

TABLE 4
Items Scores: Memory for Items on Three Different Prospective Tasks by Adults from Various Age Groups

			Subject age groups (in years)				Age effects[b]
Task	Item		65–69 (n = 31)[a]	70–74 (n = 41)	75–79 (n = 38)	80–95 (n = 23)	χ^2 (1)
Name	Pen	O[c]	.74 (.44)	.66 (.48)	.37 (.49)	.39 (.50)	9.55[d]
		GCMT[e]	.88 (.33)	.87 (.34)	.82 (.39)	.90 (.32)	.02
	Paper	O	.81 (.40)	.73 (.45)	.37 (.49)	.43 (.51)	13.03[d]
		GCMT	.96 (.19)	.97 (.18)	.82 (.39)	1.00 (.00)	.15
Letter	Pen	O	.87 (.34)	.78 (.42)	.76 (.43)	.65 (.49)	2.04
		GCMT	.93 (.26)	.91 (.28)	.97 (.18)	.94 (.25)	.08
	Letter	O	.77 (.43)	.78 (.42)	.68 (.47)	.57 (.51)	2.53
		GCMT	.83 (.38)	.91 (.28)	.87 (.35)	.81 (.40)	.12
	Envelope	O	.90 (.30)	.83 (.38)	.71 (.46)	.57 (.51)	12.21[d]
		GCMT	.97 (.19)	.97 (.17)	.90 (.31)	.81 (.40)	10.57[d]
Check	Pen	O	.90 (.30)	.83 (.38)	.76 (.43)	.61 (.50)	4.59[d]
		GCMT	.93 (.25)	.85 (.36)	.91 (.30)	.78 (.43)	.62
	Envelope	O	.94 (.25)	.95 (.22)	.74 (.45)	.65 (.49)	11.48[d]
		GCMT	.97 (.18)	.98 (.16)	.88 (.34)	.83 (.38)	5.43[d]
	Check	O	.97 (.18)	.95 (.22)	.84 (.37)	.78 (.42)	5.16[d]
		GCMT	1.00 (.00)	.98 (.16)	1.00 (.00)	1.00 (.00)	<.01

[a] The listed n per age group is relevant only for the O values. The GCMT values are based only on that subset of subjects who had remembered the task (see Table 3).
[b] Age effects were computed by logistic regression analysis.
[c] O = Overall. Values show mean performance (*SD* in parentheses) across all subjects.
[d] Significant with $p < .05$.
[e] GCMT = Given Correct Memory on the Task. Values show mean performance (*SD* in parentheses) across that subset of subjects who had remembered the task (see Table 3).

The contingent scores show that of the subjects who remembered the prospective tasks, nearly all of them also remembered the to-be-requested items. We found statistical evidence for an age-related decline on only two items: requesting the envelope for the letter task and requesting the envelope for the check task (for statistics, see Table 4).[5] One possibility is that the failure to find more age effects in the contingent items scores is due to the fact that performance was at or near the ceiling. Such ceiling effects seem typical also of performance in real-life situations. For example, when the ProM task is to post a letter in the course of the day or to convey a message upon encountering a particular person, we are likely to master the retrospective component, provided we successfully recollect the prospective component. Overall, the contingent scores suggest that subjects were minimally challenged by the RetM demands of our tasks, a finding consistent with previous work on memory for short and meaningfully organized lists which tends to remain effective even in old age.

Activities scores. The activities scores are summarized in Table 5. Again, there are two entries for each activity: The first shows overall performance and represents the total proportion of subjects that performed each activity. The second entry is a contingent score that shows performance of only those *subjects who had requested all items for each task.* For the youngest group, 23 of 31 subject had requested all items for the name task, and 17 of the 23 (i.e., .74 according to Table 5) wrote their name as instructed. As discussed above, the overall scores confound prospective requirements (i.e., remembering that something had to be done) and retrospective requirements (i.e., recollecting items and recollecting what needed to be done with them). The contingent scores provide a purer index of explicit retrieval from episodic RetM, and only they are discussed further.

