

Cognitive aging and increased distractibility: costs and potential benefits

M. Karl Healey¹, Karen L. Campbell^{1,2} and Lynn Hasher^{1,2,*}

¹*Department of Psychology, University of Toronto, Toronto, ON M5S 3G3, Canada*

²*The Rotman Research Institute, Baycrest, 3560 Bathurst Street, Toronto, ON, M6A 2E1, Canada*

Abstract: Older adults show a characteristic pattern of impaired and spared functioning relative to younger adults. Elsewhere we have argued that many age-related changes in cognitive function are rooted in an impaired ability to inhibit irrelevant information and inappropriate responses. In this chapter we review evidence that as a direct result of impaired inhibitory processes, older adults tend to be highly susceptible to distraction. We suggest that because the distinction between relevant and irrelevant is seldom either clear or static, distractibility can manifest as either a cost or a benefit depending on the situation. We review evidence that in situations in which it interferes with the current task, distraction is disproportionately detrimental to older adults compared to university aged adults, but that when previously distracting information becomes relevant, older adults show a benefit whereas younger adults do not.

Keywords: cognitive aging; inhibition; suppression; distractibility

A person's cognitive abilities and intellectual proficiencies are not static across their life but rather follow a distinct developmental trajectory. The most salient phase of this trajectory may be the rapid increase in ability during childhood and adolescence, followed by changes in ability as people age. Relative to young adults (aged 18–30), older adults (typically 65+ years old) do more poorly on laboratory tests measuring a variety of abilities such as attention control (Cohn et al., 1984; Gazzaley et al., 2005; Hasher et al., 2007), working memory (May et al., 1999), and long-term memory (Grady and Craik, 2000; Park et al., 2002).

Despite the fact that older adults experience difficulty with a wide variety of cognitive tasks,

aging is not characterized by a generalized decline in cognitive ability. For example, older adults show performance comparable to (or in some cases superior to) younger adults on tests of semantic memory and verbal ability (older adults routinely outperform younger adults on vocabulary tests: Park et al., 2002; Verhaeghen, 2003), and decision making (Kim and Hasher, 2005; Kim et al., 2005; Mather, 2006; Peters et al., 2007). Moreover, as will be seen, factors that contribute to poor performance in some situations can lead to superior performance in other situations. Therefore, aging is characterized by changes in cognitive function that manifest as a distinct pattern of preserved, impaired, and occasionally enhanced performance.

A major goal of cognitive aging research has been to determine what underlies this pattern of impaired and preserved functioning, and to this end, a number of theories have been advanced.

*Corresponding author. Tel.: +1 416 978 1557;
Fax: +1 416 978 4811; E-mail: Hasher@psych.utoronto.ca

For example, it has been suggested that older adults' difficulties stem from a general reduction in processing speed (Salthouse, 1996), or from structural and functional changes in the prefrontal cortex (West, 1996, 2000); still others have argued that age-related changes in memory arise from a deficit in the ability to form associations between the various aspects of an episode (e.g., a fact and the context in which it was learned: Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2004a, b; Oberauer, 2005). Our own view and that of an increasing number of researchers is that reductions in the ability of attention to regulate distraction underlies many age-related deficits (Hasher and Zacks, 1988; Hasher et al., 1999, 2007). In this chapter we discuss some of the unique predictions that derive from this view and review the relevant empirical evidence. We begin with a brief overview of the attentional dysregulation account of cognitive aging.

The environment constantly presents us with massive amounts of information and it is far beyond our ability to actively process all of it and carefully consider all possible responses. However, to accomplish our goals we must process at least some of this information and decide upon an appropriate response. Therefore, one of the primary obstacles to successful information processing and interaction with the environment is winnowing the relevant from the irrelevant, the appropriate from the inappropriate. We argue that this obstacle is overcome by using attention to actively inhibit information that is currently irrelevant, and to suppress prepotent but momentarily inappropriate responses. That is, we view inhibitory processes as narrowing the scope of information processing and the resulting overt responses by excluding information and responses that are situationally inappropriate (for a more detailed exposition of this view, see Hasher and Zacks, 1988; Hasher et al., 1999, 2007).

