

Different Patterns of Prospective, Retrospective, and Working Memory Decline across Adulthood

Maria Alice de Mattos Pimenta Parente

Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil

Irene Meyer de Taussik

Universidad de Buenos Aires, Argentina

Eduardo Daura Ferreira

Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil

Christian Haag Kristensen

Universidade do Vale do Rio dos Sinos, São Leopoldo, Brazil

Abstract

Previous studies have compared young and old adults' performance on prospective memory tasks but little attention has been given to possible changes in middle-aged participants. This study was designed to compare changes in prospective memory (PM), retrospective memory (RM), and working memory (WM) across adulthood. Eighty-five Brazilian adults were subjected to word-spans, working memory, text recall and prospective verbal tests. Logistic regression analysis showed that decline probability in word-span tests differed in comparison to WM and PM tests, suggesting that difficulties in tasks that require executive functions are already present in both middle-aged adults and older adults, and underscoring the need to include middle-aged adults in the investigation of age-related memory decline.

Keywords: Aging; memory; cognitive impairment

Los Modelos Diferentes de Declive de la Memoria Prospectiva, Retrospectiva, y de Trabajo por la Madurez

Compendio

Este estudio fue diseñado para comparar los cambios en la memoria probable (PM) con los cambios en el retrospectivo (RM) y la memoria activa (WM) por la madurez. Se sometieron ochenta y cinco adultos brasileños a palabras-span, memoria activa de trabajo, llamada del texto y pruebas verbales prospectivas. Una regresión logística mostró la probabilidad de declive en pruebas del palabra-span comparada con WN y pruebas de PM. En las pruebas del palabra-span, el declive era más evidente después de la séptima década, considerando que en WM y la memoria de PM había un declive gradual, percibido como una queja de memoria en la madurez. Estos resultados sugieren que la dificultades en tareas que requieren las funciones ejecutivas ya presentes en adultos de mediana edad y los adultos más viejos y muestra la importancia de incluir los grupos de mediana edad en las investigaciones de envejecimiento cognoscitivas.

Palabras-clave: Memoria; memoria de trabajo.

Memory failures are often considered the first evidence of abnormal aging. As a result, more and more individuals going through adulthood are concerned about the possibility of early memory decline and cognitive deterioration, thus increasing the demand for neuropsychological assessment. Lack of references and normative studies about normal performance in middle aged adults poses a problem when administering neuropsychological assessment, since research has mainly worked with young university students and elderly populations.

Park et al. (1996) and Park (2000) have studied different measures of cognitive functions in an adult sample, ranging from ages 20 to 90. They described systematic decline in span tasks and free- and cued-recall tasks, as well as in processing speed but found no changes in semantic memory (vocabulary tasks). The authors conclude that age differences are not universal for all memory systems and that these appear more clearly in tasks that require a great deal of self-initiated processing. Although they characterized the decline as regular and generally linear, the curve of free- and cued-recall tasks, measuring retrospective long-term memory (RM), showed stabilization from the 6th to 8th decades.

Although adults, both middle-aged and older, often complain about memory difficulties, traditional neuropsychological memory tests hadn't been designed to evaluate core aspects of these complaints (Bennett-Levy & Powell, 1980). In an attempt to overcome this limitation, the concept of "everyday memory" has been incorporated to memory systems theory (Neisser, 1991), providing new ways of conducting neuropsychological assessment. In this sense, a great amount of attention has been given to a common daily living ability which consists on the capacity of mentally projecting oneself into the anticipated future through imagination, and which has been defined as prospective memory (PM; Wheeler, Stuss, & Tulving, 1997) and bears practical importance in its relation to everyday memory. Successful performance in everyday activities requires execution of actions of delayed intention at the right moment. Prospective remembering constitutes a common and important activity in daily life and enables independent living. Frequent activities include: (a) remembering to pay bills in time, (b) taking a medicine every 4 hours, or (c) making a phone call at an exact time. This is why PM is also known as memory of the future or memory of agenda, and has been acknowledged by several authors to be the aspect of memory that affects the ability to function adequately in daily life. PM is auto-initiated

