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Older adults encode more, not less: evidence for age-related attentional broadening

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ABSTRACT
Previous work has shown that older adults attend to and implicitly remember more distracting information than young adults; however, it is unknown whether they show a corresponding decrease in implicit memory for targets in the presence of distracters. Using implicit memory tests, we asked whether older adults show a tradeoff in memory between targets and distracters. Here, young and older adults performed a selective attention task in which they were instructed to attend to target pictures and ignore superimposed distracter words. We measured priming for distracter words using fragment completion and for target pictures using naming time. Older adults showed greater priming for distracting words compared to young adults, but equivalent priming for target pictures. These results suggest that older adults have a broader attentional scope than young adults, encompassing both relevant and irrelevant information.

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The presence of distraction is often differentially disruptive to older adults' performance on a target task (Lustig, Hasher, & Tonev, 2006; Rabbitt, 1965; West & Alain, 2000; Zeef, Sonke, Kok, Buiten, & Kenemans, 1996) but can also sometimes facilitate performance (May, 1999), with the direction of the effect determined by congruency between the distraction and the target task (May, 1999; Mozolic, Hugenschmidt, Peiffer, & Laurienti, 2012; Weeks & Hasher, 2014; Yang & Hasher, 2007). Behavioral findings such as these are corroborated by neuroimaging evidence showing that older adults engage in greater processing of to-be-ignored information compared to young adults (Campbell, Grady, Ng, & Hasher, 2012; Gazzaley, Cooney, Rissman, & D'Esposito, 2005).

Attending to distraction does not only impact the concurrent performance of older adults but it also influences subsequent performance, as has been demonstrated in a number of transfer studies using implicit tests of memory for previously seen distraction. Older adults show transfer of perceptual (Rowe, Valderrama, Hasher, & Lenartowicz, 2006) and conceptual (Amer & Hasher, 2014) knowledge of distraction to later tasks, which can facilitate performance if distraction later becomes relevant (Amer & Hasher, 2014; Rowe et al., 2006). A recent study also demonstrated that presenting to-be-remembered words as distraction after an initial list learning trial

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can prevent forgetting of repeated items among older adults, even without awareness on the part of participants (Biss, Ngo, Hasher, Campbell, & Rowe, 2013). Distraction transfer has also been leveraged as an effective intervention to improve learning and reduce forgetting of face-name pairs in older adults (Biss, Rowe, Weeks, Hasher, & Murphy, in press; Weeks, Biss, Murphy, & Hasher, 2016). However, while it is clear that older adults both attend to and implicitly make use of distracting information, it is unknown whether attending to distraction comes at the expense of implicit memory for co-occurring target information. Testing this prediction is critical to the development of distraction-based memory interventions for older adults, since any benefits conferred by the presence of "helpful" distraction could be offset by increased costs to memory for targets if such a trade-off exists.

From a general capacity point of view (Kahneman, 1973) and particularly from views that older adults have reduced working memory capacity relative to young adults (Bopp & Verhaeghen, 2005; Park et al., 2002), richer knowledge of distraction should be associated with poorer knowledge of concurrently presented target information (Craik, 2013; Schmitz, Cheng, & De Rosa, 2010), a hypothesis that has not yet been empirically tested. Alternatively, older adults may simply have less control over the scope of attention, resulting in a broader mental window that enables the encoding of both relevant and irrelevant information as well as sustained access to that information over time (Campbell, Hasher, & Thomas, 2010; Campbell, Trelle, & Hasher, 2014; Hasher, Zacks, & May, 1999). If this were the case, the incidental encoding of distraction could come at no cost to the encoding of target information. Discriminating between these two mutually exclusive predictions is necessary to address the discrepancies between capacity-based and attentional-broadening-based views of cognitive aging.