A direct consequence of this inhibitory deficit is that older adults will actually process more total information than will younger adults, with a greater proportion of that information being irrelevant. To the extent that successful task performance depends on selectively attending to only relevant information, older adults will be

disadvantaged relative to younger adults. That is, in situations that demand a narrow focus of attention, older adults are likely to be more distracted than are younger adults. However, in some situations it is not clear which information is relevant and which is irrelevant and it is also often the case that information that was irrelevant at one point in time becomes relevant at a later point. In situations such as these, a tendency to process irrelevant information can actually be beneficial, with older adults ultimately showing better performance than younger adults.

In the following sections we review work, by ourselves and colleagues, demonstrating the various impacts that increased distractibility has on older adults' cognition. First we will consider ways in which distractibility can hamper the performance of older adults. Then we will consider ways in which distractibility (or perhaps more appropriately, a wide scope of attention) can enhance performance.

Disruptive effects of distraction

On processing speed

Older adults are substantially slower than younger adults on simple measures of processing speed such as the rate at which a participant can compare two strings of letters and determine whether they are identical or not. Performance on these tasks accounts for a considerable proportion of age-related variance on memory tasks such as free recall and paired associate learning, prompting the claim that reduced processing speed is a major cause of age-related cognitive impairments (see Salthouse, 1996, for a review). However, even though the basic task in most processing speed measures is quite simple (e.g., compare two letter strings), many such items are actually presented on a single page, producing a cluttered display. If older adults are especially vulnerable to distraction, such clutter could have a negative impact on their processing speed. That is, distractibility and not reduced processing speed per se may cause older adults to be slow on these measures.

To test the idea that distraction partially determines older adults' performance on speed

measures, Lustig et al. (2006) created low and high distraction versions of two common speed measures. In the letter comparison task (Salthouse and Babcock, 1991), participants are shown two strings of three, six, or nine letters (e.g., RXL ___ RXL) and must indicate whether the two strings are the same or different. The standard version of the task consists of two pages each with 21 pairs of strings. For the high distraction version, Lustig et al. presented the strings on a computer with 24 pairs per screen (48 total). For the low distraction condition they presented the same 48 pairs but one at a time (each stayed onscreen until the participant responded).

Unsurprisingly, reaction time increased as the number of letters per string increased, and overall, older adults were slower than younger adults (see Fig. 1). More interestingly, the older but not younger adults were faster in the low distraction condition than in the high distraction condition. That is, the standard presentation of multiple items in a single cluttered array disproportionately slowed older adults' reaction times and thus exaggerated age differences in processing speed. Moreover, older adults' performance on the high distraction version of the computerized task showed higher correlations with their performance

on more traditional pen and paper speed tests than did performance on the low distraction version.

Lustig et al. (2006) performed a similar distraction reducing manipulation on another widely used speed task, The Symbol Digit Substitution test (Royer et al., 1981). It consists of a page with 90 unfamiliar symbols and participants must substitute a digit (1–9) for each symbol according to a provided translation key. The speed with which they can carry out this translation provides a measure of processing speed. Lustig et al.'s high distraction version presented 93 symbols on each screen, whereas the low distraction version presented the same symbols but one at a time. As with the letter comparison task, younger adults were equally fast across distraction conditions (far right column of Fig. 1), but older adults, though slower than younger adults overall, were considerably faster in the low distraction condition than in the high distraction condition.

Lustig et al. (2006) showed that older adults are indeed especially susceptible to distraction and that this susceptibility contributes to slowing on tasks once thought to be relatively pure measures of processing speed. While use of an uncluttered display did not completely eliminate age-related slowing, it did reduce it substantially, clearly

