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Attentional Disregulation: A Benefit for Implicit Memory

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The authors investigated the effect of age and time of testing on the ability to control attention and addressed the possibility that older adults' susceptibility to distraction may sometimes facilitate performance on a later cognitive task. Using a modification of a G. Rees, C. Russell, C. D. Frith, and J. Driver (1999) procedure, the authors asked the participants to make same or different judgments on line drawings superimposed with task-irrelevant letter strings. Memory for the distractors was subsequently tested with an implicit memory task. Both older and young adults demonstrated greater memory for distractors at nonoptimal times of day than at optimal times of day; however, older adults showed considerably better memory for the distractors than did young adults.

Keywords: implicit memory, word fragment completion, aging, distraction

A growing body of research suggests that performance on a wide range of cognitive tasks may be determined, at least in part, by the ability to prevent irrelevant information from gaining access to attention and that this ability may depend, to some extent, on efficient inhibitory control (Hasher, Zacks, & May, 1999; Lustig, Hasher, & Tonev, in press). Although the term *inhibition* has been used in a number of different ways in cognitive research (e.g., Anderson & Bjork, 1994; Postman & Underwood, 1973), here we refer to *inhibition* as a set of attentional processes that regulate the flow of information to facilitate the completion of a current goal. When attentional control is efficient, irrelevant information is suppressed so that the relevant and irrelevant materials do not compete simultaneously for the focus of attention (Cassavaugh, Kramer, & Peterson, 2004). Also, when goals or tasks change, efficient control will update and suppress the no-longer-relevant information (e.g., Lustig, May, & Hasher, 2001). The contents of consciousness are thus limited to currently relevant material, and the disruptive effects of interference are reduced (Gazzaley, Cooney, Rissman, & D'Esposito, 2005; Hasher, Lustig, & Zacks, in press). As such, age differences in inhibitory regulation may play a major role in determining age differences on many cognitive tasks.

There is a rich literature in cognition dealing with the disruptive costs of concurrent distraction (e.g., Eriksen, 1995; Strayer & Johnston, 2001). This is particularly notable in cognitive gerontology, in part because substantial literature suggests that older adults are more easily distracted by concurrently presented irrelevant information than are young adults (e.g., Madden & Langley, 2003; but see McDowd & Shaw, 2000). Indeed, the reduced ability to handle distraction may be part of the reason that older adults typically show slower and less accurate performance on cognitive tasks (e.g., Lustig et al., in press; Winocur & Moscovitch, 1983). Older adults' susceptibility to concurrent and recently relevant distraction impairs performance on a variety of tasks including speech comprehension and reading (Carlson, Hasher, Zacks, & Connelly, 1995; Tun, O'Kane, & Wingfield, 2002), attention tasks such as Stroop tasks (e.g., Cohn, Dustman, & Bradford, 1984), visual search (Scialfa, Esau, & Joffe, 1998) and flanker tasks (e.g., Zeef, Sonke, Kok, Buiten, & Kenemans, 1996), and both explicit and implicit memory tasks (Hartman & Hasher, 1991). Taken together, then, these findings suggest that older adults often have difficulty limiting the focus of their attention to target material and that they may be processing, at some level at least, both concurrently relevant and irrelevant information.

By contrast, young adults are generally adept at ignoring irrelevant information. An extreme example of this ability is seen in the phenomenon of inattentional blindness, in which young adults fail to notice unattended information that actually occurs in the center of the visual field (e.g., Mack & Rock, 1998; Most et al., 2001). Additional evidence of the ability of young adults to narrowly focus attention comes from a neuroimaging study (Rees, Russell, Frith, & Driver, 1999) in which young adults were instructed to make same or different judgments regarding a continuous stream

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of line drawings and to ignore superimposed words or random letter strings. A subsequent recognition test found no reliable memory for the unattended words, and functional magnetic resonance imaging data showed similar neural activity for words and random letter strings, suggesting that under certain conditions, unattended words are not distinguished from random letters despite being directly fixated. By contrast, when participants were instructed to attend to letter strings and ignore the pictures, a different pattern emerged: differential neural activity for words and random letter strings. It should be noted that these studies were limited to the investigation of inattentional blindness in young adults.