Our goal was to address the question of whether older adults' task performance is affected by distraction because they attend to the *wrong* items, as a limited capacity view might suggest, or to *too many* items, as an attention dysregulation view would suggest. To these ends, we employed a modified version of a 1-back paradigm previously used to demonstrate distracter suppression in young adults (Campbell, Grady et al., 2012; Rees, Russell, Frith, & Driver, 1999) and distracter processing in older adults (Anderson, Campbell, Amer, Grady, & Hasher, 2014; Campbell, Grady et al., 2012; Rowe et al., 2006). After a 1-back task in which young and older adults were asked to attend to pictures of familiar, nameable objects and ignore irrelevant superimposed words, we assessed implicit memory for distracting words using a word fragment completion task and implicit memory for the target pictures using picture naming times. Based on previous studies (Campbell, Grady et al., 2012; Rowe et al., 2006), we anticipated that older adults would show more priming for the distracting words compared to young adults. The task most critical to our research question was the picture naming task; if, perhaps due to capacity limitations, older adults attended to distracting words at the cost of target pictures, we predicted that they would show less priming for target pictures compared to young adults. Alternatively, if older adults have a broader scope of attention, encompassing both targets and distracters, an age-related increase in distracter priming would not be accompanied by a decrease in target priming compared to young adults.

Method

Participants

Thirty-two young adults aged 18–28 years (*M* = 19.2, SD = 2.2; 9 males) recruited from an undergraduate database and 32 older adults aged 60–76 years (*M* = 66.9, SD = 4.3; 7 males) recruited from the community participated in the experiment for course credit or payment. Independent samples *t*-tests revealed that older adults were more educated than young adults (M_{young} = 13.1 years, M_{old} = 17.0 years), *t*(62) = 4.66) *p* < .001, *d* = 1.16, and had higher vocabulary scores than the young adults (M_{young} = 28.6, M_{old} = 36.5), *t* (62) = 11.24, *p* < .001, *d* = 2.80. These participants were tested on a procedure that closely resembled that used by Rowe et al. (2006) to measure priming for distraction, here with the addition of a target priming task at the end. An additional 32 young and 32 older adults were recruited to provide baseline naming times for the purpose of calculating priming for target pictures seen by participants in the experimental group. Participants in the baseline condition were comparable to those in the experimental condition in age, *t*(126) = .38, *p* = .70, *d* = .07, education, *t*(126) = .41, *p* = .68, *d* = .07, and vocabulary scores, *t*(126) = .37, *p* = .71, *d* = .07. These participants performed only the picture naming task after participating in a separate psychology experiment.

One young adult in the experimental condition scored very poorly on the 1-back task (*z*-score = −3.56); so, another young adult was tested as a replacement. No participants reported being aware of the connection between the 1-back task and the word fragment task, although nine young adults and eight older adults reported that they noticed that some of the target pictures from the 1-back task reappeared in the picture naming task. Since the pattern of results did not change when their data were removed, they are included in the results reported below.

Materials

Picture stimuli

Ninety-nine pictures of highly nameable objects were selected from Snodgrass and Vanderwart (1980) for use as target stimuli in the 1-back and/or picture naming tasks; 30 of these pictures appeared on both the 1-back task and the picture naming task, 44 were filler items on the 1-back task, and the remaining 25 were filler items on the picture naming task.

Of the 30 primed pictures that appeared in both the 1-back task and the picture naming task, 15 were superimposed with random letter strings in the 1-back task and 15 were superimposed with critical words that would be solutions to future word fragments, with the two sets counterbalanced across participants. None of the 30 old pictures in the naming task appeared on the repetition trials in the 1-back task. Forty-four additional pictures were presented only in the 1-back task, either with filler words (15), random letter strings (24), or no words (5), and were not seen again in the experiment. In the picture naming task, participants saw the 30 target pictures intermixed with an additional 25 pictures that were completely new to all participants. All pictures used in the naming task had at least 90% name agreement between young and older adults according to normative data from Yoon et al. (2004).