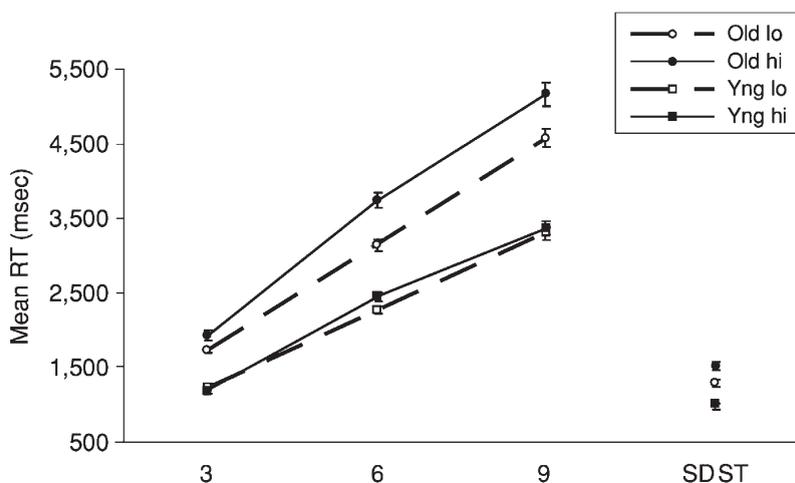


Fig. 1. Mean per item reaction time on the letter comparison task and the symbol digit substitution task (SDST; far right) as a function of age and distraction (hi or lo). Adapted from Lustig et al. (2006). Published by the Psychonomic Society. (Reprinted with permission.)

illustrating the influence distraction can have on older adults.

On reading speed

The speed measures discussed in the previous section assess the rapidity with which one can complete a simple but unfamiliar cognitive task. But even in a familiar, well-learned task the presence of distracting information can have a differentially disruptive impact on the performance of older adults. That is, even if older adults usually have no problem completing a given task and show minimum deficits relative to younger adults, performing the task under conditions of unusually high distraction will cause a precipitous decline in their performance while having a much smaller impact on the performance of younger adults.

One domain that should be particularly familiar for older adults is reading. Most older adults have a lifetime of reading experience and are quite skilled at it. However, sometimes older adults have to read a given piece of text in the midst of other, distracting, information. A common example is reading a newspaper or magazine: the article you are interested in is surrounded by other articles and advertisements that could potentially draw your attention away from the relevant text. To determine whether distracting information does indeed impede older adults' reading, Connelly

et al. (1991) used a task in which participants had to read a short story with irrelevant text interspersed with the relevant text (the irrelevant text was distinguished by a different type face; see Fig. 2A). They found that for control stories in which no distracting information was presented, older adults' reading speeds were only slightly slower than younger adults', but that when distracting words and phrases, which were related to the meaning of the relevant text, were included (text-related condition), the older adults were disproportionately slowed (see Fig. 3). Once again, introducing distraction to a task increased age differences in processing speed.

In a second experiment, Connelly et al. (1991) manipulated the nature of the distracting information. In the text-related condition the information was related to the content of the story (as in Experiment 1); in the text-unrelated condition words were also used as distraction but were unrelated to the story; in the x-string condition, strings of X's were interspersed with the text (see Fig. 2B). As seen in Fig. 4, both older and younger adults were reliably slowed relative to the no distraction control by all forms of distraction, but in each case the effect of distraction was greater for older adults. Note that for both groups, distracting words produced more slowing than did x-strings, but that for younger adults it did not matter whether the words were related to the text or not, in contrast, related words produced more slowing

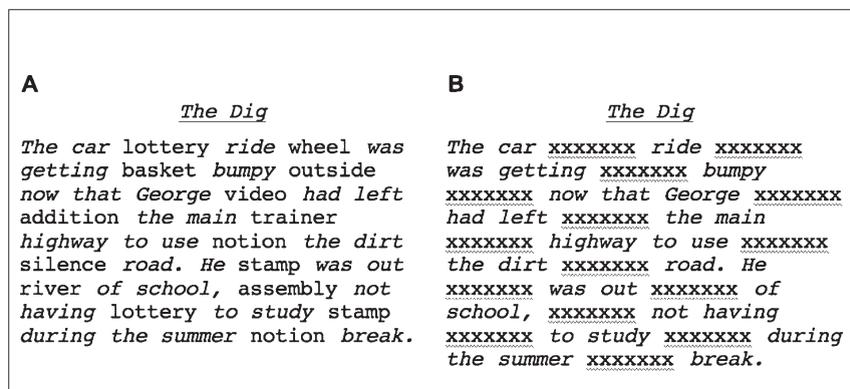


Fig. 2. Examples of the reading with distraction task. The text-related condition is shown on the left and the x-string condition is shown on the right.