The means from the contingent activity scores are comparable to the contingent item scores. For subjects who requested all relevant items, they also tended to remember what to do with them, and there was little evidence of any influence due to the age variable (for statistics, see Table 5). We found statistically significant evidence for an age-related decline for only one activity, signing the letter. As with the items scores, it is possible that the failure to find age effects in memory for the other activities is due to the fact that performance was at or near ceiling. The contingent activity scores suggest that subjects were minimally challenged by the retrospective requirements of our tasks.[6]

RetM Tasks

For a more direct, purer index of explicit episodic RetM, the neuropsychological battery included three standardized tests—the Benton Visual Retention test, the Buschke recall test, and the Rey Auditory Verbal learning test. Performance on the Benton Visual Retention test was marred by ceiling effects and thus not used. Sub-

[5] Regression analyses show the same age effects if they are run on the contingent scores summarized in Table 4 or if they are run on the overall scores with each subject's task score entered as an additional predictor.

[6] For the regression analyses of the activity scores, any item-score variables (specifically, requesting the envelope for the letter task and requesting the envelope for the check task) that showed a significant age effect was also entered as a predictor.

TABLE 5
Activities Scores: Memory for Activities on Three Different Prospective Memory Tasks by Adults from Various Age Groups

Task	Activity		Subject age groups (in years) 65–69 (n = 31)[a]	70–74 (n = 41)	75–79 (n = 38)	80–95 (n = 23)	Age effects[b] χ^2 (1)
Name	Write name	O[c]	.65 (.49)	.51 (.51)	.37 (.49)	.30 (.47)	7.58[d]
		GCMaI[e]	.74 (.45)	.67 (.48)	.77 (.44)	.67 (.50)	.05
Letter	Date letter	O	.65 (.49)	.66 (.48)	.55 (.50)	.35 (.49)	5.63[d]
		GCMaI	.82 (.39)	.79 (.42)	.73 (.46)	.60 (.52)	2.34
	Sign letter	O	.84 (.37)	.80 (.40)	.63 (.49)	.52 (.51)	4.95[d]
		GCMaI	1.00 (.00)	.96 (.19)	.86 (.35)	.80 (.42)	4.05[d]
	Copy name	O	.87 (.34)	.76 (.43)	.66 (.48)	.52 (.51)	9.15[d]
		GCMaI	.95 (.21)	.93 (.26)	.95 (.21)	.90 (.32)	<.01
	Copy street	O	.90 (.30)	.80 (.40)	.71 (.46)	.52 (.51)	12.54[d]
		GCMaI	1.00 (.00)	.96 (.19)	1.00 (.00)	.90 (.32)	.58
	Copy city	O	.90 (.30)	.80 (.40)	.71 (.46)	.48 (.51)	15.24[d]
		GCMaI	1.00 (.00)	.96 (.19)	1.00 (.00)	.90 (.32)	.58
	Copy postal code	O	.87 (.34)	.80 (.40)	.71 (.46)	.48 (.51)	12.90[d]
		GCMaI	.95 (.21)	.96 (.19)	1.00 (.00)	.90 (.32)	.04
Check	Date check	O	.90 (.30)	.90 (.30)	.79 (.41)	.74 (.45)	2.64
		GCMaI	.96 (.19)	.94 (.24)	.96 (.20)	.92 (.29)	.01
	Pay to	O	.94 (.25)	.90 (.30)	.76 (.43)	.70 (.47)	5.98[d]
		GCMaI	1.00 (.00)	.94 (.24)	.96 (.20)	1.00 (.00)	.01
	#Amount	O	.97 (.18)	.95 (.22)	.82 (.39)	.74 (.45)	7.84[d]
		GCMaI	1.00 (.00)	1.00 (.00)	.96 (.20)	.92 (.29)	3.63
	Amount written	O	.94 (.25)	.95 (.22)	.84 (.37)	.78 (.42)	3.75
		GCMaI	.96 (.19)	1.00 (.00)	1.00 (.00)	1.00 (.00)	1.46
	Sign check	O	.97 (.18)	.88 (.33)	.84 (.37)	.78 (.42)	2.73
		GCMaI	1.00 (.00)	.91 (.29)	1.00 (.00)	1.00 (.00)	.88
	Check in envelope	O	.87 (.34)	.80 (.40)	.58 (.50)	.61 (.50)	7.30[d]
		GCMaI	.93 (.27)	.88 (.33)	.80 (.41)	.92 (.29)	.27

[a] The listed n per age group is relevant only for the O values. The GCMaI values are based only on that subset of subjects who had recollected all of the items for each task.
[b] Age effects were computed by logistic regression analysis.
[c] O = Overall: Values show mean performance (*SD* in parentheses) across all subjects.
[d] Significant, with $p < .05$.
[e] GCMaI = Given Correct Memory for all Items. Values show mean performance (*SD* in parentheses) across only that subset of subjects who had remembered all of the items to-be-requested for each task.

jects' performance on the two remaining tests is summarized in the top part of Table 6. The means show significant age-related declines in performance (for statistics, see Table 6) consistent with findings from previous studies.

