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Age-related differences in updating working memory

Martial Van der Linden*†, Serge Brédart* and **Annick Beerten**
Cognitive Neuropsychology Unit (NECO), University of Louvain, Belgium

Age-related differences in updating working memory were investigated in two experiments using a running memory task. In the first experiment, the task of the young and elderly subjects was to watch strings of four to 10 consonants and then to recall serially the four most recent items. Results revealed no age effect. A second experiment was then carried out using a memory load that was close to memory span: lists of six to 12 consonants were presented and subjects had to recall the last six items. Age interacted with list length but not with serial position. This dissociation is discussed in terms of Baddeley's (1986) model.

Several authors have suggested that many of the age-related differences in cognitive performance are the consequence of a decline in the effectiveness of working memory (see Salthouse, 1990, 1991 for a review). Working memory refers to a limited capacity system which is responsible for the processing and temporary storage of information while cognitive tasks are performed.

Baddeley's model represents the most extensively investigated theoretical account of working memory (Baddeley, 1986, 1992; Baddeley & Hitch, 1974). This model comprises a modality-free controlling central executive which is aided by a number of subsidiary slave systems ensuring temporary maintenance of information. Two such systems have been more deeply explored: the phonological loop and the visuospatial sketchpad. The visuospatial sketchpad system is assumed to be involved in setting up and maintaining visuospatial images. The articulatory loop system is specialized for processing verbal material and is composed of two subsystems: a phonological store and an articulatory rehearsal process.

The core of the working memory model is the central executive. The central executive is assumed to be an attentional control system responsible for strategy selection and for control and coordination of the various processes involved in short-term storage and more general processing tasks. An important characteristic of this system is that its resources are limited and divided into different processing and storage functions.

Convincing evidence for the existence of the different components included in the working memory model comes from the study of brain-damaged patients with short-term memory impairments. Some patients showing a deficit of auditory short-term memory that was attributed either to a selective impairment of the phonological store

* Now at the University of Liège.
† Requests for reprints should be addressed to Martial Van der Linden, University of Liège, Neuropsychology Unit (B-18), 13-4000 Liège, Belgium.

(Vallar & Baddeley, 1984) or to a disturbance of the articulatory rehearsal process (Belleville, Peretz & Arguin, 1992) have been reported. Other patients showing a specific impairment of the visuospatial sketchpad (Hanley, Young & Pearson, 1991) and of the central executive (Van der Linden, Coyette & Seron, 1992) have been described. Other data show that the central executive is particularly sensitive to the effects of Alzheimer's disease (Baddeley, Bressi, Della Sala, Logie & Spinnler, 1991; Baddeley, Logie, Bressi, Della Sala & Spinnler, 1986; Morris & Baddeley, 1988).

A number of studies have also reported that some aspects of working memory might be particularly sensitive to the effect of age (for a review see Salthouse, 1991; Van der Linden, 1993). In fact, elderly subjects seem to be relatively unimpaired in tasks that call for passive storage of a small amount of material. On the other hand, age differences are more important in tasks that require subjects to carry out processing while simultaneously storing information. These findings suggest that ageing is characterized by a decline in the capacity of the central executive (Baddeley, 1986) while the automatic processes (in particular operations by the phonological loop) remain intact. However, age might principally affect the flexibility and the processing abilities of the central executive rather than simply capacity (Craik, Morris & Gick, 1990).

Finding a working memory task in which the role of the central executive can be clearly distinguished from that of slave systems is a major difficulty in studying age effects on working memory. In a recent study, Morris & Jones (1990) showed that the running memory paradigm initially used by Pollack, Johnson & Knaft (1959) meets this requirement. The task requires subjects to watch strings of consonants whose length is unknown to them, and then to recall serially a specific number of recent items. The running span task requires considerable flexibility of information processing and a progressive shift of attention, i.e. discarding some items while new ones are registered.

Morris & Jones (1990) showed that the running memory task requires two independent mechanisms: the phonological loop and the central executive. The updating process requires central executive resources but not the phonological loop. Conversely, the serial recall component of the task requires the phonological loop but not the central executive. Indeed, these authors showed that irrelevant speech and articulatory suppression affect the serial recall aspect of the running task independently of the number of updates that had to be made in young adults. Moreover, updating affects performance independently of the effects of irrelevant speech and articulatory suppression. These results were obtained when subjects' task was to recall either the last four items presented or the last six items (i.e. when the memory load was close to, or beyond the span of subjects). Finally, although the updating process disrupts performance, the number of updates does not seem to be important, at least in young subjects and within the range of list lengths explored in those studies. Morris & Jones concluded that 'the executive can either perform several updates in rapid sequences without overloading its capacity or it has a very rapid "recovery" rate when performing such operations' (p. 117).