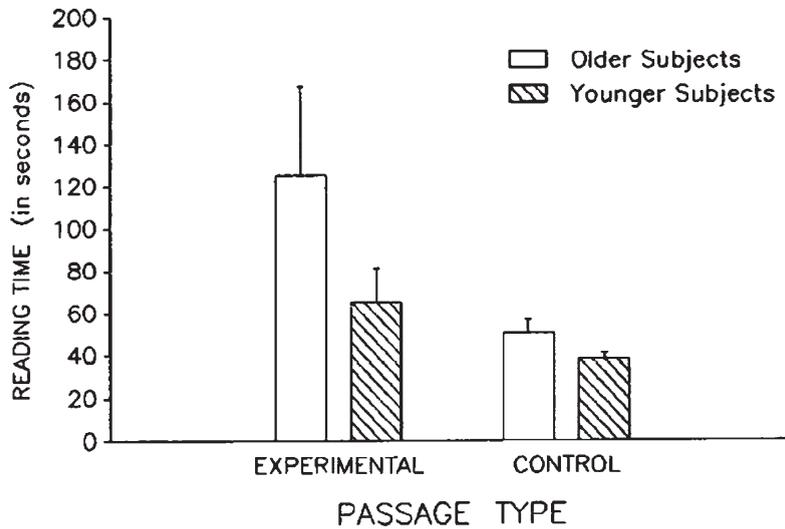


Fig. 3. Reaction times for older and younger adults on the reading with distraction task (experimental) and the control condition (Control) where no distracting information was interspersed with the relevant text. Adapted from Connelly et al. (1991). Published by APA. (Reprinted with permission.)

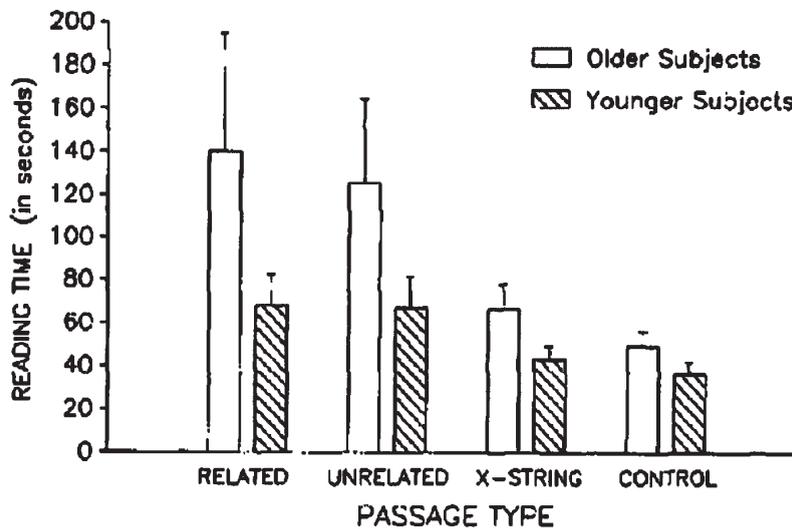


Fig. 4. Reaction times for older and younger adults on text-related, text-unrelated, x-string, and control passages. Adapted from Connelly et al. (1991). Published by APA. (Reprinted with permission.)

than unrelated words for older adults. This differential effect of relatedness suggests that while younger adults were distracted by the words, they were able to ignore any relation to the text material; older adults apparently processed the meaning of the words and incurred an additional

cost when they were related to the main text. Overall, distraction was much more disruptive for older adults (a difference of ~90 s between the control and related conditions) than for younger adults (~30 s). Thus, Connelly et al. showed that even if older adults are highly familiar and skilled

with a task, their performance is extremely sensitive to distraction.