Relation Between ProM and RetM

Are ProM proper and explicit, episodic RetM related to each other, and do they depend on the same or on similar cognitive resources? In a first attempt to answer this question, we have treated the task scores as indexing something that is unambiguously

TABLE 6
Variables Selected for the Exploratory Factor Analysis and Performance by Adults from Various Age Groups

	Subject age groups (in years)				Age effect[a]		Age^2 effect[a]	
	65–69 (n = 31)	70–74 (n = 41)	75–79 (n = 38)	80–95 (n = 22)	r^2	$F(1, 130)$	Δr^2	$F(1, 129)$
RetM tests								
Buschke 1–3[b]								
M	10.02	9.34	9.33	8.78	.087	12.32*	.001	.08
SD	1.00	1.21	1.46	1.37				
RAVLT A1–5[c]								
M	9.82	9.19	8.99	8.46	.046	6.26*	<.001	.05
SD	1.46	1.84	2.66	2.04				
RAVLT A6[d]								
M	10.69	9.38	9.50	8.98	.034	4.54*	.001	.11
SD	2.89	2.78	3.43	3.72				
RAVLT B1[e]								
M	5.47	4.95	5.04	4.00	.054	7.39*	<.001	.62
SD	1.57	2.15	1.93	1.45				
Attention tests								
Cancel H[f]								
M	27.64	29.67	27.83	36.76	.117	17.14*	.043	6.53*
SD	4.87	7.21	5.37	10.31				
Card sorting								
M	105.69	108.56	113.02	141.98	.245	42.20*	.046	8.32*
SD	17.28	19.25	22.51	26.96				
Digit symbol[g]								
M	41.48	39.11	38.69	28.27	.126	18.68*	.001	.12
SD	9.34	9.80	12.68	7.97				
Semantic fluency								
Verbal fluency								
M	36.35	34.88	33.71	28.14	.058	8.04*	.004	.57
SD	9.55	9.73	10.72	8.23				
Animal naming								
M	18.71	16.98	16.62	14.95	.102	14.79*	.001	.11
SD	4.12	3.83	3.28	4.88				
Picture naming[h]								
M	761.29	835.16	928.71	1049.15	.168	26.19*	.002	.36
SD	143.01	236.42	237.88	302.49				

[a] Age and age^2 effects were computed by regression analysis.
[b] Buschke recall test (see Spreen & Strauss, 1991); average recall for trials 1 to 3.
[c] RAVLT (see Spreen & Strauss, 1991); average recall for trials 1 to 5 on List A.
[d] RAVLT (see Spreen & Strauss, 1991); list A delayed recall (trial 6).
[e] RAVLT (see Spreen & Strauss, 1991); list B recall.
[f] Cancel H (see Graf, Uttl, & Tuokko, 1995); in seconds per block.
[g] Subtest from WAIS-R.
[h] Picture–word Stroop test (see Graf, Uttl, & Tuokko, 1995); picture naming speed in milliseconds per item.
* $p < .05$.

prospective, ProM proper, in contrast to the contingent item scores and the contingent activity scores which seem more indicative of explicit, episodic RetM. The majority of the contingent scores were limited by ceiling effects and thus were not usable. However, two of eight contingent item scores (i.e., requesting the envelope for the letter task, and requesting the envelope for the check task) were not invalidated by obvious ceiling effects. For both of these scores, regression analyses showed significant age effects that were not predicted by the task scores (see Table 4), thereby suggesting that the age effects observed in our indexes of ProM and RetM reflect different influences.

