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Greater priming for previously distracting information in young than older adults when suppression is ruled out

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Abstract

The use of previously distracting information on memory tests with indirect instructions is usually age-equivalent, while young adults typically show greater explicit memory for such information. This could reflect qualitatively distinct processing (encoding) of distracting information by younger and older adults, but could also be caused by greater suppression of such information by younger adults on tasks with indirect instructions. In Experiment 1, young and older adults read stories containing distracting words, which they ignored, before studying a list of words containing some previously distracting items for a free recall task. Half the participants were informed of the presence of previously distracting items in the study list prior to recall (direct instruction), and half were not (indirect instruction). Recall of previously distracting words was age-equivalent in the indirect condition, but young adults recalled more distracting words in the direct condition. In Experiment 2, participants performed the continuous identification with recognition (CID-R) task, which captures a measure of perceptual priming and recognition on each trial, and is immune to suppression. Priming and recognition of previously distracting words was greater in younger than older adults, suggesting that the young engage in more successful suppression of previously distracting information on tasks in which its relevance is not overtly signalled.

Keywords*:* aging, distraction, priming, implicit memory, suppression

Word count: 7894

Age-related changes in attention and inhibitory control can negatively affect performance on many tasks. For instance, older adults show greater disruption than younger adults on tasks when irrelevant or distracting information is present (e.g., Connelly, Hasher, & Zacks, 1991; Darowski, Helder, Zacks, Hasher, & Hambrick, 2008; May, 1999). According to the inhibitory deficit hypothesis (Hasher & Zacks, 1988), this is because older adults are worse than younger adults at ignoring such task irrelevant information, which leads to additional processing of this information.

Encoding of task irrelevant information can also affect performance on subsequent tasks (see Weeks & Hasher, 2014). Studies have shown that older adults experience more proactive interference than younger adults on various memory tests (e.g., Gazzaley, Cooney, Rissman, & D'Esposito, 2005; Gerard, Zacks, Hasher, & Radvansky, 1991; Hamm & Hasher, 1992; Hay & Jacoby, 1996, 1999; Lustig, May, & Hasher, 2001; May, Hasher, & Kane, 1999; Rowe, Hasher, & Turcotte, 2008), but there are also situations in which memory in relation to previously task irrelevant information is better in older relative to younger adults. For example, Rowe, Valderrama, Hasher, and Lenartowicz (2006) found that older adults completed more word fragments with solutions that had appeared as distraction in an earlier task than young adults did. Also, Campbell, Hasher, and Thomas (2010) found enhanced recall in older compared to younger adults for picture-word pairs that had appeared in a previous phase as distraction. These findings are consistent with the notion that older adults engage in additional processing of task irrelevant information in comparison to younger adults, which can be beneficial on future tasks if such information becomes relevant.

However, recent studies have uncovered evidence that young adults can also access from memory previously distracting information when it becomes relevant to the task goals. In Thomas and Hasher (2012), young and older adults read a series of stories containing distracting words that they were asked to ignore. They then studied a list of words, which was half comprised of the distracting items from the stories, for a free recall test. When participants were not made aware that the study list contained previously distracting items (indirect instruction), young and older adults' free recall of the previously distracting words was equivalent (Experiment 1). However, when participants were informed that the study list contained words that had appeared earlier in the experiment (direct instruction), young adults' memory for the distracting words surpassed that of older adults' (Experiments 2 and 3). Importantly, in Thomas and Hasher's Experiment 3, participants were not informed about the presence of distracting items until immediately before recall, so the greater retrieval of distracting items by young adults cannot be attributed to deeper encoding of the study list and must be due to accessing the distracting information encoded during the story reading task. In another study, Gopie, Craik and Hasher (2011) asked participants to indicate the text colour of words, while ignoring the words themselves. Participants then performed a word-fragment completion (WFC) task under either indirect instructions (to complete the fragments with the first word that came to mind) or direct instructions (to complete the fragments with the distracting words from the previous phase).[1] The use of previously distracting items as solutions in the indirect condition was greater in older relative to younger adults (greater implicit memory for previously distracting information), but in the direct condition young adults were able to retrieve more of these items than older adults. Given these findings, it cannot be the case that older adults encode more task irrelevant information than young adults. Both are able to retrieve previously distracting information from memory, but age differences emerge depending on the task requirements – specifically, whether or not the information is explicitly called upon.

