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Age and synchrony effects in visuospatial working memory

Gillian Rowe [a]; Lynn Hasher [ab]; Josée Turcotte [c]
[a] University of Toronto, Toronto, Ontario, Canada [b] Rotman Research Institute of Baycrest Centre, Toronto, Ontario, Canada [c] Laurentian University, Sudbury, Ontario, Canada

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Short article

Age and synchrony effects in visuospatial working memory

Gillian Rowe
University of Toronto, Toronto, Ontario, Canada

Lynn Hasher
University of Toronto, Toronto, Ontario, Canada, and Rotman Research Institute of Baycrest Centre, Toronto, Ontario, Canada

Josée Turcotte
Laurentian University, Sudbury, Ontario, Canada

Younger and older adults were administered a computerized version of the Corsi Block visuospatial working memory (VSWM) span task at either their peak or off-peak time of day and in either a high-interference (ascending order of administration, starting with short lists first) or low-interference (descending order, starting with longest lists first) format. Young adults' span scores were highest in the ascending format. By contrast, older adults performed better in the low-interference format, replicating findings with verbal memory span studies. Although both age groups benefited from being tested at their peak time, the advantage was far greater for older adults, but only in the low-interference format; their scores on the high-interference format were not helped by peak-time testing. These findings are consistent with the suggestion that young adults' performance on span tasks is influenced by practice and strategies, but the performance of older adults is heavily influenced by interference—which is best controlled at peak times of day. Our findings suggest that both time of testing and interference play critical roles in determining age differences in VSWM span, and both a reduction in interference and peak-time testing may be necessary to optimize older adults' performance and to maximize the reduction in age differences.

Keywords: Visuospatial working memory; Age differences; Circadian arousal patterns; Interference effects; Corsi Block Task.

A growing body of research suggests that the cognitive performance of older adults is determined by multiple factors, including the ability to prevent irrelevant information from gaining access to

Correspondence should be addressed to Gillian Rowe or Lynn Hasher, Department of Psychology, University of Toronto, 100 St George Street, Toronto, ON M5S 3G3, Canada. E-mail: gillian@psych.toronto.edu or hasher@psych.toronto.edu

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attention (Hasher, Lustig, & Zacks, 2007). Older adults are known to have more difficulty controlling the focus of their attention than younger adults, making them particularly vulnerable to the detrimental effects of irrelevant information from a number of sources, including from the recent past (Hasher et al., 2007; Winocur & Moscovitch, 1983). This latter effect, descriptively called proactive interference (PI), occurs when previously presented but no-longer-relevant materials disrupt the ability to recall the most recently presented information. The detrimental effect of PI has long been recognized in a number of situations, most recently in tasks involving verbal working memory (e.g., Bunting, 2006; Lustig, May, & Hasher, 2001). Of particular relevance to the current work, PI is known to differentially lower the memory performance of older adults (e.g., Ikier, Yang, & Hasher, 2008; Winocur & Moscovitch, 1983).

Typically, working memory (WM) tasks present to-be-remembered information over multiple trials, increasing gradually from a small to a large number of items. Given that a high span score is determined by successful performance on the longer set sizes, and that PI builds up across trials, it is not surprising that older adults generally perform more poorly than younger adults on span tasks. Reversing the conventional order of presentation (so starting with the longest instead of the shortest set size) in verbal WM span tasks reduces the effects of irrelevant, prior trial information during recall of the longest set sizes, differentially improving older adults' performance (Lustig et al., 2001). A similar manipulation has recently generalized these findings to a visuospatial working memory (VSWM) task (Rowe, Hasher, & Turcotte, 2008).

Physiological evidence suggests that attentional control is also tied to daily arousal patterns (e.g., Cermakian & Boivin, 2003), and in the behavioural literature there are reports of synchrony effects, with regulation of thought and action better at an individual's peak than at an off-peak circadian arousal period (e.g., May, Hasher, & Stoltzfus, 1993). Of particular relevance to the current study, the ability to ignore distraction is especially prone to synchrony effects, affecting performance on a number of cognitive tasks, including implicit (Rowe, Valderrama, Hasher, & Lenartowicz, 2006) and explicit memory (e.g., May et al., 1993) as well as problem solving (May, 1999). Many of these tasks are dependent on efficient attentional control processes for optimum performance, processes that serve to limit the detrimental effect of interference by focusing on information relevant to one's current goal (Lustig, Hasher, & Zacks, 2007). When testing is synchronized with a person's peak circadian period, attention regulation and memory are better than when testing is done at an asynchronous time of day.