Factor analysis. For a stronger examination of the relation between pro- and retrospective memory, we used data from the entire battery of tests (see Table 2) that was given to subjects in the present study, and we carried out an exploratory factor analysis. This analysis included the ProM task scores from the name and letter tasks (the check task scores were not used because of ceiling problems) as well as the RetM scores listed in the top part of Table 6. In addition, we selected at least three different indicators for the other factors that we suspected of being related to ProM proper. The selected indicators, and subjects' performance on each of them, arranged by age-groups, appear in Table 6. All data were screened for uni- and multivariate outliers and missing values. There was a total of nine missing values (between 0 & 4 missing values per variable), and they were replaced with values predicted by age and age^2. We also found 16 univariate outliers (between 0 and 3 outliers per variable), and they were replaced by values equal to the upper or lower bound (whichever was nearer to the value) of the 99% confidence interval. The data from one subject were identified as a multivariate outlier (and thus not included in the factor analysis) by means of the Mahalanobis distance statistic, with the criterion set at χ^2 (12) $>$ 32.91, at $p = .001$.

The indicators used for the factor analysis were intended to target three domains (see Table 6): retrospective explicit memory, attention and processing speed, and verbal-naming fluency. Table 6 lists the results from regression analyses conducted to identify age and age^2 effects. There was a significant age effect on each variable, and two variables, Cancel H and Card Sorting, also showed significant age^2 effects. Therefore, in order to learn more about other commonalities—other than age—between performance on these variables and on our ProM tasks (i.e., on ProM proper), we partialed out the influences due to age prior to conducting the factor analysis.[7] The correlations among the unadjusted original scores are listed on the top half of Table 7, and the correlations that remain after partialing out influences due to age are shown in the bottom half. The factor analysis used the unweighted least-squares (ULS) solution, with oblique rotation (oblimin), and accepted all factors with eigenvalues $>$1 (Harman, 1976).

The results of the factor analysis based on the partial correlations are reported in Table 8. The analysis revealed three factors. The first received strong loadings from

[7] Also prior to conducting the factor analysis on the age-adjusted scores, we split the data into two age groups (dividing at age 75), and Bartlett's test for the equality of the age-group variance/covariance matrices showed no significant difference (Box's $M = 96.40$, $p = .23$), thereby justifying using all subjects in the same factor analysis.

six different tasks/variables: Cancel H, Card Sorting, Digit Symbol, Verbal Fluency, Animal Naming, and Picture Naming. This collection of tasks is generally assumed to index a variety of cognitive skills or capacities (e.g., Lezak, 1995; Spreen & Strauss, 1991), including speeded visual search, visual scanning, sustained attention and concentration, as well as the speed, ease, and accuracy of knowledge search and retrieval (Salthouse, 1996). Factor 1 seems to capture the system's basic resources, its processing capacity (e.g., Kausler, 1994; Salthouse, 1996). Factor 2 received loadings from four tasks/variables: Buschke 1–3, RAVLT A1–5, RAVLT A6, and RAVLT B1 (see Table 8), suggesting that this factor is an index of explicit episodic RetM. Finally, the prospective task scores loaded on Factor 3. When the factor analysis was run on the original scores, rather than on the age-adjusted scores, the outcome remained the same: the same factor structure emerged (same variables loaded on each factor), although the actual factor loadings were different.

The factor correlations listed on the bottom of Table 8 show that the resource factor correlated more strongly with Factor 2 ($r = .51$), an index of explicit RetM, than with Factor 3 ($r = .36$), an index of ProM proper. Table 8 also shows that Factors 2 and 3 were only weakly correlated ($r = .20$), consistent with the view that ProM proper and explicit episodic RetM are distinct, dissociable memory functions.

DISCUSSION

The main goals of the present study were to investigate age-related differences in ProM proper and in explicit episodic RetM and to examine the relationship among ProM proper, RetM, and other cognitive functions. Directly relevant to the first of these goals, we found a substantial age-related decline on the task scores, on our index of ProM proper. Second, performance on standardized tests of explicit episodic RetM showed the expected age-related decline. Third, the magnitude of the age-effects seemed comparable, in terms of r^2, on our indexes of ProM proper (.10 and .03 for the name and letter task, respectively), and for explicit episodic RetM (ranging from .03 to .09 for the measures listed in Table 6). Forth, the factor analysis of the age-adjusted scores showed different loadings for RetM and ProM proper. It also showed that attentional resources is weakly correlated with performance on both memory test types, but more strongly with RetM than ProM.