Word stimuli

Critical words were selected using word fragment completion norms (Ikier, 2005) to ensure that young and older adults had similar rates of completing the critical word (.08 and .10, respectively). Two lists of 15 critical words were counterbalanced such that half of participants saw items from list A and the other half saw items from list B as distraction in the 1-back task. Lists were matched on average word length (*M* = 6.0 letters), number of letters in fragments (*M* = 3.4 letters), and the number of fragments that began with each letter (i.e., first, second, third, etc.). Distracters were randomly assigned to pictures and then double checked to ensure that picture–word pairs were not semantically related. All word fragments from both lists were included in the fragment task, along with 15 easy filler word fragments included to make participants feel successful and to conceal the connection between tasks.

Procedure

Participants in the experimental condition began with the Rowe et al. (2006) procedure measuring priming for distraction, followed by the task measuring priming for targets at the end. The distracter priming task was always run before the target priming task in order to replicate the Rowe et al. (2006) procedure and to avoid awareness of the connection between tasks. First, participants performed a 1-back task on pictures, ignoring superimposed words. After a 10-min visuospatial filler task, they performed a word fragment completion task in which some fragments could be solved using distracter words from the 1-back task. Finally, they performed a picture naming task in which some target pictures from the 1-back task reappeared, along with new pictures that were included to obscure the connection between the 1-back and picture naming tasks. Participants in the baseline condition performed only the picture naming task and thus provided an estimate of naming time in a naïve sample. All participants completed a demographic questionnaire and a (Shipley, 1946) vocabulary questionnaire before being compensated and debriefed. None of the participants were informed of the connection between tasks.

1-Back task

Pictures were sequentially presented in the center of a screen for 1000 ms each with a 500-ms ISI. Using a keyboard, participants indicated whether or not each picture repeated in sequence by pressing YES (the F key) or NO (the J key) and were instructed to ignore any superimposed distracting letters. The task began with a series of five pictures with no distracting letters followed by a primacy buffer of eight pictures superimposed with random letter strings, then 53 randomly intermixed pictures superimposed with critical words, filler words, or random letter strings, and finally, a recency buffer of eight pictures superimposed with random letter strings. There were 10 picture repetition trials in the task, with 3–8 trials between repetitions.

Word fragment task

After a 10-min visuospatial filler task, participants saw a series of word fragments presented for 3000 ms each and were asked to respond aloud with the first solution that came to mind that fit the fragment. They saw 45 fragments in total, 15 of which could be solved by critical words presented as distraction in the 1-back task, 15 of which could be solved by critical words from the unprimed list, and 15 of which were easy filler fragments. Word fragments appeared in a fixed, alternating order for all participants. Priming for distracting words was calculated as the difference between percentage of primed fragments solved and the group average percentage of unprimed fragments solved.

Picture naming task

Immediately after the word fragment task, participants saw a series of 55 pictures on the screen and were asked to name each picture into a microphone as quickly and accurately as possible. Pictures were shown for a maximum of 2 s each but disappeared once the microphone detected a response. Each picture was followed by a 500-ms ISI. After three buffer pictures, the remaining old and new pictures were presented in a randomized order that was different for each participant. Of the 30 old pictures in the naming task, half had been presented with critical distracter words in the 1-back task and half had been presented with random letter strings, with distracter type counterbalanced across participants. Since no naming time differences emerged between these two counterbalanced picture sets (see Results section), we collapsed across the distracter type variable to create a set of target pictures from the 1-back task which could then be compared between groups. To control for potential age group differences in overall response time (RT), we calculated the speedup in naming time for target pictures compared to new pictures as a proportion of overall naming time for new pictures [i.e., (new RT − target RT)/new RT]. Since the target and new picture sets were not counterbalanced, priming for target pictures from the 1-back task was assessed by comparing the speedup for the target picture set between the primed experimental group and the age-matched, naïve baseline group (Figure 1(b)). After the picture naming task, participants were asked if they noticed a connection among any of the tasks they performed.