In general, there are age differences in circadian arousal patterns. The majority of older adults (70–75%) are more likely to reach their peak early in the day than later (less than 7%). By contrast, younger adults (35%) typically report being at their best later in the day, and only 7% of North American college students report being morning types (May & Hasher, 1998). With respect to attention regulation, May (1999) reported that, although problem solving without distraction does not alter across the day, the ability to solve verbal problems in the face of distraction varied depending on whether or not testing was synchronized with peak circadian arousal periods. Problems were solved equally well in the presence and absence of concurrent distraction at a peak time of day (late afternoon) for evening-type young adults. By contrast, early in the morning, young adults' problem solving was greatly influenced by the presence of distraction. The ability to regulate distraction also varies across the day for older adults, who are better able to ignore distraction in the morning (their peak time) than in the afternoon (their off-peak time), consistent with their general morningness tendencies (Rowe et al., 2006). Of particular relevance to the present study, there is evidence that PI also exerts a greater influence at off-peak than at peak times of day, an effect that has a greater bearing on older than younger adults (Hasher, Chung, May, & Foong, 2002).

Taken together, these findings suggest that age differences typically reported in the cognitive ageing literature may be influenced by many factors, including older adults' increased vulnerability to interference and the influence of circadian arousal patterns across the day. However, the vast majority of memory research on attentional regulation of distraction and circadian arousal has focused on verbal material. Although recent work (Rowe et al., 2008) has highlighted the role of PI in age differences in VSWM, to our knowledge little is known about the influence of circadian arousal patterns on memory for visuospatial information, and nothing at all is known about the combined influence of PI and differences in circadian arousal patterns across the day. Here we consider the contribution of PI and testing period to age differences in VSWM by manipulating the amount of PI in a VSWM span task and whether or not testing is synchronized with a person's peak circadian arousal period. We do this by testing older and younger adults on a modification of the classic nine-location Corsi Block Task (CBT; Corsi, 1972), a tool widely used to assess visuospatial memory in both clinical and nonclinical populations (e.g., Smyth & Scholey, 1994). Each age group was tested at their peak or off-peak time and performed the task in either the typical, ascending format (shortest set sizes presented first), or in a PI-reducing, descending format (longest set sizes presented first). We anticipated a replication of previous findings (e.g., Rowe et al., 2008), with better performance by older adults on the interference-reducing, descending format than on the more typically used ascending format. The critical issue here, then, was the existence of a synchrony effect on visuospatial span performance for younger and older adults, and we anticipated best performance for both younger and older adults at peak test times. As mentioned above, older adults are differentially vulnerable to PI, and here we consider whether those effects are lessened at peak as compared to off-peak times of testing. We note that other work has suggested that young adults show a benefit of practice in verbal and spatial span tasks (e.g., Rowe et al., 2008), and here we also consider whether those effects are greater at peak than at off-peak times of day.

Method

Participants

A total of 56 young adults (*M* age = 19.08 years, *SD* = 2.08; range = 18–30 years) and 56 older adults (*M* age = 67.41 years, *SD* = 4.56; range = 60–76 years) were selected on the basis of their score on the Horne–Ostberg Morningness/Eveningness Questionnaire (MEQ), a reliable and valid paper-and-pencil task that correlates highly with physiological markers of circadian arousal (Yoon, May, & Hasher, 1998). Younger adults were all evening types (MEQ < 37) and had a mean MEQ score of 32.66 (*SD* = 6.74). Older adults were morning types (MEQ > 58) and had a mean MEQ score of 62.00 (*SD* = 15.54), which was reliably higher than that of young adults. Participants were randomly assigned to either the ascending or the descending span condition and were tested individually. Half of the participants in each age group were tested early in the morning (8 a.m. or 9 a.m.; a peak time for older adults, off-peak for young adults), and half were tested late in the afternoon (4 p.m. or 5 p.m.; a peak time for young adults, off-peak for older adults). Older adults had more years of education (*M* = 14.66, *SD* = 4.50) than younger adults (*M* = 12.46, *SD* = 0.72), as well as higher vocabulary scores (*M* = 34.38, *SD* = 4.73; *M* = 31.43, *SD* = 4.75, respectively) on the Shipley vocabulary test. Data were discarded if participants failed to meet criterion on years of education (minimum = high-school diploma) or showed evidence of cognitive impairment (more than 6 on the Short Blessed Test: SBT, Pfeiffer, 1975). One older adult was excluded on these bases, leaving a sample of 56 young and 55 older adults. Young adults were all university students and received course credit. Older adults were volunteers registered with the University of Toronto's older adult participant pool, and received remuneration based on $10 for each hour of participation time.