The aim of the present study was to investigate whether ageing affects on-line updating performance and serial recall performance equally or differently. A running memory task similar to that used by Morris & Jones (1990) was performed by young and older adults. In the first experiment, subjects were presented with lists of four, six, eight and 10 consonants and were asked to recall the four most recent items. In a second experiment, the subjects' task was to recall the six last presented items (a memory load closer to the memory span) and lists of six, eight, 10 and 12 consonants were presented.

EXPERIMENT 1

Method

Subjects

Subjects were 18 young and 18 elderly adults. Young subjects (eight males and 10 females) were students from Louvain-la-Neuve University. They were aged between 19 and 27 (mean age = 22.3) with 15.3 years of education on average (SD = 1.5) and a mean score on the Mill Hill Vocabulary Test (French language version of the multiple choice synonym subtest, Gérard, 1983) of 28.5. The elderly subjects (eight males and 10 females) were recruited from the Senior University: they were healthy people living in the community, aged between 60 and 75 years (mean = 65.8) with 14.7 years of education on average (SD = 2.1). The mean Mill Hill score was 30.7. The vocabulary scores of the elderly were significantly higher than those of the students ($t(34) = -2.06$, $p = .05$) but the level of education was not significantly different across the two samples ($t(34) = .994$).

Materials

A total of 24 random lists of consonants were constructed. Lists of four, six, eight and 10 consonants were used. No consonant was repeated in the same list and sequences sounding like words and abbreviations were avoided. The first eight trials were used as practice trials and were not included in the following analyses. Experimental trials comprised four trials for each list length.

Procedure

The consonants were printed in black on white cards and were presented at a rate of one item per second. The various lists were presented in a standard randomized order with the restriction that no more than two lists of the same length were presented successively. The subjects were asked to recall serially the last four items: strict forward serial recall was required (i.e. subjects had to report serial position 1 before 2, etc.) and subjects were asked to guess any letter they could not recall before making the next response. Before starting the experiment, subjects were warned that they would be presented with lists of four, six, eight and 10 consonants and that these lists would be given in a random order. However, they were not informed of the length of each list before presentation.

Results

The number of correct recalls for each list length and for each serial position (maximum score = 4 for each serial position) was the dependent measure. A three-way 2 (age) × 4 (list length) × 4 (serial position) ANOVA, taking age as a between-subject factor and list length and serial position as within-subject factors, was carried out on these scores.

The analysis revealed main effects of list length ($F(3, 102) = 18.59$, $p < .0001$) and serial position ($F(3, 102) = 22.09$, $p < .0001$) but there was no significant effect of age ($F(1, 34) = 2.507$; $p = .098$). The two significant main effects were qualified by a 'list length × serial position' interaction ($F(9, 306) = 2.21, p < .05$) but there were no significant interactions of list length and serial position with age (both $Fs < 1$) and no higher order interaction ($F < 1$).

An analysis of the effect of serial position for each list length (using Newman–Keuls' test at $p < .05$ level) revealed: (*a*) no effect of serial position for list lengths four and six; (*b*) higher scores for serial position 4 than for positions 1 and 2 for list length eight and for list length 10 (see Fig. 1).

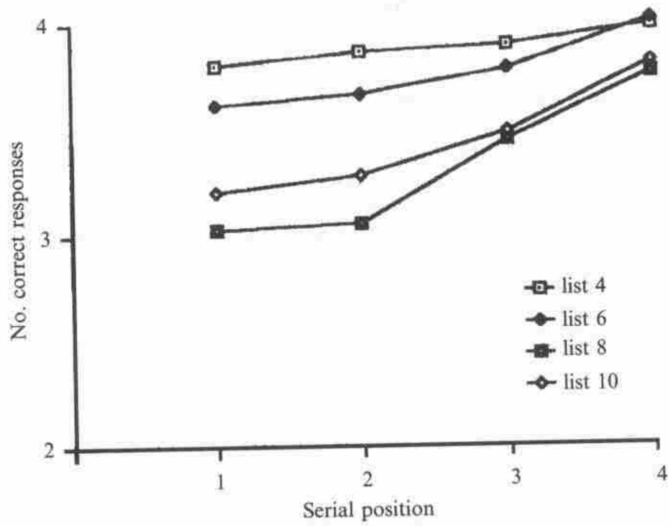

Figure 1. Mean number of correctly recalled items (max. = 4) as a function of list length and serial position.