Physiological evidence suggests that attentional control is tied to daily arousal patterns (e.g., Cermakian & Boivin, 2003; Hur, Bouchard, & Lykken, 1998; Kerkhof, 1985), and in the behavioral literature, there are reports of synchrony effects, with better regulation of thought and action at a peak time than at an off-peak time of day (e.g., Yoon, May, Goldstein, & Hasher, in press). In general, there are age differences in circadian arousal patterns; older adults are more likely to report being at their best earlier in the day, whereas young adults typically reach their peak later in the day (e.g., Hasher et al., 1999). With respect to attention regulation, May (1999) reported that the ability to solve verbal problems in the face of distraction varied with the time of day and circadian preference patterns. Problems were solved equally well in the presence and in the absence of a distraction at a peak time of day (late afternoon) for evening-type young adults. By contrast, early-in-the-morning problem solving was greatly influenced by the presence of a distraction. The ability to regulate distraction also varied across the day for older adults, who were better able to ignore distraction in the morning than in the afternoon, consistent with their general morningness tendencies.

The vast majority of research on attentional regulation of distraction focuses on the negative effects of poor regulation, that is, slowed or error-prone performance. In the present study, we address the possibility that poor attentional regulation may actually have some unexpected positive consequences, consequences that are seen after the target task is completed. We do this by using a modification of a Rees et al. (1999) procedure in which we instructed participants to ignore irrelevant words or letter strings superimposed on rapidly presented objects, the identities of which they were instructed to compare. Implicit memory for the distracting words was subsequently tested with a word-fragment completion task. Because there is evidence of poorer attentional regulation at off-peak times compared with peak times of day (more so for older adults than for young adults), we tested each age group at a peak or an off-peak time of day. We found dramatic evidence of the benefits of poor attentional regulation: There was greater subsequent memory for distractors in older adults than in young adults, with better performance by both age groups at their off-peak times of day.

Method

Participants and Design

The experiment was a 2 (age: young vs. older) × 2 (time of testing: morning vs. afternoon) between-subjects design. We selected 28 evening-type young adults (age 18–30 years) and 32 morning-type older adults (age 60–75 years) on the basis of their score on the Horne-Ostberg Morningness–Eveningness Questionnaire (MEQ), a reliable and valid paper-and-pencil task that assesses individual circadian preferences (e.g., Horne & Ostberg, 1976, 1977; Smith, Reilly, & Midkiff, 1989).[1] 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, an off-peak time for young adults), and half were tested late in the afternoon (4 p.m. or 5 p.m.; a peak time for young adults, an off-peak time for older adults). Young adults were all university students and received course credit. Older adults were community-dwelling volunteers and received payment.

Materials

We selected 60 line drawings from Snodgrass and Vanderwart (1980) and superimposed the drawings with either random letter strings (30 in total) or words (20 in total: 10 target and 10 filler words). Two lists of 10 unrelated target words, with an average length of six letters, were chosen on the basis of previously collected word-fragment completion norms for older and young adults (Ikier, 2005). The fragments were chosen to have age equivalent rates of completion with scores of 0.11 and 0.08 (both lists) for older and young adults, respectively. The two sets of target words were counterbalanced across participants within each age group.

Memory for the distracting words was tested with a word-fragment completion task. Equal numbers of the fragments began with the first, second, or third letter in the word, for example, L_T_E_Y (LOTTERY), _E_ON (MELON), and _ _ILE_ (SMILES). All had multiple solutions in the language—but only one in the experiment. Of the 30 word fragments used, 10 were fragments of study-phase words, 10 were control fragments of words from the list not seen by a particular participant (average number of letters in fragments = 3.35), and 10 were easily solved fragments that served as fillers to ensure participants felt successful during the task and to obscure the connection between the test and input task.

Procedure

The experiment consisted of a study phase and test phase, divided by a visuospatial working memory filler task (a version of the Corsi Block Test; Corsi, 1972). In the study phase, participants viewed a rapid stream of 55 individual pictures, 50 of which were superimposed with a string of random letters (n = 30), a filler word (n = 10), or a target word (n = 10) from one of the two lists. Participants were instructed to ignore the letter strings or words and to press the space bar whenever two consecutive pictures were identical. Each picture and letter pair was presented at the center of a computer screen for 1,000 ms, with an interstimulus interval of 500 ms. On the basis of research suggesting that distractors are more likely to be detected at the beginning of a task (Treisman, Squire, & Green, 1974), the presentation sequence was as follows: A primacy buffer with 5 pictures with nothing superimposed was followed by 8 pictures with random letter strings superimposed and 34 pictures with either random letter strings (14 in total) or words (20 in total) superimposed. The list concluded with a recency buffer of 8 additional pictures with superimposed random letter strings. Consecutive pictures occurred seven times amid the critical 34 trials, with lags ranging from 2 to 7 intervening pictures. No words were repeated during the picture comparison task.