Materials

The experimental span task was programmed using E-prime software (Psychology Software Tools, Inc., Pittsburgh, PA, USA). We used a computerized version of the CBT with the nine potential target locations presented as two-dimensional grey squares of equal size (3 cm^2) against a white background and arranged in the randomized display of Corsi's (1972) original task (see Figure 1). Stimuli were presented on a touch screen monitor with a display area of 38.10 cm. A total of 12 target sequences were chosen based on those used in the spatial span task of the Wechsler Memory Scale–Third Edition (Wechsler, 1997).

Procedure

Subsequent to reading the task instructions, participants were given one practice trial with a two-location sequence, after which sequences were presented in either an ascending (starting with set size 4 and progressing to set size 7) order of difficulty, or in a PI-reducing, descending (from 7 to 4 locations) order of difficulty. In both conditions, 3 trials at each of the four set sizes were presented for a total of 12 trials. All 3 trials of a set size were presented before continuing to the next set size. Except for the ascending versus descending order of test administration, the same spatial sequences were used for all participants.

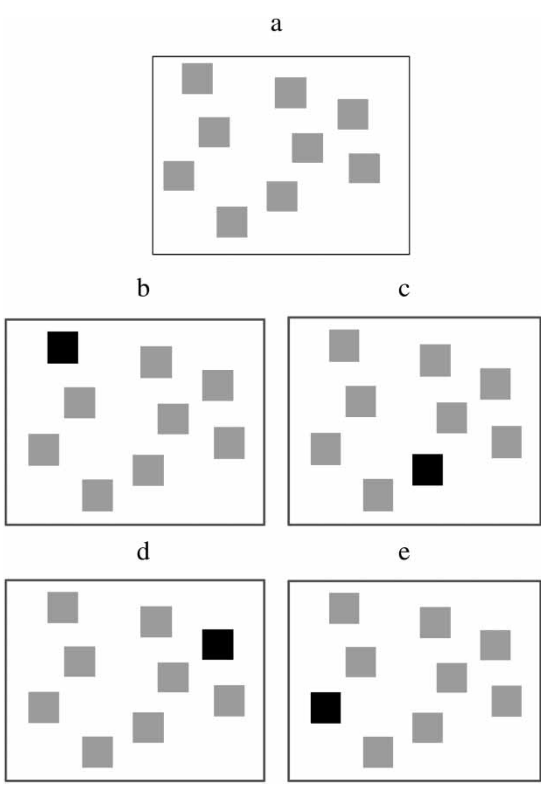

Figure 1. *Example of the experimental display showing the display used at the start of the study phase (before target locations presented) and at test (a), and presentation of a four-location sequence (b–e).*

Each trial began when the participant pressed the keyboard's spacebar, following which the display of nine grey squares (blocks) on a white background was presented for 1,200 ms. A pattern of the required number of target locations was then presented sequentially, with each target location identified by a 1,500-ms change in colour from grey to black (see Figure 1). Immediately after presentation of the to-be-remembered sequence, participants were prompted to recall target items by touching the relevant squares in the order of presentation. The critical measure of span was the percentage of trials (sequences) correctly recalled in the order presented.

Results

There were no main effects or interactions of age, MEQ score, education, or vocabulary with testing period or task presentation, indicating that within each age group, those randomly assigned to be tested at a peak versus off-peak time or in the ascending versus descending condition did not differ on age, MEQ, education, or vocabulary (all Fs < 1).