On problem solving

The two studies discussed thus far have focused on the speed of cognitive processing. But slowed performance is not the only effect of increased susceptibility to distraction. For instance, May (1999) demonstrated that distraction impacts not only how *fast* older adults process information, but also the way in which the information is processed. Participants performed the remote associates task (RAT: Mednick, 1962) in which they are shown three words that are (distantly) related to a fourth word and they must produce this fourth linking word (e.g., “space” for the three words, Ship, Outer, and Crawl). In the standard task, the word triplets are presented alone, but on some trials May presented ostensibly irrelevant words along with the word triplet (one for each word in the triplet, presented below the relevant word). These distracting words were in fact related to the triplet word to which they were paired and suggested a meaning inconsistent with the relevant meaning of its paired triplet word. For example, inconsistent distractors for “ship, outer, crawl” would be “ocean, inner, floor” which do not suggest the “space” meaning of the triplet words. Participants were told that paying attention to the distractors would always impede solving the RAT problem. The rationale of the design is that if older adults are unable to ignore distraction, they should attend to the distracting words, which would prime an irrelevant meaning of the RAT words and make detection of the link between the words less likely.

There is evidence that the efficiency of inhibitory processes varies in a circadian fashion, and that there are individual and age differences in the time of peak efficiency; generally being in the morning for older adults and the evening for university aged adults (Hasher et al., 1999; Yoon et al., 2007). By testing participants at peak and off-peak times of day, May (1999) capitalized on this circadian variation in distractibility to determine whether susceptibility to distraction influences the impact of irrelevant information on RAT solution rates within an age group.

Younger adults tested at their peak time of day were not influenced by the distracting information. In contrast, older adults tested at their peak time of day did show a significant cost of distraction: they solved approximately 10% fewer RAT problems when inconsistent distractors were presented compared to the no-distraction condition. However, when tested at off-peak times of day, both age groups showed a negative impact of distraction. Younger adults tested in the morning were no longer able to successfully ignore the distracting information, leading them to solve approximately 10% fewer RAT problems when distraction was present. Older adults tested in the evening were even more impaired by the distraction, solving approximately 17% fewer RAT problems when distraction was present. Thus, May (1999) demonstrated that older adults’ susceptibility to distraction extends beyond simple slowing; older adults are not only distracted by irrelevant information, they process the information and it influences the products (i.e., RAT solutions) of their cognitive processing. Moreover, susceptibility to distraction varies across the day, and even younger adults can incorporate irrelevant information into their information processing when tested at off-peak times.

Neural correlates of distractibility

The behavioral evidence reviewed above clearly indicates that older adults have difficulty controlling distraction, and there is now some evidence regarding the neural signatures of older adults’ increased susceptibility to distraction. For example, Jonides et al. (2000) used the recent negatives task, which requires participants to resolve interference between relevant and irrelevant memory traces. On each trial of the task, participants are shown a set of four letters to remember followed by a probe letter. Participants must indicate if the probe matches any of the letters from the memory set. There are two types of trials that require negative responses: non-recent negatives on which the probe was not a member of any recent memory set, and recent negatives on which the probe is not a member of the current set, but had been a member of the just previous set. Thus, correct

responding on recent negative trials requires participants to ignore the familiarity of the probe and to say “no.” For younger adults, reaction times on recent negative trials were slower than on non-recent negative trials, and the former were associated with increased activity in the left lateral prefrontal cortex. Older adults showed even greater slowing to recent negatives relative to non-recent negative trials but showed *less* activation in the same left lateral prefrontal area. These results suggest that older adults’ inability to ignore currently irrelevant information (in this case the familiarity of previous trial items) is related to decreased activation in the prefrontal cortex areas believed to be responsible for distraction control.

Further evidence of the neural correlates of distractibility comes from a study by Gazzaley et al. (2005). They presented participants with a series of faces and scenes (e.g., a sunset). In one condition participants were told to ignore the faces and remember the scenes, in another condition they were told to remember the faces and ignore the scenes. Gazzaley et al. found that when they were told to remember the scenes and ignore the faces, both older and younger adults showed increased activity in the parahippocampal place area (PPA), a region known to be involved in the processing of scenes, relative to a control condition where participants passively viewed the pictures. In contrast, when told to ignore the scenes, activity in the PPA decreased below baseline, but only for younger adults: older adults did not show decreased activity when scenes were irrelevant. That is, when scenes were relevant, there were no age differences in PPA activity but when scenes were irrelevant distraction, younger adults suppressed PPA activity but older adults did not. Moreover, the extent to which activity in the PPA was suppressed when remembering faces, predicted memory accuracy. Thus, one neural signature of older adults’ distractibility appears to be activity in processing areas that fails to discriminate between relevant and irrelevant information.