Results

Selective attention task

Young adults had higher accuracy scores on the 1-back task than older adults (M_{young} = 98.2%, M_{old} = 94.4%), $t(62) = 4.27$), $p < .001$, $d = 1.07$. Accuracy as a function of distracter type (i.e., superimposed word vs. random letter strings) was not analyzed since only pictures on nonrepetition trials were counterbalanced and errors (i.e., false alarms) occurred on less than 1% of those trials. Reaction times on nonrepetition trials were analyzed with a 2 (age group: young vs. older) × 2 (distracter type) ANOVA which revealed only a main effect of age group such that that young adults were faster to respond on all 1-back trials compared to older adults, $F(1,62) = 47.52$, $p < .001$, MSE = 14,043, $\eta_p^2 = .43$ Neither young nor older adults showed differential slowing on the 1-back trials with distracting words compared with distracting random letter strings (see Table 1).

Priming for distracting words

For each age group, we calculated priming as the difference between each participant's rate of fragment completion for primed items minus the group average rate of fragment completion for unprimed items (Table 2), as is typically done in this literature (Amer &

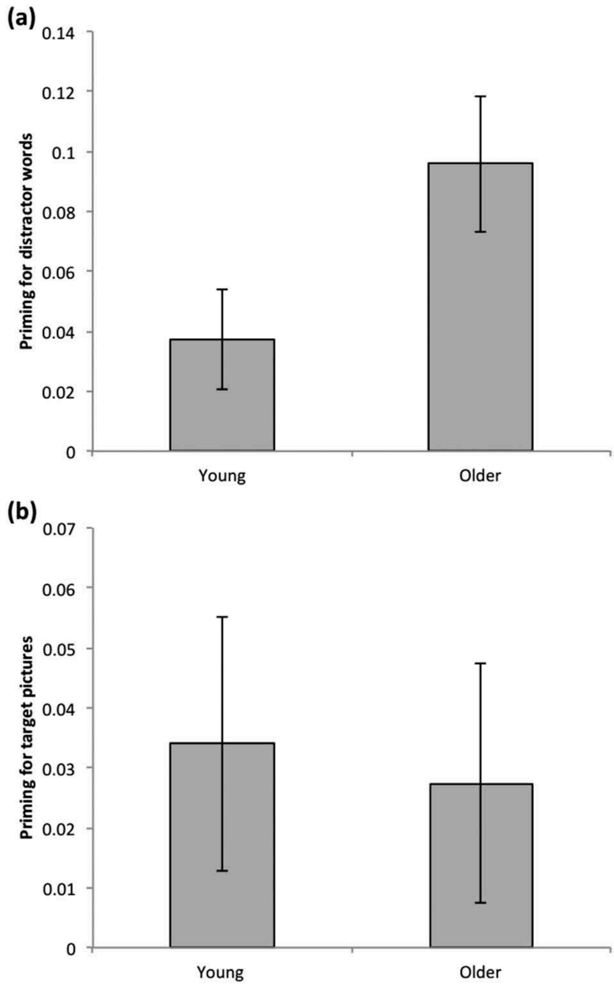

Figure 1. (a). Mean priming scores for distracting words from the 1-back task. Priming was calculated for each individual as proportion of primed fragments solved minus the group average proportion of unprimed fragments solved. Older adults show significantly more priming for distracters than do young adults. (b) Priming for target pictures is illustrated as the difference in proportional speedup for target pictures between conditions (experimental and baseline). There is no effect of age on target priming. Error bars represent 1 standard error of the mean.

Table 1. Reaction times for non-repetition trials on 1-back task.

	Distracter type	
Age group	Words	Random letter strings
Young adults (*n* = 32)	474 (13)	484 (12)
Older adults (*n* = 32)	623 (18)	623 (16)

Standard errors are shown in parentheses. Older adults were slower to respond than young adults, but neither age group's reaction times were affected by the content of distraction.

Hasher, 2014; Campbell, Grady et al., 2012; May, Hasher, & Foong, 2005; Rowe et al., 2006). Both young and older adults showed significant priming for distracting words (M_{young} = 3.7%, t_{young} (31) = 2.69, p = .011, d = .97; M_{old} = 9.6%, t_{old} (31) = 4.59, p < .001,

Table 2. Proportion of word fragments correctly solved.