Gopie et al. (2011) suggested that the age-differential pattern of retrieval of previously distracting information on explicit and implicit tests reflects qualitatively distinct initial processing of such information by young and older adults. They argue that, when distracting information is present, older adults process it in a more shallow, perceptual fashion compared to young adults, who encode this information at a relatively more deep and conceptual level (see Craik, 1983; 1986, for a detailed explanation of how depleted encoding resources due to aging results in a reduction in the ability to engage in elaborative memorial processing). Most implicit memory tests rely on perceptual (data-driven) processing, while explicit retrieval requires more elaborate conceptual processing (see Craik, Moscovitch, & McDowd, 1994; Jacoby, 1983; Roediger & Blaxton, 1987), so this may explain the age-differential pattern of performance on these tasks. That is, older adults' shallow, perceptual encoding might lead to superior performance on implicit tasks that reinstate this type of processing at retrieval, whereas young adults' use of deep, conceptual encoding might lead to greater performance on explicit tasks that draw upon this type of processing at retrieval (transfer-appropriate processing, Morris, Bransford, & Franks, 1977; Roediger, Weldon, & Challis,1989). In support of this, Gopie et al. (2011; Experiment 3) showed that when young adults' attention during the study phase was reduced (by giving them a second simultaneous task) such that they were forced to encode distracting items superficially, the pattern of results simulated that seen in older adults: completion of word fragments using previously distracting items was greater under indirect than direct instructions.

Another compelling explanation for the age-differential pattern concerns age differences in retrieval control. It is well established that young adults are better than older adults at switching tasks without as much interference from earlier ones (e.g., Kray & Lindenberger, 2000; Lien, Ruthruff, & Kuhns, 2008; Lustig et al., 2001; May, Hasher, & Kane, 1999; Mayr, 2001), and suffer less 'response conflict' in relation to familiar but irrelevant items stored in memory (Jonides et al., 2000). Moreover, Hasher, Zacks, and May (1999) argue that the process of suppression (deactivation) of no-longer-relevant information is more efficient in young than older adults. Thus, young adults may be better able to suppress previously encoded distracting information on future tasks in which its use is not deemed relevant (i.e., on a task with indirect instructions). For example, in Thomas and Hasher (2012), participants were initially exposed to distracting words in the context of a story reading task, before studying a list of words (half previously distracting) for a free recall test. The free recall task was either performed under indirect instructions (where there was no mention of the presence of previously distracting items in the study list), or direct instructions (in which participants were informed that some words in the study list had appeared earlier in the experiment). Therefore, as the authors explained, young adults in the indirect condition may have limited their retrieval solely to the studied list of words, and suppressed the seemingly irrelevant distracting words that were encoded during the story reading task. By contrast, when the test phase instructions pointed to the reading task as another relevant source of information (the direct condition), young adults may have been able to relax their constraint on retrieval in order to output the previously encoded distracting items from the stories as well. Due to a deficit in such retrieval control, older adults may not be as good at suppressing previously distracting items in the indirect condition, and so their recall in this condition may reflect a search of memory based on the studied list of words as well the distracting words from the stories.

The present study examined whether the age-differential pattern of retrieval of previously distracting information is due to greater suppression by young than older adults on tasks with indirect instructions (e.g., as suggested by Thomas and Hasher, 2012), or to qualitatively distinct initial encoding of such information (e.g., as suggested by Gopie et al., 2011). As in previous studies, we use the term ‘suppression’ to label the process that attempts to restrict retrieval of previously distracting information on tasks in which it is not deemed relevant, but we do not attempt to elucidate the mechanisms of any such suppression. The goal of Experiment 1 was to attempt to replicate the observation by Thomas and Hasher (2012) that transfer of previously distracting information influences subsequent retrieval in different ways in young and older adults depending on whether the task instruction is direct or indirect. This is important given the impact and implications of such a finding. To preview, we observed a significant interaction between task instruction (direct/indirect) and word type (distracting/new [new items are those presented in the study list but not the stories]) in young adults only, demonstrating similar recall of previously distracting and new items when the task instruction was direct, but lower recall of previously distracting than new items when the instruction was indirect. Experiment 2 then examined age differences in relation to previously distracting information on a perceptual implicit task in which suppression is discouraged (outlined in the introduction to Experiment 2). If the age-differential pattern is due to greater suppression of previously distracting information by younger than older adults, a task that eliminates suppression should lead to greater transfer of distraction in younger adults. Conversely, if the age-differential pattern is due to qualitatively distinct initial encoding of distraction (i.e., conceptual encoding by young adults and perceptual encoding by older adults), one would predict greater perceptual priming in older than younger adults.

Experiment 1

Young and older participants read a series of short stories containing distracting words, which they were asked to ignore. After a 10 minute filler task they studied a list of words for a recall test, which was half comprised of the distracting items from the stories. Finally, participants were asked to free recall the items from the study list. Initial encoding of distraction was incidental given that participants were asked to ignore the distracting words in the stories, and were not aware during the reading task that some of the words would later become relevant. Immediately prior to recall, half the participants were informed that some of the words on the study list had appeared earlier in the experiment (direct instruction group, similar to Thomas and Hasher, Experiment 3), while the other half were not informed of the connection between the reading task and the study list (indirect instruction group, similar to Thomas and Hasher, Experiment 1). Thus, although the free recall task itself is explicit, only half the participants were given instructions that pointed directly to the reading task as a relevant source of information.