Taken together, the Jonides et al. (2000) and Gazzaley et al. (2005) studies suggest that older adults are impaired at distraction control abilities mediated by the prefrontal cortex and this impairment results in processing of information regardless

of relevance as reflected by indiscriminant activation in processing areas such as the PPA.

Fortuitous effects of distraction

To this point we have discussed the negative consequences associated with being distracted by irrelevant information. However, outside the laboratory the delineation between irrelevant and relevant is often fuzzy and tends to change unpredictably. For example, if you are reading a journal article with the aim of finding evidence to support a claim you want to make in a paper you are writing, any data or arguments not directly relevant to your claim could be considered distraction that should be inhibited. When you begin to write your next paper, however, some of the data that were previously a distraction may now be very relevant. Indeed, the ability to connect disparate, seemingly unrelated (i.e., mutually irrelevant) ideas might be one key aspect of creativity (Peterson and Carson, 2000). In this light the distractibility resulting from older adults’ inefficient inhibitory processes can be seen as a wider scope of attention. If this wider scope leads to processing information that interferes with the current task, a cost is incurred, but it is also possible that a less constrained focus of attention may lead to processing information that initially seems irrelevant but later turns out to be quite relevant, either to the current task or to a subsequent task; in such cases distractibility may actually be beneficial. In the following sections we will review several empirical demonstrations of the positive consequences of distractibility.

Benefiting from concurrent distraction

In addition to investigating how distraction can impede RAT performance, May (1999) tested whether distracting information can improve RAT performance. This was accomplished by including a condition in which distractors were consistent rather than inconsistent with the relevant meanings of the RAT triplet words. For example, for “space, outer, crawl” relevant distractors would be “rocket, atmosphere, attic,” all of which suggest

the “space” meaning of the triplet words. The pattern of results found when these consistent distractors were presented was virtually a mirror image of the inconsistent distractor data. For younger adults tested at peak times, distraction had no impact on the likelihood of reaching a solution. In contrast, older adults tested at peak times were marginally more likely to solve the problems if distraction was present. When participants were tested at off-peak times the effects of distraction were increased: both younger and older adults were more likely to solve the RAT problems if consistent distractors were present. The effect of consistent distractors clearly illustrates that ostensibly irrelevant, distracting information does not always impair cognitive processing. Moreover, it is not simply a case of older adults always attending to distraction but younger adults flexibility attending or ignoring depending on the situation: when their distraction control abilities were at peak efficiency, younger adults effectively ignored the distraction even though it would have been beneficial for them to attend to it.

Benefiting from previously relevant information

Although proactive interference is usually associated with a decrement in performance on conventional cognitive tasks, there may be certain situations in which previously relevant information becomes relevant once again. One such situation was demonstrated by May and Hasher (1998), who showed that older but not younger adults can make use of non-relevant words in a later task. In the first phase of that study, young and older adults generated endings to normatively high-Cloze sentences (e.g., “Before you go to bed turn off the _____. Expected ending: “lights”). On half of these trials, the generated ending (e.g., “lights”) was disconfirmed and was replaced by an experimenter-provided target ending (e.g., “stove”), which participants were told to remember for a later memory test. The critical question was whether participants would suppress the disconfirmed endings (e.g., “lights”) and remember only the target endings (e.g., “stove”).

In order to assess their memory for the items, participants were given a new set of medium-Cloze

sentences that could each be completed with several different endings. Importantly, some of these sentences could be completed with the disconfirmed endings (e.g., “The baby was fascinated by the bright _____,” for “lights”), some could be completed with the target endings (e.g., “She remodeled the kitchen and replaced the old _____,” for “stove”), and some could be completed with previously unseen control words. The main question was whether participants would show priming for the critical items. That is, would they use these endings (e.g., “lights” and “stove”) to complete more sentences than participants who had seen a different set of endings at study? Furthermore, would young and older adults show different amounts of priming for the target and disconfirmed items?