[1] The MEQ classifies individuals as evening, neutral, or morning types (e.g., Horne & Ostberg, 1977; Smith, Reilly, & Midkiff, 1989). In normative studies (e.g., Intons-Peterson, Rocchi, West, McLellan, & Hackney, 1998; May & Hasher, 1998; May, Hasher, & Stoltzfus, 1993; Yoon, May, Goldstein, & Hasher, in press), researchers report that well under 10% of young North American undergraduates show a morning preference, and less than 5% of older adults are evening types, a major difference in arousal patterns between young and older adults.

After an interval of approximately 10 min, during which participants completed the nonverbal filler task, participants viewed 30 word fragments presented on a computer screen at a rate of 3,000 ms per fragment. Participants were instructed to respond aloud with the first solution that came to mind. Responses were recorded by the experimenter. Following the test phase, we asked all participants whether they noticed any connection among the tasks. Participants who noticed a connection were probed for details, and those who noticed the connection between the study and the test session were excluded from the data analysis. The participants then completed a health questionnaire and the Shipley Vocabulary Test (Shipley, 1976).

Results

Participants

Among the participants, 5 young adults and 2 older adults reported being aware of a connection between the study and test phases and were replaced by other participants. Young adults (M age = 19.08 years, SD = 2.08, range = 18–30 years) had a mean score of 32.66 (SD = 6.74) on the MEQ, which classified them as evening types, and a mean score of 31.11 (SD = 4.82) on the Shipley Vocabulary Test. Older adults (M age = 67.41, SD = 4.56, range = 60–76 years) had a significantly higher score than young adults on the MEQ (M = 62.00, SD = 15.54), $t(58) = 11.57$, $p < .001$, which classified older adults as morning types. Older adults did not have higher scores on the vocabulary test (M = 31.76, SD = 7.83, $p > .70$), but they did have more years of education (M = 14.66, SD = 4.50) than young adults (M = 12.46, SD = 0.72), $t(58) = 2.33$, $p = .02$. There were no main effects or interactions of either of these variables with time of testing, indicating that within each age group, those randomly assigned to be tested at a peak time versus an off-peak time of day did not differ on age, MEQ, vocabulary, or education.

Scoring

Separate baseline word-fragment completion rates (the proportion of solved fragments from the unseen list) were determined for each age group and time of testing condition. These did not differ either by age (Ms = 12% & 9% for young and older adults, respectively) or by peak times (M = 11%) versus off-peak times (M = 9%), all Fs < 1. Nonetheless, because of these small differences in the age and time of testing conditions, we also calculated priming with the baseline completion rates for each individual. Our results did not differ on the basis of the method used; thus, here we report only results that are based on group baselines. For each participant, priming scores were calculated as the difference between the proportion of target-word fragments correctly solved and their condition's baseline.

Performance on the Picture Comparison Task

There were no age or time of day differences on the picture comparison task.[2]

Implicit Priming Effects

A 2 × 2 analysis of variance was performed on priming scores, with age (young vs. older) and time of testing (a.m. vs. p.m.) as between-subjects factors (Table 1). Overall, older adults showed greater priming for the critical words, $F(1, 56) = 29.99$, $MSE = 0.02$, $p < .01$. The interaction between age and time of testing was reliable, $F(1, 56) = 16.14$, $MSE = 0.02$, $p < .01$. Older adults demonstrated greater priming in the afternoon than in the morning, $t(30) = 3.26$, $p < .01$. Young adults displayed the opposite pattern: greater priming in the morning than in the afternoon, $t(26) = 2.14$, $p = .04$.[3] Although there were reliable age differences in the afternoon, $t(29) = 5.12$, $p < .01$, performance of young and older participants did not differ in the morning, $p > .17$. It is worth noting that young adults showed above-baseline priming only in the morning, at an off-peak time of day. At a peak time of day, young adults showed no implicit memory for the distracting words, even though the words were in the center of objects they were examining. This finding is consistent with earlier reports of inattentional blindness in young adults (e.g., Rees et al., 1999) and with the problem-solving findings of May (1999).