¹ Address: Department of Psychology, UFRGS, Ramiro Barcelos, 2600, 90035-003, Porto Alegre, RS, Brazil. *E-mail:* malicemp@terra.com.br

and this is a main contrast with RM. The latter refers to the individual's ability to relive past experiences by thinking about previous situations, which include recognizing a familiar face, recalling the details of an accident, or retrieving the name of a city. Neisser (1991) observed that remembering describes at least two different temporal perspectives: *remembering what we have done*, which includes the events of the past and *remembering what we must do* which is related to future plans. Thus, PM is about the memory for projecting oneself into the future and thus it is related with future events and information.

According to Burgess and Shallice (1997) and to Burgess, Veitch, Costello, and Shallice (2000), the RM system is a prerequisite to PM operation. They propose that although remembering to perform future tasks may require the ability to recall past events and situations, the retrospective component only constitutes a small part of what is required. In this sense, correlation analysis was not significant in several studies that compared PM to RM (Einstein & McDaniel, 1990; Maylor, 1990; Meacham & Leiman, 1982). However laboratory studies have produced divergent results (Hicks, Marsh, & Russell, 2000) demonstrating that correspondence between RM and PM may be related to the nature of the task. Traditional regularities of retrospective forgetting observed in Ebbinghaus' (1885/1913) classical studies were reproduced by Meacham and Leiman when the retention interval was manipulated in naturalistic event-based prospective tasks, but only when the participant did not resort to using a reminder tag.

Considering a temporal perspective, it is possible to include one more mnemonic system differentiation, working memory (WM), which helps to hold information in on-line present activity. This perspective may suggest the existence of three independent memory stores: RM (recall of past events), WM (maintaining certain information in an ongoing activity) and PM (projecting information into the future).

Nevertheless, there is no clear opposition between PM and WM. Burgess and Shallice (1997) and Ellis (1996) proposed that PM is a complex system including retrospective components as well as WM resources. For Ellis there are four phases in PM. In the first phase of PM, intention of a specific action is formed and encoded. This phase corresponds to the retrospective component of PM. The second phase refers to the performance interval (i.e., the delay between encoding an intention and its retrieval and performance) and is believed to be the most important aspect of PM. This interval distinguishes PM from other complex cognitive processes, such as, problem solving, executive functions, and working memory. For this reason Burgess and Shallice, as well as Ellis, substituted the term PM for *the realization of delayed intentions*. The third phase corresponds to the initiation and execution of the

intention, which may demand the same mechanisms of WM and require divided attention. The fourth phase represents the cancellation of the intention.

Neuropsychological approaches show that both WM and PM are closely related to executive functions (Bisiacchi, 1996; Burgess & Shallice, 1997). Both PM and WM are involved with plan formulation and holding the information in one's mind while the plan is assembled, evaluated and implemented (Cohen, 1991; Kliegel, Martin, McDaniel, & Einstein, 2000). While WM involves on-line tasks and therefore has an important attentional resource, PM must include delayed intentions activation, due to the performance interval.

Experimental studies showed that older adults perform poorly on PM tasks (Mäntylä & Nilsson, 1997). Kidder, Park, Hertzog, and Morrell (1997) also observed that older adults performed more poorly than younger adults on PM tasks under higher prospective load in laboratory studies, but a reverse pattern was found in natural prospective experiments since reminding strategies are allowed. In general, naturalistic studies found a reverse pattern; i.e., a superior performance by older adults (for revision, see Rendell & Craik, 2000). The degree of age-related change depends on many factors, including the type of experiment (artificial laboratory, naturalistic laboratory, and naturalistic field), type of task (event- vs. time-based), age group, as well as other cognitive processes and emotional disorders that interfere with memory (Birt & Graf, 2000; Hicks et al., 2000; McDaniel & Einstein, 1993).