As can be seen in Fig. 5, young and older adults showed the same amount of priming for the to-be-remembered target words. However, a very different pattern of results emerged for the disconfirmed items. Older adults demonstrated similar amounts of priming to disconfirmed and target items, suggesting that their failure to inhibit no-longer-relevant words left them as accessible as words they intended to remember. Young adults, on the other hand, demonstrated below-baseline priming for the disconfirmed items, suggesting that they were so effective at suppressing this information that it became even less accessible than usual. Thus, older adults demonstrated greater implicit memory for the disconfirmed items than younger adults. Although we traditionally speak of the disadvantages of failing to inhibit information that is no longer relevant (e.g., Hasher et al., 1999), whenever that information becomes relevant again, older adults may well be at an advantage.

Benefiting from information that was never relevant

At any given moment, we are bombarded with information, some of it relevant, some of it not. However, information that is distraction at one moment may become the focus of attention in the next. In this section, we discuss two studies in which information that served as distraction on one task later became relevant on another task. Both studies point to the same conclusion: older

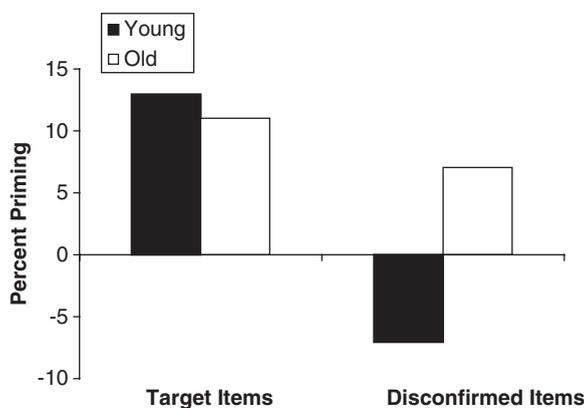


Fig. 5. Priming of disconfirmed and target items for each age group. Adapted from May and Hasher (1998). Published by APA. (Reprinted with permission.)

adults can outperform younger adults when past distraction becomes relevant.

As previously stated, young adults are quite proficient at ignoring distracting information. In fact, they are even capable of ignoring words that are presented at central fixation (Rees et al., 1999). In a seminal fMRI study, participants were shown rapid streams of letter strings (words and nonwords) superimposed on objects and were told to attend to either the letters or the objects. Their task was to press a button whenever an item in the attended stream repeated. In the attend-letters condition, participants' brain activity distinguished between words and nonwords. That is, words activated parts of the brain associated with word-processing, while nonwords did not. Conversely, in the attend-objects condition, brain activity did not distinguish between words and nonwords, suggesting that these young participants were capable of blocking out the irrelevant letter stimuli, even though they were looking right at it.

In a recent behavioral adaptation of this paradigm, Rowe et al., (2006) showed that older adults fail to ignore the superimposed words *and* they can use their implicit memory for these words to aid performance on a future task. Young and older adults were shown overlapping pictures and letter strings (words and nonwords) and were told to press a button whenever the same picture was shown twice in a row. Thus, in order to perform this task efficiently, participants should have always tried to ignore the distracting

words/nonwords. After a brief filled interval, memory for the distracting words was tested implicitly with a word fragment completion task, which included a number of fragments that could be solved with distracting words from the previous task. For each participant, priming scores were calculated as the difference between the proportion of target-word fragments they correctly solved and the baseline-completion rates for those fragments.