Table 1
Mean Priming Percentage as a Function of Age and Testing Time

	a.m.		p.m.	
Group	M	SD	M	SD
Young (evening types)	9	11	0.0	12
Older (morning types)	14	9	33	20

Note. The morning (a.m.) is peak time for older adults and off-peak time for young adults. The evening (p.m.) is peak time for young adults and off-peak time for older adults.

Discussion

Existing research demonstrates the downside of age-related declines in attentional regulation, such as slower search times and reduced accuracy on a wide range of tasks when a distraction is present (e.g., Carlson et al., 1995; Winocur & Moscovitch, 1983). Also, some work suggests that attentional regulation varies with circadian arousal patterns across the day (e.g., May, 1999), with greater disruption from concurrent distraction at off-peak times of day. Here we demonstrate a surprising advantage of poor attentional regulation, with older adults showing greater implicit memory for distractors than young adults. Although all participants were instructed to disregard the distracting words, older adults'

[2] Accuracy and reaction times were available for the seven pictures that repeated. There were no age or time of day differences for accuracy (ranging from 93% to 97%), $F < 1$. Also, there were no age differences or time of day differences for reaction times, $F(1, 56) = 1.58$, $p = .39$, $MSE = 24486.49$, for the largest F, although older adults were slightly slower (M = 574 ms) than young adults (M = 528 ms). With only seven trials, these measurements of online distraction effects are not likely to be stable, and no further analyses were done.

[3] Previous research (May & Hasher, 2004) has shown that young adults who report their optimum time of day to be midday (neutral types) do not differ on performance across the day. We also tested 28 (14 a.m. and 14 p.m.) neutral-type young adults. There was no significant difference between the priming scores of neutral-type young adults tested early in the morning (M = 7%) and those tested later in the afternoon (M = 5%), $p >$ 0.6.

presumed reduced ability to ignore irrelevant information resulted in a downstream advantage, seen in their enhanced performance on a subsequent task in which the distractors from the first task were now relevant. These findings are dramatically different from those typically reported in the cognitive aging literature in which older adults typically performed more poorly than young adults on the majority of tasks involving distraction (Lustig et al., 2001; Madden & Langley, 2003). Here, we show that susceptibility to distraction can sometimes be helpful for both older and young adults, but by far the greatest advantage is afforded to older adults. We should note that our conclusion that older adults were more bothered by concurrent distraction is just an assumption, as we have no direct evidence to confirm this. There is, however, substantial literature (e.g., Carlson et al., 1995; Madden & Langley, 2003; May, 1999) that leads us to adopt this view; thus, evidence of distraction is based on priming performance. It is also possible that both groups have equal initial activation but that older adults have sustained activation (see also May, Zacks, Hasher, & Multhaup, 1999).

Our findings also demonstrate the critical influence of time of testing on performance. We tested participants at a peak time or an off-peak time of day, when attentional regulation is at its most efficient and least efficient, respectively. For both young and older adults tested at peak times (p.m. for young, a.m. for older) there is less evidence of implicit memory for the distraction. Indeed, for young adults, there is no evidence of priming whatsoever at peak times; they show above baseline priming only in the morning. Older adults, however, are far less susceptible to distraction in the morning, their peak arousal time, than in the afternoon. Thus, the downstream consequences of distraction are more likely to be seen at off-peak times than at peak times of day for both young and older adults. This pattern is consistent with a number of similar findings that showed less susceptibility to both concurrent and previously relevant distraction at optimal times of day for both young and older adults (e.g., May, 1999; May & Hasher, 1998).

The "down" side of poor attentional regulation, typically reported in the cognitive aging literature, suggests that older adults are at a distinct disadvantage compared to younger adults. Although there is plentiful evidence supporting the disruptive effect of distraction in many situations, the "up" side is that there are occasions, as demonstrated in the present study, when a reduced ability to control attention unknowingly and unintentionally can benefit subsequent cognitive functioning (see Kim, Hasher, & Zacks, in press). One might speculate that for older adults in general, and for anyone operating at off-peak times of day, unattended information may be, on occasion, automatically activated, thus guiding behavior (e.g., Dijksterhuis, Bos, Nordgren, & van Baaren, 2006; Ferguson & Bargh, 2004; Hasher & Zacks, 1979) and at least in some situations, as here, facilitating the completion of a current goal.

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