Discussion

Experiment 1 showed that when the memory load is low (only four items) elderly subjects performed as well as young subjects. Furthermore, the disruptive effects of the updating process were relatively slight in both age groups. The data showed no evidence for disruptive effects for list lengths four and six. The updating process disrupted performance at positions 1 and 2 for list lengths eight and 10.

The use of a sub-span memory load, which makes few demands on central executive resources, presumably explains why no age difference was obtained. According to Baddeley (1986; see also Vallar & Papagno, 1986), the verbal serial recall depends on both the phonological loop system and the central executive. The phonological loop system is able to store only a limited number of items in the correct order but the central executive may increase this number either by improving the working of the phonological loop (for example, by grouping items in higher level units) or even by using its own storage capacity. It is plausible that holding a four-item memory load is not dependent enough upon central executive resources to show an effect of concurrent updating. The second experiment was carried out to investigate this point further by using a higher memory load.

EXPERIMENT 2

Method

Subjects

Subjects were 18 young and 18 elderly adults from the same pool of volunteers as in the previous experiment. None of these subjects had taken part in the previous experiment. Young subjects (11 male and seven female) were aged between 18 and 30 (mean = 22.8). The mean level of education was 15.0 years (SD = 3.4) and the mean Mill Hill score was 26.4. Elderly subjects (10 male and eight female) were aged between 59 and 72 (mean = 65.4). The mean Mill Hill score was 29.8 and the mean level of education was 14.3 years (SD = 1.97). The older subjects scored significantly higher on the vocabulary test ($t(34) = -3.45$, $p < .01$) but the level of education did not differ significantly across the two age groups ($t(34) = 1.047$).

Materials and procedure

The procedure and the type of materials were the same as those used in the previous experiment. Lists of six, eight, 10 and 12 consonants were presented and subjects were asked to recall the last six items.

Results

A three-way 2 (age) × 4 (list length) × 6 (serial position) ANOVA was performed on the mean number of correctly recalled items for each list length and each serial position (maximum score = 4 for each serial position). The analysis showed main effects of age($F(1, 34) = 32.65$, $p < .0001$), list length ($F(3, 102) = 28.99$, $p < .0001$) and serial position ($F(5, 170) = 26.99$, $p < .0001$). An 'age × list length' interaction ($F(3, 102) = 3.13$, $p < .05$; see Fig. 2) and a 'list length × serial position' interaction ($F(15, 510) = 5.19$, $p < .0001$) were obtained but the analysis showed no 'age × serial position' interaction ($F < 1$; see Fig. 3) and no higher-order interaction ($F < 1$).

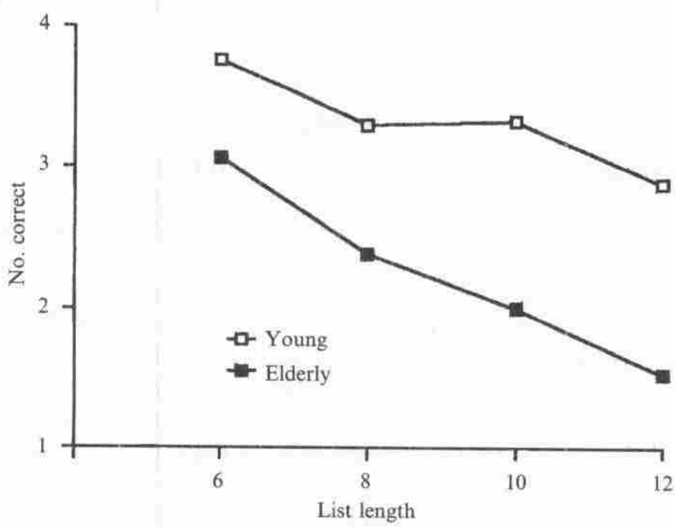

Figure 2. Mean number of correctly recalled items (max. = 4) as a function of age and list length.