Method

Participants

Participant demographic information is summarised in Table 1. Forty-eight young adults (seven male; *M* age = 20.25 years, *SD* = 2.16) and 48 older adults (ten male; *M* age = 70.25 years, *SD* = 6.10) took part in Experiment 1. The young participants were students from the University of York and Middlesex University, London, all of whom participated in exchange for course credit. The older adults were local members of the University of the Third Age (U3A) organisation, who responded to an advertisement seeking volunteers. All participants were native English speakers who reported good health. We replaced the data from two young and two older participants in the indirect instruction group who reported awareness of the connection between the distracting words in the stories and the later memory test. No other participants were excluded (our exclusion criteria included a Mini Mental State Exam (MMSE) score of under 27 – no older participant in the current study scored below 28 – and/or a failure to understand or complete the task in full). Our sample size was calculated based on the average effect size reported by Thomas and Hasher (d = 0.84). Twenty four participants per group were required to ensure 80% power to detect effects of this magnitude.

[Table 1 about here]

Design

The experiment used a mixed factorial design with the between-participants factors age group (young/older adult), and instruction (direct/indirect), and the within-participants factor word type (distracting/new). The number of words correctly recalled in each condition was the dependent measure.

Materials

The original materials were obtained from Thomas and Hasher. Four stories with an average length of 174 words were used in the reading task. The stories were presented in Century 12-point font, with target text italicized, and distracting words in standard, upright text. Each story contained 16 distracting words that were repeated five times (each story contained 80 distracting items in total, and each distracting word was shown 20 times across the four stories). Three lists of eight words, between three and eight letters in length, were used as distracting items, matched for frequency, word length, and concreteness were used. Sixteen words (i.e., two lists) were presented as distracting items in the stories, and half appeared again in the study list, along with eight new words (i.e., the final list). The other eight distracting words in the stories served as filler items, and were not presented in the later parts of the experiment. They were included to reduce the chance of participants noticing the connection between the words in the reading task and subsequent phases. The three word lists were counterbalanced such that each item appeared equally often as a target distracter, filler distracter, and new item.

Procedure

Participants were tested individually, and the duration of the experiment was approximately 90 minutes. Participants completed a background questionnaire and a near vision test prior to the reading task. Participants were presented with four stories, one at a time, and asked to read them aloud. They were informed of the presence and appearance of the distracting words, and told that their task was to read aloud only the text printed in italics, and to completely ignore and not read out the distracting words in upright text. They were asked not to follow along the line of text with their finger while reading, and were given a short practise story to read before the main task. They were told that they would be asked questions about what happened in the stories later. Reading times and errors (number of verbalisations of distracting words) were recorded by the experimenter.

Following this phase was a 10 minute distracter task in which participants completed a series of arithmetical sums. Immediately after, participants were told that they would study 16 words for a free recall task. They were not informed that some of the words had appeared earlier as distracting items in the stories. Each word was presented in the centre of the computer screen in Century 12-point font for 1,500ms, followed by a blank screen for 500ms. Participants were instructed to pay full attention to the words. Immediately after presentation of the final word, participants were asked to free recall as many of the words as possible, in any order. Half the participants in both groups were informed immediately prior to recall that some of the items in the study list had appeared earlier in the experiment (direct instruction), and the other half were not (indirect instruction). Finally, after participants had finished their free recall, those in the indirect instruction group were asked whether they had noticed any connection between the tasks, and if so, to describe it (this was to gauge awareness that some of the words in the study list had been presented as distracting items in the stories).

Finally, participants completed the remaining tests, including the Wechsler Test of Adult Reading (WTAR), the Wechsler Adult Intelligence Scale (WAIS-III) Vocabulary and Digit Symbol Substitution tests, and the MMSE (older adults only).

Results and Discussion

An alpha level of .05 was used, and all *t*-tests were two-tailed.