	Fragment type	
Age group	Primed	Unprimed
Young adults (*n* = 32)	.11 (.01)	.08 (.01)
Older adults (*n* = 32)	.19 (.02)	.09 (.02)

Standard errors are shown in parentheses.

d = 1.65), with older adults showing significantly more priming for distracting words than young adults, *t*(62) = 2.33, *p* = .023, *d* = .58, as in previous studies (Campbell, Grady et al., 2012; Rowe et al., 2006) (see Figure 1(a)).

Priming for target pictures

Naming times for mispronounced or stuttered words, which amounted to 1.7 (5.7%) reaction times per young adult and 2.4 (8.2%) reaction times per older adult, were removed. Picture naming times that were more than 2.5 standard deviations from the mean for each participant group and distracter type (e.g., distracting words or random letter strings), which amounted to an average of .86 (2.8%) naming times per young adult and .74 (2.5%) naming times per older adult, were also removed.

Because there were no naming time differences between pictures previously paired with critical words and those previously paired with random letter strings for either age group, largest *F*(1,62) = 1.02, *p* = .32, MSE = 2120, $\eta_p^2 = .02$ we collapsed across distracter type. Priming for target pictures was defined as a difference in the proportional speedup for target pictures in the experimental condition compared to the baseline condition (Table 3).

Priming for target pictures was analyzed with a 2 (age group) by 2 (condition: experimental vs. baseline) ANOVA on proportional speedup scores for target pictures, which yielded only a significant main effect of condition, *F*(1, 124) = 4.45, MSE = .007, *p* = .04, $\eta_p^2 = .04$, such that primed participants showed a greater speedup than naïve baseline participants, but no effect of age group, *F*(1, 128) = .143, MSE = .007, *p* = .71, and no interaction, *F*(1, 124) = .052, MSE = .007, *p* = .82. This outcome suggests that both age groups showed equivalent priming for target pictures from the selective attention task (Figure 1(b)).

In summary, older adults showed greater priming for distracter words and an equivalent amount of priming for target pictures compared to young adults. There was thus no evidence that the age-related pattern of encoding distracter words came at a cost to encoding target pictures.

Table 3. Picture naming times by group (in ms).

Condition	Age group	Target pictures	New pictures	Proportion speedup for target pictures
Experimental	Young adults (*n* = 32)	781 (120)	872 (135)	.099 (.088)
Experimental	Older adults (*n* = 32)	768 (105)	859 (131)	.102 (.075)
Baseline	Young adults (*n* = 32)	763 (143)	820 (162)	.065 (.082)
Baseline	Older adults (*n* = 32)	851 (187)	920 (173)	.074 (.082)

Standard deviations are in parentheses. Proportion speedup was calculated as the naming time difference between new pictures and target pictures from the 1-back task as a proportion of new picture naming time.

Discussion

The current study replicated previous work showing increased priming for distracters in older compared to younger adults and extended this literature by testing whether or not the increase in encoding of distraction is accompanied by a decrease in encoding of target items. We assessed attentional allocation in young and older adults by measuring implicit priming for distracter words and target pictures following a selective attention task on pictures. We found no evidence of a cost to targets associated with attending to distraction. Instead, older and younger adults showed equivalent priming for target pictures.

As in previous studies, we found that older adults showed greater implicit knowledge of distracting words than young adults (Campbell, Grady et al., 2012; Rowe et al., 2006), which we take as evidence that older adults paid more attention to distraction in the picture-based 1-back task. Evidence to support this position also comes from a neuroimaging study (Campbell, Grady et al., 2012) that used a very similar paradigm and demonstrated that priming for distraction was associated with less activation in a network of frontal and parietal attention control regions and that these regions were underactivated in older compared to younger adults in the presence of distraction. Unlike the young adults tested by Campbell, Grady et al., (2012), young adults in our sample did show a small amount of priming for distracting words, which amounted to roughly a third of the priming shown by older adults. This finding contrasts with others showing that young adults cannot distinguish between new items and old-unattended items in a recognition task (Butler & Klein, 2009; Hoffman, Bein, & Maril, 2012; Rees et al., 1999) but is consistent with reports of young adults showing implicit priming for previously distracting words (Biss & Hasher, 2011; Butler & Klein, 2009; Stankiewicz, Hummel, & Cooper, 1998). We attribute this finding to the fact that, at least under some circumstances, word reading can be an automatic process that is not completely suppressed, even by young adults (Kahneman & Chajczyk, 1983; Ruz, Wolmetz, Tudela, & McCandliss, 2005). Memory for involuntarily processed distracters seems to be measurable with tests of implicit priming (Butler & Klein, 2009; Stankiewicz et al., 1998) or confidence judgments (Hoffman & Tzelgov, 2012) but not with tests of explicit memory (Butler & Klein, 2009; Hoffman et al., 2012; Rees et al., 1999).