The finding of an age-related decline in ProM proper replicates and extends previous research by Dobbs and Rule (1987). According to our knowledge, Dobbs and Rule's study is the only previous investigation that attempted a direct assessment of ProM proper. Their study required subjects to complete a questionnaire at home, and thus, it was possible for performance to be confounded with an age difference in the use of memory aids and strategies. This type of confounding influence is ruled out by the present study, where subjects were tested under controlled laboratory conditions.

The present study, in conjunction with the experiment by Dobbs and Rule (1987), demonstrates that it is possible to distinguish between, and assess directly, the pro- and retrospective components of prospective memory tasks. The ability to assess ProM proper directly complements and augments the indirect strategies that have been used for capturing this component in previous studies. The need for assessing the pro- and retrospective components independently of each other arises, in part,

TABLE 7
Correlations (Period Omitted) among Performance of Two Prospective Tasks and of Various Cognitive Tests for Original Scores (Top Panel) and for Age-Corrected Scores (Bottom Panel)

	Correlation matrix for original scores												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Name task	100												
2. Letter task	55	100											
3. Buschke 1–3[a]	18	20	100										
4. RAVLT A1–5[b]	24	21	70	100									
5. RAVLT A6[c]	26	21	65	76	100								
6. RAVLT B1[d]	12	15	42	54	36	100							
7. Cancel H[e]	−24	−33	−35	−46	−41	−29	100						
8. Card Sorting	−31	−21	−33	−38	−30	−31	68	100					
9. Digit Symbol[f]	25	19	35	47	44	37	−61	−64	100				
10. Verbal Fluency	35	25	23	37	25	20	−38	−43	47	100			
11. Animal Naming	33	28	32	35	28	30	−43	−43	34	49	100		
12. Picture Naming[g]	−27	−16	−21	−26	−22	−13	44	43	−33	−32	−46	100	
13. Age	−35	−17	−29	−21	−18	−23	34	49	−35	−24	−31	40	100

Correlation matrix for age-corrected scores

	1	2	3	4	5	6	7	8	9	10	11	12
1. Name task	100											
2. Letter task	53	100										
3. Buschke 1–3[a]	08	16	100									
4. RAVLT A1–5[b]	19	18	68	100								
5. RAVLT A6[c]	21	19	65	79	100							
6. RAVLT B1[d]	04	11	39	54	33	100						
7. Cancel H[e]	−14	−31	−29	−42	−38	−26	100					
8. Card Sorting	−18	−17	−24	−33	−25	−27	61	100				
9. Digit Symbol[f]	15	14	27	43	41	32	−57	−58	100			
10. Verbal Fluency	29	22	18	33	22	15	−32	−36	42	100		
11. Animal Naming	25	24	25	31	25	25	−38	−36	26	45	100	
12. Picture Naming[g]	−15	−09	−10	−21	−16	−06	36	26	−22	−23	−38	100

Note: $N = 132$; $r_{\alpha=0.5} = .17$.

[a] Buschke recall test (see Spreen & Strauss, 1991); average recall for trials 1 to 3

[b] RAVLT (see Spreen & Strauss, 1991); average recall for trials 1 to 5 on list A

[c] RAVLT (see Spreen & Strauss, 1991); delayed recall (trial 6) of list A

[d] RAVLT (see Spreen & Strauss, 1991); list B recall

[e] Cancel H (see Graf, Uttl, & Tuokko, 1995); in s per block

[f] Subtest from WAIS-R

[g] Picture–Word Stroop test (see Graf, Uttl, & Tuokko, 1995); picture naming speed in ms per item

TABLE 8

Results of Analysis with Three-Factor Unweighted Least-Squares Solution Followed by Oblique (Oblimin) Rotation on Performance of Prospective Tasks and of Various Other Cognitive Tests plus Correlations among Factors

	Factor[a]		
	1	2	3
1. Name task	−03	00	**88**
2. Letter task	08	04	**56**
3. Buschke 1–3[b]	−07	**78**	00
4. RAVLT A1–5[c]	02	**94**	02
5. RAVLT A6[d]	−04	**83**	09
6. RAVLT B1[e]	14	**46**	−07
7. Cancel H[f]	**−75**	−07	04
8. Card Sorting	**−81**	05	09
9. Digit Symbol[g]	**67**	14	−11
10. Verbal Fluency	**46**	02	19
11. Animal Naming	**45**	06	18
12. Picture Naming[h]	**−42**	04	−06
Correlations among factors			
Factor 1	100		
Factor 2	51	100	
Factor 3	36	20	100