A $2 \times 2 \times 2$ analysis of variance (ANOVA) was performed on span scores (see Figure 2), with age (young vs. older), testing period (peak vs. off-peak), and presentation format (ascending vs. descending) as between-subject variables. There was a main effect of age, with, overall, younger adults having higher span scores ($M = 63$, $SD = 17$) than older adults ($M = 40$, $SD = 19$), $F(1,\ 103) = 51.70$, $p < .001$. The three way interaction of Age × Testing Period × Presentation Format was significant, $F(1, 103) = 4.64$, $p = 0.03$, and because this interaction qualified both two way and main effects,

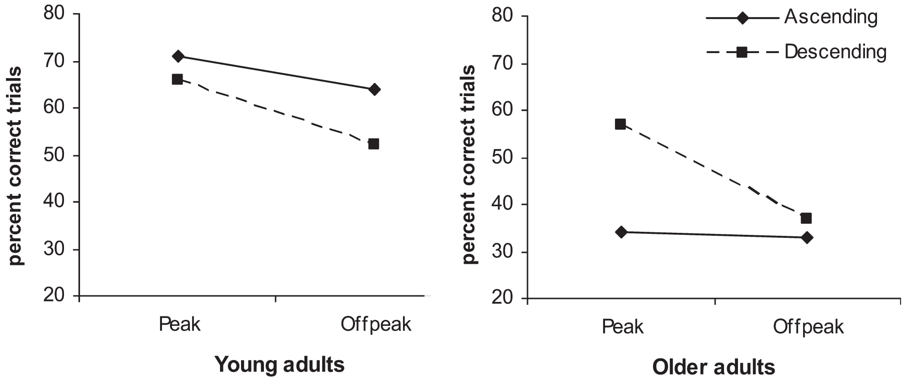

Figure 2. *Mean percentage of correct trials for younger and older adults tested at their peak and off-peak times.*

subsequent analyses are reported within each age group separately.

Young adults

A 2 (testing period) × 2 (presentation condition) ANOVA showed a main effect of testing period, $F(1, 52) = 4.42$, $p = .04$, and a main effect of presentation format, $F(1, 52) = 5.01$, $p = .03$. The interaction was not significant, $p = .38$. Performance was better at peak ($M = 68$, $SD = 14$) than at off-peak ($M = 59$, $SD = 19$) time of day, and was better on the ascending ($M = 68$, $SD = 16$) than on the descending ($M = 58$, $SD = 18$) format. Young adults' advantage in the ascending format replicates previous findings (e.g., Rowe et al., 2008) where the authors bring up the possibility that young adults benefit from practice and strategy use stemming from beginning with short lists first.

Older adults

A 2 (testing period) × 2 (condition) ANOVA showed a main effect of testing period, $F(1, 51) = 5.10$, $p = .03$, and a main effect of presentation format, $F(1, 51) = 8.28$, $p < .01$, effects that were qualified by the reliable interaction between time of testing and presentation format, $F(1, 52) = 5.38$, $p < .04$. At a peak testing time, performance in the PI-reduced descending format was better than that in the ascending format, $t(14) = 2.98$, $p < .01$ ($M = 57$, $SD = 19$; $M = 34$, $SD = 17$, respectively). However, this advantage was no longer seen at an off-peak time of day, when performance was similar in the descending ($M = 37$, $SD = 18$) and ascending ($M = 33$, $SD = 15$) formats, $p = .67$. Older adults' overall poor performance later in the day suggests that the detrimental effect of off-peak testing far outweighs any benefit gained by reducing interference, and the advantage of such a manipulation is only seen when attentional control is at its best.