Older adults demonstrated a substantial amount of priming for the distractor words when tested at their peak time of day (14%) and an even greater amount of priming when tested at their off-peak time of day (33%). Thus, older adults benefited from their attention to the distracting words at both peak and off-peak times, although this benefit was more pronounced in the afternoon when their ability to ignore the words was presumably lower. By contrast, young adults showed no priming for the distractor words when tested at their peak time of day (~0%) and only a small amount of priming when tested at their off-peak time of day (9%). Thus, similar to the findings of Rees et al. (1999), the young adults in this study were capable of ignoring words presented at central fixation, as indexed by their lack of implicit memory for the words. Only at their off-peak time of day, when inhibitory control was poorest, did younger adults show a slight benefit of distraction. Overall, older adults demonstrated greater implicit memory for the distracting words than young adults. These results suggest that

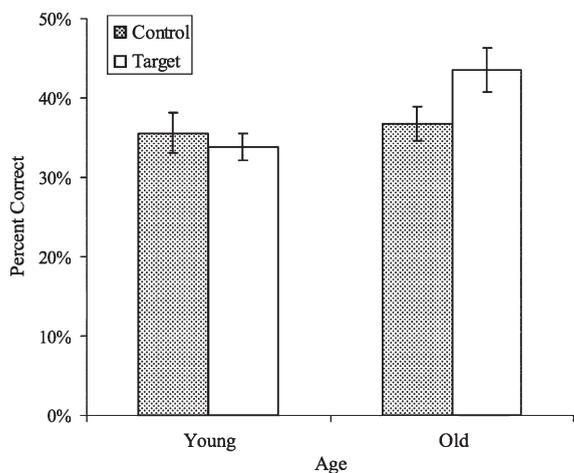


Fig. 6. Mean percent correct scores for control and target RAT problems for each age group. Adapted from Kim et al. (2007). Published by the Psychonomic Society. (Reprinted with permission.)

susceptibility to distraction can sometimes be helpful to both young and older adults, although by far the greatest advantage is afforded to older adults.

In a related study, Kim et al. (2007) demonstrated that older adults can also use their implicit memory for distracting information to aid in their performance on the RAT. Participants first performed a modified version of the reading with distraction task, in which the distracting words were actually solutions for the upcoming RAT problems. The reading task was followed by a 15 min filled interval and finally, participants received 50 RAT problems. A third of these problems could be solved by distracting words seen during the initial reading with distraction task, while another third served as control items (solutions for which were seen by participants in the alternate counterbalance condition). Older participants were expected to solve more of the target problems than young adults, as they were expected to read more of the distracting words and to be unable to inhibit them to baseline levels once activated.

As can be seen in Fig. 6, this is precisely the pattern of results that was found. Young and older adults did not differ in their performance on the control RAT problems. That is, when the solutions had not been previously viewed as distraction, young and older adults solved an equal proportion

of problems. However, when the solutions to those problems had previously served as distraction on the reading task, older adults outperformed their younger counterparts on the problem-solving task. These surprising results demonstrate a clear benefit of older adults' greater access to distraction. In fact, the benefit of distraction reported here is even more astounding than that reported by May (1999), as the useful distracting information in this study was *not* shown concurrently with the RAT problems. Older participants capitalized on their access to information that was never relevant in the first place. This 'downstream' effect is quite similar to the 'far transfer' effects widely sought after in younger adults in the training and problem-solving literature (e.g., Barnett and Ceci, 2002). Older adults, with their reduced ability to suppress the past, may be better suited to transferring information from one situation to another in order to solve a problem.

Conclusion

Aging is associated with a decrease in the ability to inhibit irrelevant information. As a result, older adults are less able to regulate their attention and they end up processing more distracting information than younger adults. In this chapter, we have discussed some of the deleterious effects that increased susceptibility to distraction can have on older adults' cognitive performance. Inadvertently attending to irrelevant information can slow down processing on simple cognitive tasks (Lustig et al., 2006), disrupt a skilled activity such as reading (Connelly et al., 1991), and hinder problem solving on the remote associates task (May, 1999). However, we have also reviewed some exciting new work pointing to the potential benefits of increased susceptibility to distraction. For instance, older adults demonstrate greater implicit memory for distracting information (May and Hasher, 1998; Rowe et al., 2006) and when that distracting information is actually pertinent, they can use it to outperform younger adults at problem solving (May, 1999; Kim et al., 2007). These findings highlight the notion that cognitive aging is characterized by both losses and gains, and that whether to consider reduced inhibitory control as a help or a hindrance depends entirely on the situation.

Acknowledgments

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