[a] Only loadings printed in bold (>.30) are interpreted.
[b] Buschke recall test (see Spreen & Strauss, 1991); average recall for trials 1 to 3.
[c] RAVLT (see Spreen & Strauss, 1991); average recall for trials 1 to 5 on list A.
[d] RAVLT (see Spreen & Strauss, 1991); list A delayed recall (trial 6).
[e] RAVLT (see Spreen & Strauss, 1991); list B recall.
[f] Cancel H (see Graf, Uttl, & Tuokko, 1995); in seconds per block.
[g] Subtest from WAIS-R.
[h] Picture–word Stroop test (see Graf, Uttl, & Tuokko, 1995); in milliseconds per item.

because these components are likely to be influenced by different variables (e.g., the length of to-be-remembered list, attentional resources). For a specific illustration of this possibility, one of our recent studies (Graf & Uttl, 1999) showed that a study-test delay manipulation produced a decline in the ProM component but not in the RetM component. Conversely, the use of related versus unrelated to-be-remembered materials affected the RetM but not ProM component. We believe that the general method used in the present study for separating between the ProM and RetM components sets the stage for pursuing more fine-grained analysis of the different processes, strategies, and memory functions that determine performance on ProM tasks.

The findings from the present study are directly relevant to two related predictions derived from Craik's (1983, 1986) influential proposal about age-related changes in memory test performance. Craik assumed that aging is associated with a decline in the capacity for processing information and that the requirements for processing capacity are greater for ProM than RetM tests. Based on these assumptions, we expected larger age-related declines in ProM proper than in explicit episodic RetM. In addition, we expected to find a stronger relationship between processing capacity and ProM than between processing capacity and RetM. By contrast to these expectations, the results showed comparable age-related declines—measured by r^2 due to age—in ProM and RetM, and a factor analysis revealed a stronger (albeit not significantly stronger) correlation between the processing resource factor and the RetM factor, than between the processing resource factor and the ProM factor.

In fairness to Craik's (1983, 1986) proposals, we acknowledge that his predictions focused on prospective memory task performance rather than on ProM proper. Our factor analysis results would have been more favorable to his proposal if the analysis had focused on overall ProM task performance rather than on the ProM proper scores. We elected to use the ProM proper scores on the assumption that Craik's intention was to focus on the unique demands of prospective tasks and these are most directly indexed by ProM proper scores.

The finding of similar age-related declines in ProM and RetM permits several interpretations. One possibility is that this finding reflects the fact that our index of ProM proper was less reliable than that obtained from the standardized measures of RetM. However, this possibility seems ruled out, at least weakened, by the finding (summarized in Table 7) of similar intertask correlations. A second possibility builds on the observation that in previous research of RetM, age-related declines were often smaller when overall test performance was higher (e.g., recognition versus recall test performance), and by implication, a smaller age effect might have occurred in our study if ProM was higher than RetM performance. Evidence against this possibility is the finding that in the present study, performance was lower on the prospective name task (task score average ∼.60) than on the Buschke (∼.80), and yet, both tasks showed similar r^2 values due to age. Yet another possibility is that our findings are peculiar to the specific tasks used for assessing ProM and RetM. Finally, there is the possibility that Craik's proposal is wrong. Future research will address the latter two possibilities.

The finding of a similarly strong relationship between the processing resource and RetM factor, and the processing resource and ProM factor, raises questions about another aspect of Craik's (1983, 1986) proposal. Craik did not explicitly define processing resources, and for the purpose of the present study, we operationalized this construct in the manner that has often been used for other studies of age-related changes in cognition (e.g., Cerella, 1990; Graf & Uttl, 1995; Salthouse, 1996; Salthouse, Kausler, & Saults, 1988; Verhaeghen & Salthouse, 1997). However, there are other ways to operationalize processing resources, for example, as working memory capacity (e.g., Baddeley, 1986; Just & Carpenter, 1992), and they may yield results that are supportive of Craik's proposal.