The type of task performed is a variable that can be selectively affected by age. One prospective task differentiation is related to the way the *to-be-remembered* information is activated. An event-based task has external cues that prompt remembering. For instance, *When you see Maria* (the external cue), *please give her this message*. A time-based task, in comparison, depends on internal cues, where the subject has to synchronize his or her internal time to the interval's delay, thus requiring self-initiated processes. For example, *In 15 minutes I must turn off the oven*. The third kind of prospective task, and quite frequent in daily life, are the repetitive tasks: *I must take this medicine every four hours*, which supposes the inhibition of the ongoing activity in order to carry out the action. McDaniel and Einstein (1993) found age differences in time-based tasks but not in event-based tasks, suggesting that the capacity of self-monitoring one's own action progressively decreases with age.

The aim of the present investigation was to study memory performance during adulthood using a PM task and to determine the existence of RM, WM, and PM decline. The main issue was to observe whether there was a particular PM decline or whether we could predict PM changes across adulthood on the basis of what we know about RM and/or WM changes. Moreover this study observed the performance on the three types of PM intentions related to event, time and repetitive tasks during aging.

Method

Participants

A total of 85 adults (53 women and 32 men) participated in this study. They were divided in three age groups. The first group consisted of 31 young adults with an age interval between 21 to 39 years of age ($M=22.81$; $SD=3.41$). The second group consisted 25 middle age adults ranging in age from 40 to 59 years ($M=50.32$; $SD=7.08$). The third group of participants (29 old adults) ranged in age from 60 to 81 years ($M=66.97$; $SD=5.76$). They were all tested individually, in a quiet place, at different community locations such as university, athletic, and religious sites in the city of Porto Alegre, Brazil. Inclusion criteria were as follows: (a) age = 20 years; (b) at least 8 years of formal education ($M=12.74$; $SD=2.86$); and (c) a Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975; Brazilian version by Chaves & Izquierdo, 1992) score = 27 ($M=28.37$; $SD=3.13$). Considering screening procedures participants were excluded if they presented a history of serious neurological or psychiatric disorders, alcohol abuse, use of centrally active drugs, or clinically relevant memory complaints.

Materials and Procedures

The assessment included a verbal memory battery designed for this study. In addition to verbal specificity, all tasks proposed a reading input activity. These consisted of:

1. Verbal span tests - which were used in order to assess general capacity of encoding verbal information. Participants read three different series of frequent words, which they were asked to recall randomly. The examiner recorded the number of words correctly recalled. The series were composed by: (a) phonological similarity words [candy (*bala*), bag (*mala*), living room (*sala*), etc.], (b) short two-syllable words [book (*livro*), house (*casa*), etc.] and (c) long words with four syllables or more [bird (*passarinho*), restaurant (*restaurante*), etc.].

2. Verbal working memory task - based on Daneman and Carpenter's paradigm (1980). A dual-task methodology proposed the simultaneous operation of reading several long sentences, while retaining in memory the last word of each sentence. Participants were presented with three series of sentences (beginning with two, three, four sentences, and so on) and were asked to recall the last word of those sentences in each series. Participants were scored on their ability to recall last words from the sentences in each trial.

3. Text comprehension task (logical memory) - a story about an odd episode that happened in the Andes was presented to the participants. This story consisted of 57 propositions, 29 classified as macro-propositions and 28 as details, according to Kintsch and Van Dijk's theory (1978). The subject was asked to recall the information in the text with the greatest number of details after reading it once. The percentage of recalled macropropositions and details were scored.

4. Prospective memory test - the paradigm used to collect the data in the present study proposed goal-directed activities comparable to those people performed in complex

environments (Kliegel, McDaniel, & Einstein 2001). Neuropsychological clinical practice has shown that simple PM tasks did not reflect the memory complaints of adults still engaged in their activities. Considering the multiplicity of demands in daily life, this study proposed a multi-intentional task. This included a cover task (representing the external demands) and several instructions referring to different intentions. The cover task required reading aloud a story about a certain bird and its characteristics making it a very low emotional content story. The story was composed of 15 sentences arranged into 8 paragraphs. Numbered parentheses were inserted with the following information *first instruction*, *second instruction*, and so on, written in bold letters. The subject was asked to interrupt the reading every time an instruction was found, and was asked to look up its content in a booklet located next to the text.