The distinct age-related increase in priming for distraction that we observed, along with other studies showing decreased top-down inhibition of distraction in older adults (Bell, Buchner, & Mund, 2008; Gazzaley et al., 2005; Geerligs, Saliasi, Maurits, Renken, & Lorist, 2014), supports the existence of an age-related deficit in inhibiting processing of irrelevant information (Hasher & Zacks, 1988). Other studies employing implicit test tasks have reported broader encoding in older adults (c.f. Ballesteros, Reales, Mayas, & Heller, 2008). For instance, older adults have been shown to retain implicit knowledge of spatial (Campbell et al., 2010) and temporal (Campbell et al., 2014) relationships between items, and to detect statistical regularities in both attended and unattended streams simultaneously (Campbell, Zimerman, Healey, Lee, & Hasher, 2012). These findings are also consistent with neuroimaging evidence showing reduced suppression of distracter stimuli (Chadick, Zanto, & Gazzaley, 2014; Haring et al., 2013; Milham et al., 2002) as well as broader coding by older adults (Campbell, Grady et al., 2012; Schmitz et al., 2010). These findings, together with the current study, support the hypothesis that aging is associated with a change in attentional scope such that targets and distracters are processed together, at least when they are presented in close spatial or temporal proximity. Our observation of age-equivalent target priming may be limited to the type of paradigm used here and most commonly used in the literature (i.e., the 1-back task with distraction); therefore, it remains an open question whether attention to targets suffers as a result of distraction in any other tasks previously used to demonstrate age differences in distracter coding – reading with distraction for example (Connelly & Hasher, 1993; Connelly, Hasher, & Zacks, 1991).

While at first blush, this result may seem at odds with explicit memory studies showing worse memory for targets on the part of older adults (Light & Singh, 1987), the implicit memory findings described here may actually provide a basis for previously reported explicit memory findings. Specifically, if older adults automatically and involuntarily encode a broad range of relevant and irrelevant information at study, their explicit memory may be more vulnerable to the disruptive effects of interference than that of younger adults, impairing their performance at test (Hasher et al., 1999; Healey, Ngo, & Hasher, 2014).

Age-related deficits in explicit memory have also been attributed to a lack of attentional resources at encoding and a corresponding decrease in the ability to perform deep processing of items (Craik, 1986; Craik & Broadbent, 1983; Craik & Rose, 2012). Since our test tasks measured implicit priming of incidentally encoded items, our results do not necessarily contradict this processing account of age-related recall impairments. They do, however, raise the possibility that older adults implicitly encode more than what is measured with explicit recall tests, which are known to rely on efficient strategy use (Kirchhoff, Anderson, Barch, & Jacoby, 2012) and are susceptible to stereotype threat (Eich, Murayama, Castel, & Knowlton, 2014).

In conclusion, the results of the current study suggest that increased implicit knowledge of distraction is not accompanied by decreased implicit knowledge of targets from a selective attention task, at least under the present circumstances where targets and distracters overlap spatially. Follow-up work is needed to determine whether older adults' attention to targets suffers when distracters appear in different locations are more salient, or when the perceptual load of the task is otherwise increased. Based on the results of the present study, we suggest that older adults appear to be processing *too much* information, which may be the underlying cause of their poor task performance in the face of distraction.

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