Neuropschological investigations have emphasized the connection between prospective memory and frontal lobe functions (e.g., Burgess & Shallice, 1997; Glisky, 1996; McDaniel, Glisky, et al., 1999). In a related article (Graf & Uttl, 2001), we have argued that what is unique about ProM tasks is that they require noticing (becoming aware of) cues as telltale signs (of previously formed plans or intentions) when they occur as part of ongoing thoughts, actions, or situations. By this view, successful prospective remembering requires sharing resources between ongoing activities and ‘‘monitoring’’ the environment for telltale signs, and these cognitive functions implicate the frontal areas. An ongoing study (Jacova, Graf, & Uttl, 2000) examines the possibility that monitoring the environment for telltale signs is a type of divergent thinking (i.e., a frontal lobe function) and that age-related declines in this type of thinking can predict age differences in ProM proper.

A systematic search for and examination of processing components, as well as of task attributes, that might influence performance is required in order to illuminate the relationship between the present finding of an age-related decline in ProM proper and the mixed pattern of results obtained from previous investigations (for a review see Birt, 1999; Brandimonte, Einstein, & McDaniel, 1996). As a first step toward this goal, we recommend the use and development of research methods that permit direct assessment of ProM proper. We also endorse the recommendation by Einstein and McDaniel (1996) to subdivide ProM in a manner similar to that used for RetM research (i.e., short- and long-term memory). Concretely, Graf and Uttl (2001) proposed that such subdivisions of ProM might be made in terms of the different conscious experiences that are associated with different kinds of prospective activities. Future research will explore if differences in the resource demands of different processing tasks account for the complex pattern of findings in the literature.

REFERENCES

Baddeley, A. (1986). *Working memory.* Oxford, UK: Clarendon Press.

Birt, A. (1999, unpublished manuscript). Prospective memory and aging: An exploratory meta-analysis.

Brandimonte, M., Einstein, G. O., & McDaniels, M. A. (Eds.). (1996). *Prospective memory: Theory and applications.* Mahwah, NJ: Erlbaum.

Burgess, P. W., & Shallice, T. (1997). The relationship between prospective and retrospective memory: Neuropsychological evidence. In M. A. Conway (Ed.), *Cognitive models of memory* (pp. 247–272). Cambridge, MA: MIT Press.

Canadian Study of Health and Aging Working Group. (1994). Canadian study of health and aging: Study methods and prevalence of dementia. *Canadian Medical Association Journal,* **150,** 899–913.

Cerella, J. (1985). Information-processing rates in the elderly. *Psychological Bulletin,* **98,** 67–83.

Cerella, J. (1990). Aging and information processing rate. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (3rd ed., pp. 201–221). San Diego, CA: Academic Press.

Cerella, J., Poon, L. W., & Williams, D. M. (1980). Age and the complexity hypothesis. In L. W. Poon (Ed.), *Aging in the 1980s: Psychological issues* (pp. 332–340). Washington, DC: American Psychological Association.

Cerella, J., Rybash, J., Hoyer, W., & Commons, M. L. (Eds.). (1993). *Adult information processing: Limits on loss.* New York: Academic Press.

Coren, S., & Hakstian, A. R. (1988). Color vision screening without the use of technical equipment: Scale development and cross-validation. *Perception & Psychophysics,* **43,** 115–120.

Coren, S., & Hakstian, A. R. (1992). The development and cross validation of a self-report inventory to assess pure-tone threshold hearing sensitivity. *Journal of Speech and Hearing Research,* **35,** 921–928.

Craik, F. I. M. (1983). On the transfer of information from temporary to permanent memory. *Philosophical transactions of the Royal Society of London, Series B,* **302,** 341–359.

Craik, F. I. M. (1986). A functional account of age differences in memory. In F. Klix & H. Hagendorf

(Eds.), *Human memory and cognitive capabilities: Mechanisms and performances* (pp. 409–422). New York: Elsevier Science.

Diller, L., Ben-Yishay, Y., Gerstman, L., Goodkin, R., Gordon, W., & Weinberg, J. (1974). *Studies in cognition and rehabilitation in hemiplegia* (Rehabilitation Monograph No. 50). New York: New York University Medical Center Institute of Rehabilitation Medicine.

Dobbs, A. R., & Rule, B. G. (1987). Prospective memory and self-reports of memory abilities in older adults. *Canadian Journal of Psychology,* **41,** 209–222.