The instructions proposed eight different prospective self-initiated activities and one retrospective task. There were two single time-based PM tasks (e.g., *In five minutes, please write your birthday date and I will give this card to you; in 15 minutes interrupt your work and return it to me*). There were also four event-based tasks: (a) *Place a personal object somewhere in the room and do not forget to take it with you when you leave*; (b) *When you read the expression 'protected areas' (áreas protegidas), write your name at the top of this sheet of paper*; and (c) *When you finish answering the following questions, please write your name and the time you finished this task*. The fourth event-based instruction contained both a retrospective and a prospective task: *Please try to memorize the number 2479. When I ask you to recall it, please ask me if I have a message for you*. Two other event-based tasks proposed repetitive prospective tasks: (a) *Underline the word parrot (papagaio) each time you read it in the text*; or (b) *Draw a cross every time you finish reading a paragraph*.

For each correctly completed task, the subject received one point; otherwise the score was zero. In the case of the time tasks, the subject received one point if the correct action was completed within the amount of time allocated. In the case of repetitive tasks, the maximum score was 2; for single time-based tasks the score was 2; 4 was the score for the event-based tasks; and 1 was the score for the retrospective component of the prospective task.

All participants were also submitted to a Portuguese adaptation of the Yesavage Depression Scale (Yesavage, 1986) and an adaptation of the Stroop test (Stroop, 1935). In this adaptation, the participants read three lists of words, or letter sequences, for 45 seconds each. In the first task, the participants were asked to read a list with the names of four different colors printed in black ink. In the second task, they were asked to say the name of the color of different sequences of the letter "X" (printed in four different colors). Finally, in the third task, they were asked to say the color in which the word (names of four different colors) was printed (for instance, the word *red* was printed in blue ink therefore they had to say blue, which was the interference task). Scores were given to the total of colors correctly identified in 45 seconds.

Analysis

A first analysis compared the performance of young adults, middle-aged adults and older ones, and a second analyses detected curve patterns and the probability of memory decline through a logistic regression analysis. Logistic regression and log linear models have a major advantage in modeling the probability of memory decline, avoiding problems of ceiling and floor effects (Kombrot, 2000). Ordinary regression finds a function that relates continuous outcome variables, such as age, to one or more predictors. It produces a formula that predicts the probability of occurrence as a function of the independent variables. Logistic regression produces odds ratios (OR) associated with each predictor value. The odds of an event are defined as the probability of the occurrence of the outcome event divided by the probability of the event not occurring. The odds ratio for a predictor tells the relative amount by which the odds of and outcome increase or decrease and allows for the construction of a curve that relates performance to age.

Results

As stated before, two separate analyses were conducted. Thus, the results first describe the relationships between the three age groups. Due to assumptive violations of variance normality and homogeneity, comparisons between raw scores for each group were obtained through non-parametric tests. Then, the probability of memory decline was addressed through logistic regression analysis. In order to perform this analysis, raw scores were transformed into binary scores.

Comparison between Groups

Mean scores for each of the three groups are shown in Table 1. In all tests the young group showed better scores than the middle age group. The older participants obtained lower

scores than the younger. On the verbal span test, better scores were obtained for the long words trial than for phonological similar words and short two-syllable words trials in all groups.

Group differences were tested using non-parametric Kruskal-Wallis test. Regarding the verbal span test, differences were found only in the short word repetitions, $H = 7.80, p < .05$. The scores of middle-aged adults were significantly higher than those of the older adults, $H = 4.14, p < .05$, but no differences were found between young and middle-aged adults in this task. The WM test showed highly significant differences between the three groups, $H = 20.31, p < .001$. Differences appeared in early ages: young adults' performance was significantly higher than middle age adults' performance, $H = 9.92, p < .01$, but no differences were found between middle age and old adults, $H = 1.24, p > .05$.