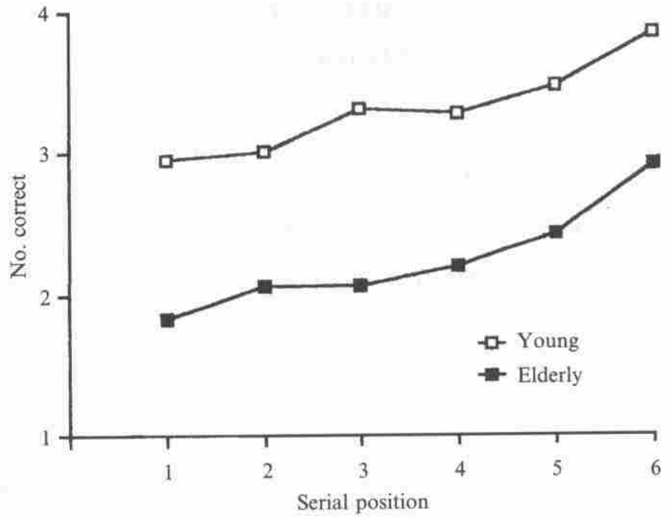

Figure 3. Mean number of correctly recalled items (max. = 4) as a function of age and serial position.

Analysis of the 'age × list length' interaction using Newman–Keuls' tests ($p < .05$) revealed: (*a*) no list length effect for young subjects; (*b*) higher scores at list length six than at list length 12 for elderly subjects; (*c*) better performance of young subjects than of elderly subjects at list length 12 but not at list lengths six, eight and 10.

Analysis of the effect of serial position for each list length showed the following pattern: (*a*) no effect of position for list length six; (*b*) higher scores at position 6 than at positions 1, 2 and 3 for list length eight; (*c*) higher scores at position 6 than at positions 1 and 2 for list length 10; and (*d*) higher scores at positions 4, 5 and 6 than at positions 1 and 2, higher scores at position 6 than at positions 3 and 4 for list length 12. No other significant difference emerged.

Discussion

Experiment 2 revealed age-related decrements in a running memory task with a memory load of six items. The running memory task requires both the phonological loop and the central executive. Morris & Jones (1990) argued that one aspect of this task (the updating process) requires central executive resources but not the phonological loop, while the other aspect of the task (the serial recall) requires the phonological loop but not the central executive. Data from Expt 2 show that the effect of ageing on the updating component and on the serial recall component of the running memory tasks may be dissociated: age interacted with the number of required updating operations but not with serial position. The absence of 'age × serial position' interaction suggests that a reduced storage capacity does not explain why elderly subjects showed weaker performance than young subjects at the running memory task. Data show that when no updating is necessary (list length six), older subjects' performance was similar to young subjects' performance. The more numerous the required updating operations, the more the older subjects' performance dropped. If Morris & Jones' (1990) hypothesis that the updating processes of the running memory task are ensured by the central executive is correct, then the present data support the idea that older subjects have decreased central executive resources: holding a memory load close to, or beyond, the memory span while carrying out on-line updating exceeded the processing capacities of the elderly subjects' central executive.

General discussion

The present study supports the hypothesis that older subjects have decreased central executive resources. Moreover, the processing functions of the central executive rather than its storage capacity seem to be particularly affected by this resource reduction. Finally, the deficit in the elderly seems to be restricted to one aspect of the central executive: processing resources. When sufficient resources are available, the updating processes that are the responsibility of the central executive seem to operate normally. We do not intend to overgeneralize these conclusions. Indeed, Parkinson (1980) has also used a running memory task in which young and elderly subjects were presented with lists of five, 10 and 15 digits and were asked to recall serially the last five items presented. Age and serial position interacted in Parkinson's study. The occurrence of such an interaction suggested that elderly subjects' storage capacities were impaired. However, it is worth noting that elderly subjects who participated in Parkinson's study were somewhat older ($M = 73.6$ years) than our older subjects ($M = 65.4$ years). Moreover, Parkinson provided no information about the education level or intelligence level of his subjects. It might be that the discrepancy between the two studies is due to the fact that the samples of elderly subjects were too different as far as age, intelligence and education variables are concerned. An effect of intelligence efficiency on scores in memory span tasks and primary memory tasks has been reported earlier (Delbecq-Derouesné & Beauvois, 1989; Goward & Rabbitt, 1988). More recently, Morris & Lamb (in press) did not report any age-related deficit in an updating task which required the recall of the last six items, but elderly subjects who participated in this study were somewhat younger than our subjects. The reasons for these discrepancies are not totally clear. Conducting a larger scale study that would involve several combinations of subjects, materials and conditions seems to be the only way to determine which factors induce a storage and/or a processing deficit.

In the present study, the size of the memory load was not manipulated as a within-subjects variable. A pilot study in which subjects were presented with both the task used in Expt 1 and the task used in Expt 2 has been carried out. This study showed that elderly subjects' performance was extremely poor in the second task whenever this task required the recall of four or six items. This result may be attributed to factors that were not investigated in our study, e.g. fatigue, stress or even the tediousness of the task.

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