Einstein, G. O., & McDaniel, M. A. (1990). Normal aging and prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **16,** 717–726.

Einstein, G. O., & McDaniel, M. A. (1996). Retrieval processes in prospective memory: Theoretical approaches and some new empirical findings. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and application* (pp. 115–141). Mahwah, NJ: Erlbaum.

Einstein, G. O., Holland, L. J., McDaniel, M. A., & Guynn, M. J. (1992). Age-related deficits in prospective memory: The influence of task complexity. *Psychology and Aging,* **7,** 471–478.

Glisky, E. (1996). Prospective memory and frontal lobes. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and application* (pp. 249–266). Mahwah, NJ: Erlbaum.

Graf, P., & Uttl, B. (1995). Component processes of memory: Changes across the adult lifespan. *Swiss Journal of Psychology,* **54,** 113–130.

Graf, P., & Uttl, B. (2001). Prospective memory: A new focus for research. *Consciousness and Cognition,* doi:10.1006/ccog.2001.0504.

Graf, P., Uttl, B., & Tuokko, H. (1995). Color- and picture–word stroop tests: Performance changes in old age. *Journal of Clinical and Experimental Neuropsychology,* **17,** 390–415.

Harman, H. H. (1976) *Modern factor analysis.* Chicago: Univ. of Chicago Press.

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General,* **108,** 356–388.

Jacova, C., Graf, P., & Uttl, B. (July 2000). *Cognitive resources that enable event-based prospective remembering.* Poster presented at the 1st International Conference on Prospective Memory, Hertfordshire, UK.

James, W. (1890). *Principles of psychology.* New York: Holt.

Jorm, A. F. (1986). Controlled and automatic information processing in senile dementia: A review. *Psychological Medicine,* **16,** 77–88.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review,* **99,** 122–149.

Kausler, D. H. (1991). *Experimental psychology, cognition, and human aging.* New York: Springer-Verlag.

Kausler, D. H. (Ed.). (1994). *Learning and memory in normal aging.* San Diego, CA: Academic Press.

Kimura, D. (1961). Cerebral dominance and the perception of verbal stimuli. *Canadian Journal of Psychology,* **15,** 166–171.

Lezak, M. D. (1995). *Neuropsychological Assessment* (3rd ed.). New York: Oxford Univ. Press.

McDaniel, M. A., Glisky, E. L., Rubin, S. R., Guynn, M. J., & Routhieaux, B. C. (1999). Prospective memory: A neuropsychological study. *Neuropsychology,* **13,** 103–110.

Rabbitt, P. M. A. (1965). An age decrement in the ability to ignore irrelevant information. *Journal of Gerontology,* **20,** 233–238.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review,* **103,** 403–428.

Salthouse, T. A. (1985). *A theory of cognitive aging.* Amsterdam: North-Holland.

Salthouse, T. A. (1988). Resource-reduction interpretations of cognitive aging. *Developmental Reviews,* **8,** 238–272.

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

Salthouse, T. A. (1993). Speed and knowledge as determinants of adult age differences in verbal tasks. *Journals of Gerontology: Psychological Sciences,* **48,** 29–36.

Salthouse, T. A., Kausler, D. H., & Saults, J. S. (1988). Utilization of path-analytic procedures to investigate the role of processing resources in cognitive aging. *Psychology and Aging,* **3,** 29–37.

Spreen, O., & Strauss, E. (1991). *A compendium of neuropsychological test: Administration, norms, and commentary.* New York: Oxford Univ. Press.

Strub, R. L., & Black, F. W. (1981). *Organic brain syndromes.* Philadelphia: F. A. Davis.

Teng, E. L., & Chui, H. C. (1987). The Modified Mini-Mental State (3MS) Examination. *Journal of Clinical Psychiatry,* **48,** 314–318.

Tuokko, H., Kristjansson, B., & Miller, J. (1995). Neuropsychological detection of dementia: An overview of the neuropsychological components of the Canadian Study of Health and Aging. *Journal of Clinical and Experimental Neuropsychology,* **17,** 352–373.

Verhaeghen, P., & Salthouse, T. A. (1997). Meta-analyses of age-cognition relations in adulthood: Estimates of linear and nonlinear age effects and structural models. *Psychological Bulletin,* **122,** 231–249.

Received July 2, 1999; published online September 7, 2001