Statistical analyses of the PM test scores revealed significance for event-based prospective tasks, $H = 21.60, p < .001$, time-based prospective tasks, $H = 7.33, p < .05$, and the retrospective component of the event prospective task, $H = 9.01, p < .05$. In all three tasks, young adults had higher performances than older adults, as follows: event prospective tasks, $H = 21.23, p < .001$, time prospective tasks, $H = 6.86, p < .01$, and the retrospective component of the event prospective task, $H = 7.90, p < .01$. The performance in the event prospective tasks decreased monotonically from the young to the older adults. The young group scores differed significantly from those of the middle age group, $H = 6.13, p < .05$, and significant differences were also found when comparing the middle age group and the oldest group, $H = 3.69, p < .05$. No age differences were found in event repetitive tasks. Global scores of the PM test decreased significantly with age, $H = 20.54, p < .001$: young adults' scores were higher than middle age group scores, $H = 6.60, p < .01$, and the latter showed a mild superiority in relation to the old adults' scores, $H = 3.71, p < .05$.

Table 1
Mean Memory Tasks Scores of Age Groups

Tasks	Young		Middle Age		Old	
	M	SD	M	SD	M	SD
Verbal span						
Phonological similarity	5.61 ^a	0.92	5.40 ^a	1.15	5.10 ^a	1.18
Short words	6.00 ^a	1.00	5.84 ^a	1.18	5.21 ^b	1.15
Long words	5.06 ^a	1.15	4.72 ^a	0.98	4.34 ^a	1.11
Verbal working memory	3.10 ^a	1.16	2.12 ^b	0.97	1.79 ^b	0.82
Text comprehension						
Macropropositions	12.37 ^a	6.69	10.48 ^a	4.50	10.07 ^a	5.50
Details	8.32 ^a	4.24	7.24 ^a	2.79	5.96 ^a	3.24
Prospective memory						
Event-based	2.61 ^a	0.98	1.88 ^b	1.05	1.31 ^c	0.76
Time-based	1.39 ^a	0.96	1.08 ^a	0.70	1.13 ^b	0.74
Repetitive	1.26 ^a	0.81	1.08 ^a	0.81	0.86 ^a	0.92
Retrospective	0.90 ^a	0.30	1.76 ^a	0.40	1.07 ^b	0.85
Total PM tasks	6.16 ^a	1.16	4.80 ^b	1.98	3.66 ^c	1.91

Note. PM = prospective memory. Means in the same row that do not share subscripts differ at $p < .05$ in the Kruskal-Wallis significant difference comparison.

Table 2
Probability of Decrement over Time in Memory Tasks

Tasks	Decrease (years)	Odds Ratio (%)
Verbal span		
Phonological similarity	5	15
	10	33
Short words	5	19
	10	42
Verbal working memory	5	29
	10	65
Prospective memory		
Time-based	5	17
	10	38
Event-based	5	31
	10	71
Retrospective	5	30
	10	69
Total PM tasks	5	28
	10	65

Note. PM = prospective memory.

In sum, age differences were found in several memory measures: short term memory repetition, WM, global scores of the PM test as well in the prospective event and time tasks and in the retrospective component of the event task. All these measures showed significantly higher performance of the young when compared with the older adults. Nevertheless, three different patterns were found in the groups. The first one, normally described in the literature, contrasted exclusively young and old adults. This was the case of the short words repetition, prospective time-based tasks and the retrospective component of the event task. The second pattern showed an earlier difference among young and middle age adults, but no differences among the latter and the old participants. This pattern occurred in the verbal WM test. The third pattern contrasted the three groups: young adults attained better scores than middle-aged adults who were significantly better than the oldest participants. This pattern suggests a sharp decline during aging and was shown in the global scores of the prospective test and when the prospective event tasks were separately analyzed.