Discussion

We tested older and younger adults on either a high (ascending order of administration) or low (descending order) interference version of a visuospatial working memory span task at a peak or off-peak circadian period, when attentional regulation is at its most or least efficient. Previous work has shown that synchronizing test administration with individuals' peak circadian arousal period is a powerful determinant of performance on various tasks in the verbal domain that require attentional control, including problem solving under distraction (May, 1999), implicit memory for distraction (Rowe et al., 2006), memory for stories (May et al., 1993), and false memory errors (Intons-Peterson, Rocchi, West, McLellan, & Hackney, 1998). In the current study, we considered both interference and circadian arousal patterns, anticipating that both younger and older adults would demonstrate enhanced performance when tested at their peak times, and older adults, who are differentially susceptible to PI (Ikier & Hasher, 2006; Winocur & Moscovitch, 1983) would show an added benefit when interference was reduced, as in the descending order of administration. The effects of time of testing were quite different for younger and older participants. Older adults performed poorly on the interference-laden ascending format regardless of whether they were tested at their peak or off-peak times, possibly reflecting the strong effect of their vulnerability to interference; for VSWM at least, the interfering effects of prior trials in the ascending format may swamp any benefits seen from testing at peak times of day. The story was very different, however, in the interference-reduced descending format. Peak-time testing improved performance dramatically, whereas off-peak testing was not helped at all by a reduction in interference. A similar finding was reported by Hasher et al. (2002), in which changing categories (thus reducing PI) on the last trial of a word recall task benefited older adults at their peak but not at their off-peak time of day. In the current study, although our manipulation reduced PI, other forms of interference—for example, from the non-target items concurrently displayed with target items—may still have been present in the task. This fact, along with older adults' general reduction in attentional control at their off-peak times, may have contributed to their overall poor performance when testing and peak circadian arousal periods were not synchronized. One slightly surprising finding in the current study was that older adults' performance in the ascending format did not improve at a peak relative to an off-peak testing time. One possible explanation is that the combined effects of PI build-up, concurrent interference, and target similarity in this particular task, which also uses unfamiliar spatial stimuli, may have negated the benefit of synchrony.

For young adults, performance improved on both task formats when they were tested at their peak time (here late in the afternoon); however, they gained no benefit from the PI-reduced condition; in fact, their performance was always better in the standard, ascending presentation. This finding of superior performance in the ascending condition is consistent with earlier work in both the verbal (e.g., Lustig et al., 2001) and visuospatial (e.g., Rowe et al., 2008) domains, and one possible reason might be that young adults can benefit from practice and strategy use (Voyer, Voyer, & Bryden, 1995) stemming from beginning with short lists first. An earlier literature on learning to learn (Postman, 1969) confirms that young adults virtually always show rapid improvement on a variety of tasks, quickly developing task-specific skills. Given that younger adults are better than older adults at ignoring irrelevant information, practice may outweigh PI effects otherwise found in ascending span procedures.

Overall, our findings suggest that VSWM span tasks may include opposing components (interference and testing period) that differentially affect younger and older adults. For older adults at least, performance on VSWM span tasks is determined not only by the ability to ignore information presented on prior trials but also by whether or not test administration is synchronized with their peak circadian arousal levels. Although testing at peak times improved younger adults' overall performance, older adults only benefited when peak-time testing was combined with a reduction in interference. A large literature has previously demonstrated the separate influence of interference (e.g., Lustig et al., 2001; Rowe, Hasher, & Turcotte, 2008) and synchrony effects (e.g., May, 1999; Yoon, May, Goldstein, & Hasher, in press) on age differences in cognitive performance. The present data indicate that, in VSWM span tasks at least, a reduction in interference and synchrony between testing and peak circadian arousal patterns may be necessary to optimize older adults' performance, thus providing a more accurate representation of age differences.

A possible alternative explanation for our findings, especially for our older participants, is that their poor performance at an off-peak time was due to general fatigue or lack of motivation; however, findings from previous research argue against this interpretation. For example, performance on many other tasks, such as vocabulary tests, reading speed, trivia knowledge, and category judgements do not vary across the day (Yoon et al., in press). The suggestion here is that these well learned or highly practised abilities may be immune to synchrony or time of day effects. Indeed, our own data confirm these findings, with no evidence that verbal ability, as measured by a vocabulary test, changed across the day for either younger or older adults. Our data, instead, are consistent with the differential influence of interference and circadian arousal patterns on younger and older adults' performance.

Although age-related differences in circadian arousal patterns and susceptibility to interference are not given much consideration in ageing studies, our findings suggest that ignoring such differences may mask older adults' true abilities and also lead to an overestimate of age differences.

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