Probability of Memory Decline During Aging

In order to establish a curve decline logistic regressions analyses were conducted. All test scores were transformed into a binary scale according to a frequency table, with a cut-off nearest to 50%. There was a mild association between age and the score in the Yesavage depression scale, $-2log = 4.67$, $p < .05$, younger adults showed a higher depression score than the older ones. Nevertheless, the Chi-square tests for independency showed that this score was independent of all scores of memory tasks. No correlation was found between Stroop test and age and with different memory tasks of this study.

There was a mild association between age and word span, measured with short words, $-2log=5.55$, $p < .05$, and phonologically similar words, $-2log=4.24$, $p < .05$, and a strong

age association with WM, $-2log=16.75$, $p < .001$, and PM task, $-2log = 16.78$, $p < .001$. No age association was found with long word span or with logical memory. The odds ratio analysis showed that the probabilities of change for a decrement are more marked for WM and for PM, especially for the longer periods of 10 years (Table 2). No age differences were found on repetitive tasks.

Figure 1 is a prediction plot showing the probability of performance considering the global scores of different tasks through adulthood, in a range between 20 and 81 years. Comparing span tasks with WM and PM tasks, there is a clear difference in the probability of success. As expected, span tasks are better performed than WM and PM in all ages. Moreover, the curves' decline shows different patterns: for the span tasks, the decline is sharper after the sixth decade whereas WM and PM decline is evident after the third decade. Therefore, marked differences on the decline occur in the middle aged only for WM and PM.

Analyses of each task showed that only three PM tests were affected by age. The first resulted from the retrospective task: *What was the number I had asked you to remember?* ($\chi^2 = 12.86$, $p < .001$); the second, the event-based task: *When you read the expression 'protected areas' please write your name* ($\chi^2 = 19.21$, $p < .001$); and the third, the time-based task: *I will give this card to you; in 15 minutes please interrupt your work and return it to me* ($\chi^2 = 7.71$, $p < .01$). The odds ratio analysis showed that the probabilities of change for a decrement were less marked for time-based tasks than for the other tasks (Figure 2), and the curve's decline for the prospective tasks were similar to the curves of the global tasks scores: the decrement of the retrospective task is more important only on later ages whereas a linear decline is shown on event and time prospective tasks.

Regression analysis by stepwise selection procedure showed that, having a probability level of 72.3%, the best predictor for PM is WM, $\chi^2 = 11.76$, $p < .001$, and long words span, $\chi^2 = 6.05$, $p < .05$.

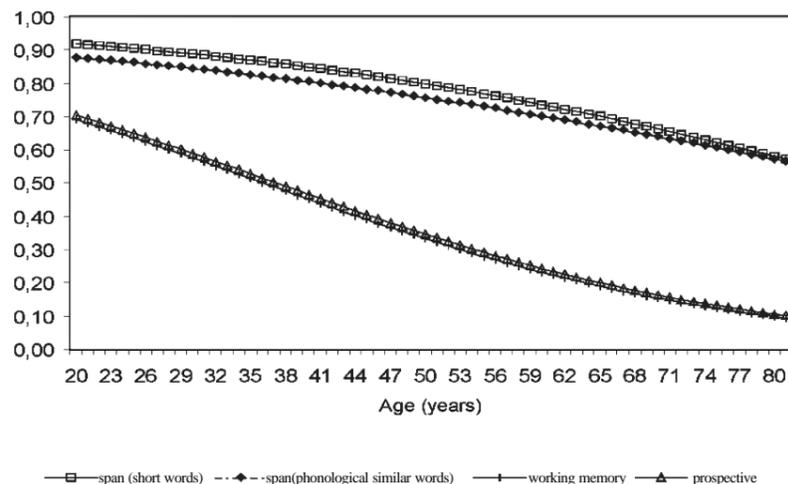


Figure 1. Probability of performance in the global scores of word span tasks, working memory, and prospective memory in adults ranging from ages 20 to 81

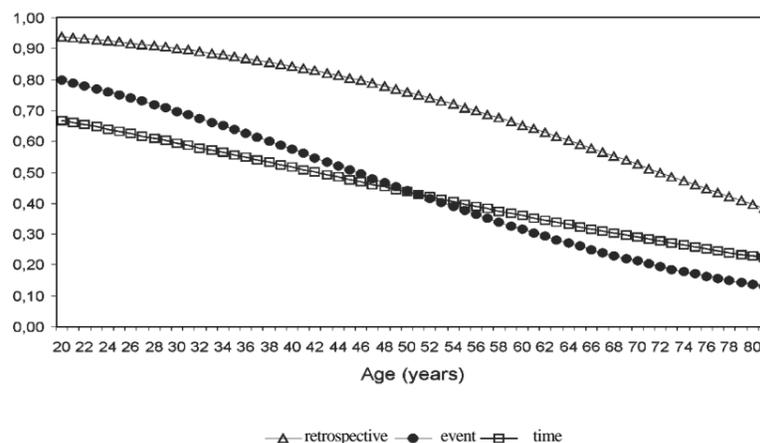


Figure 2. Probability of performance in retrospective, event and time memory tasks in adults ranging from ages 20 to 81

Discussion

Results have shown an age effect on almost all memory tasks except for story recall. The lack of differences in recalling propositions of a story was described in several previous works and they are in accordance with the concept that recalling stories implies, besides memory resources, other cognitive processes, like problem solving and schema formation, among others (for a review see Cohen, 1998). This evidence supports the assertion that the ability to remember meaningful information remains intact (Cohen & Faulkner, 1984) and is in accordance with Park's (2000) and Park's et al. (1996) results, where a decline curve for all memory tasks but vocabulary was found.

Our results provided compelling evidence of distinct patterns of memory decline. Group comparisons showed two different patterns: decline occurring during middle age and those occurring only on more advanced ages. Regression analyses confirmed these facts, showing that different tasks presented different age curves.

Clearly we cannot predict PM changes across adulthood on the basis of what we know about RM changes. Two facts confirm this dissociation: (a) retrospective recall decline appears only after the seventh decade whereas a clear decline of prospective recall, as well of WM tasks were found in middle-aged adults; and (b) performance on event- and time-based tasks were consistently worse than on the retrospective tasks. Thus, compared with long-term memories, minor predictions of age differences were found in short-term memories since difficulties occurred only among older subjects.

There seem to be different reasons for prospective failures during adulthood. Studies developed in Latin America should consider the cultural aspects. It is well documented that cognitive aging is primarily and strongly influenced by education which has a direct impact on health care quality (Teri, McCurry, & Logsdon, 1997; Huppert, Johnson & Nickon, 2000). In this study, demographic characteristics were taken into account by selecting participants with high-levels of education. Nevertheless, we cannot rule out possibilities of bias with sample group.

There are also cognitive aspects that explain vulnerability of PM memory shown in this study. According to Woodruff-Pak (1997), the existence of short term memory difficulties may suggest failures in the encoding process in older subjects. Therefore, we cannot discard the possibility that encoding failures may have increased the difficulties in these subjects in other memory processes. Among the older people, short-term memory difficulties may be contributing with failures in the initial phase during encoding and planning intention affecting the complex task performance. Studies that have found smaller age effects in recognition rather than in recall of words in short-term memory tasks have pointed that although an encoding problem may exist among the elderly, diminished proficiency in the search process may also be acting in other types of memories (Woodruff-Pak, 1997). Further studies should consider including recognition tasks in order to clarify the role of encoding and retrieval in PM processing.

On the other hand, dissociations between performance of middle-aged subjects in word span, with regard to WM and PM, shows that intact RM is apparently necessary although not a sufficient pre-requisite for good performance on WM and PM tasks. PM not only has a RM component, but also involves elements of WM, initiation, temporal sequencing, attention, and supervision system. This multi-dimensionality of PM had an influence on the prediction of decline in the middle-aged group.

The curves indicate that PM and WM performance decreased substantially with age, predicting a significant decrease in middle-aged subjects. This result contrasts with earlier work that concluded that PM performance started to decline only in those participants in their 7th decade (Kvavilashvili, Kornbrot, Mash, Cockburn, & Milne, 2000). In Mäntylä and Nilsson's study (1997), the decline from 50 to 65-70 years was marginal, with the accelerated decline starting only after 75. Nevertheless, our results are in accordance with the linear effect of age described by Huppert et al. (2000) and these results were also obtained among Argentinian subjects responding to the Spanish version of the test (Tausik, Parente, Figueiroa, & Allegri, 2003).

It should be noted that the task proposed in our study drew heavily upon a complex activity that required reading a text, and following instructions in order to reproduce complex environmental situations similar to those occurring in everyday life. Besides the goal-directed activities, the subjects needed to guide their attention to several concurrent cognitive processing.

The strong association between WM and PM raises the possibility of the existence of a similar underlying process. Participants with higher WM capacity performed better on the cognitively demanding PM tasks, regardless of age. Therefore, both components of working memory – attention and executive functions – should be considered. Restricted attentional capacity could be greater in aging subjects (Roger, 2000). Nevertheless, this study did not show correlation between Stroop test, age and PM tasks. Thus, there is a lack of indication that these difficulties are due to inhibition. Further

investigations should verify the relation between other attentional processes and different measures of PM.

A related hypothesis is that executive functions play a critical role in the performance of PM tasks proposed in this study. Tasks which showed a higher age influence were those with greater interval: therefore more interference is produced as a consequence of the concurrent activities or as a result of the high cognitive demand resulting from the task in itself. In order to perform these tasks, the initial phase of planning and encoding plays a fundamental role. In Kliegel et al.'s study (2001), planning resulted as the strongest executive predictor for the intention formation phase, providing empirical evidence that planning is related to PM performance and constitutes the cognitive process underlying intention.

Reduced time overlapping in this semi-naturalistic situation (approximately 30 minutes) made this task resemble a complex problem resolution situation: participants were engaged in reading the story aloud (the cover task) and perhaps distracted with some interesting information in the text while several prospective intentions had to be encoded and the adequate strategies had to be selected. In other words, the executive functions had to be adequately directed in order to coordinate several activities. In this way, we may interpret that PM tasks imposed a higher load on WM, and thus the realization of the delayed intention into action may have relied more heavily on executive functions.

Conclusions

Results in this study illustrate the multi-dimensional nature of memory decline. Both WM and PM tasks proposed in this study demanded a great amount of cognitive resources, therefore showing a sharp decline after the third decade and predicting difficulties in middle-aged subjects. The decline of RM and word-span tasks, in comparison, appears only after the 7th decade. The simple dissociation found in middle-aged subjects is in accordance to theoretical models that consider RM as one component of PM.

Models of higher level cognitive resources explaining age differences are supported by the present study, but the curve decline demonstrates that the overload of cognitive resources are linearly related to chronological age. The strong association between WM and PM tasks suggests that both middle-aged and older adult's difficulties are linked to the complexity of the tasks, requiring organization, planning and attention resources. Encoding failures in older adult's performance should be further investigated.

Memory decline in young adults has been neglected in aging studies despite the growing need for clinical recommendations about memory complaints in this population. Future research should consider detecting types of memory failures among middle-aged and older adults, proposing longitudinal studies when there is evidence of vulnerability in the neuropsychological assessment of possible cognitive decline, and promote early interventions when necessary. PM tasks proved to be sensitive to early decline. Being a self-initiated

process, PM is vulnerable to aging and should be included in adults' neuropsychological assessment. Detection of early cognitive markers in the prediction of progressive decline is essential in neuropsychological research. Finally, it would also be interesting to verify if those strategies developed during adulthood are still available and used by the older population to compensate for the reduction in the processing requirements in real life memory.

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Maria Alice de Mattos Pimenta Parente. Universidade Federal do Rio Grande do Sul, Brazil
Irene Meyer de Taussik. Universidad de Buenos Aires, Argentina
Eduardo Daura Ferreira. Universidade Federal do Rio Grande do Sul, Brazil
Christian Haag Kristensen. Universidade do Vale do Rio dos Sinos, Brazil