Reading task. Mean reading times were at 1.55 min (*SD* = 0.37) and 1.52 min (*SD* = 0.35) for young adults in the indirect and direct conditions, respectively, and at 1.56 min (*SD* = 0.43) and 1.64 min (*SD* = 0.45) in older adults in the indirect and direct conditions, respectively. The mean number of errors (i.e., distracting words read aloud) made by older adults was 4.38 (*SD* = 3.16) in the indirect condition and 4.00 (*SD* = 3.40) in the direct condition, and young adults made 2.92 (*SD* = 4.02) errors in the indirect condition and 3.21 (*SD* = 3.35) errors in the direct condition. Separate 2 (age group: young/older adult) by 2 (condition: indirect/direct instruction) ANOVAs showed no significant main effects on reading times or number of errors (greatest $F(1, 92) = 2.14$, $p = .147$). We also examined age differences in reading times in the first two stories only, when distraction was novel (means of 1.58 min ($SD = 0.40$) and 1.54 min ($SD = 0.50$) for young adults in the indirect and direct conditions, respectively, and 1.75 min ($SD = 0.48$) and 1.78 min ($SD = 0.48$) for older adults in the indirect and direct conditions, respectively). This analysis revealed a main effect of age group, $F(1, 92) = 5.37$, $p = .023$, $\eta_p^2 = .06$, no main effect of condition, $F(1, 92) < 1$, $p = .771$, and no interaction, $F(1, 92) < 1$, $p = .899$.

Recall. The number of previously distracting and new items recalled by young and older adults in the indirect and direct instruction conditions is shown in Figures 1A and 1B. There was a significant interaction between age group and word type (distracting/new) in the indirect instruction group, $F(1, 46) = 4.59$, $p = .038$, $\eta_p^2 = .09$, but not in the direct instruction group, $F(1, 46) < 1$, $p = .939$. Young adults in the indirect instruction condition recalled significantly more new words than older adults, $t(46) = 3.12$, $p = .003$, $d = 0.90$, which is consistent with the widely reported age-related reduction in memory, however there was no age difference in the level of recall of distracting items in this condition, $t(46) < 1$, $p = .785$. There was a significant main effect of age group in both conditions ($F(1, 46) = 5.14$, $p = .028$, $\eta_p^2 = .10$, and $F(1, 46) = 4.34$, $p = .025$, $\eta_p^2 = .10$, for the indirect instruction and direct instruction groups, respectively), but in the indirect instruction group this was driven by greater recall of new items in young relative to older adults (see above), whereas young adults in the direct instruction group recalled more of both word types in comparison to older adults (there was a main effect of word type in the direct instruction group, $F(1, 46) = 4.27$, $p = .045$, $\eta_p^2 = .09$, but not in the indirect instruction group, $F(1, 46) < 1$, $p = .837$).

The results demonstrate differential recall of distracting and new items across instruction conditions in young adults only, and this is qualified by a significant interaction between instruction condition and word type in young but not older adults ($F(1, 46) = 4.88$, $p = .032$, $\eta_p^2 = .10$, and $F(1, 46) < 1$, $p > .05$, for young and older adults, respectively). Young adults recalled marginally more new than previously distracting words when the task instruction was indirect ($t(23) = 1.83$, $p = .081$, $d = 0.44$), but this trend was eliminated (and the numerical effect reversed) when the task instruction was direct ($t(23) = 1.31$, $p = .202$). Older adults recalled a similar number of previously distracting and new items irrespective of the task instructions (both $p > .05$).

[Figures 1a and 1b about here]

The findings suggest that both young and older adults encode and can use previously distracting information in later tasks, but age differences in recall vary depending upon the instructions. Although in the indirect instruction condition there was a significant age difference in recall of new items favouring the young, there was no such age difference for previously distracting items, and this may be indicative of more successful suppression of such items by young than older adults in this condition.

Some of the present results differ to those in Thomas and Hasher (2012). In the indirect condition in the original study, older adults recalled significantly more previously distracting than new words, whereas this difference did not reach significance in the present study. Moreover, in Thomas and Hasher's study young adults recalled a similar number of the two types of words in this condition, whereas in the present study young adults recalled more new than previously distracting words. This observation strengthens the claim that younger adults engage in more successful suppression of previously distracting items: One would not expect recall of previously distracting items to be equivalent to or lower than that of new items if some form of suppression had not occurred, especially given the evidence from the direct instruction condition that young individuals can call upon this information when required. Participants were informed of the relevance of the previously distracting items only after studying the list of words, so the pattern cannot be explained by young adults suppressing these items at the point of studying the list of words. It is possible that older adults also attempt to suppress previously distracting items in this condition, but young adults are likely to be more successful at this. If older adults were also successfully suppressing the previously distracting items in this condition then we might expect their recall of such items to be lower than that for new items, but it was numerically greater (the opposite pattern to that shown by young adults).

Another explanation for the results is that young and older adults initially process distracting information in qualitatively distinct ways, resulting in differential subsequent performance on tasks with direct and indirect instructions. Older adults shallow/perceptual encoding may facilitate performance on tasks with indirect instructions, while young adults' deep/conceptual encoding may facilitate performance on tasks with direct instructions, due to transfer appropriate processing. However, if the suppression explanation above is true, there is no reason to believe that young and older adults differ in their initial encoding of distraction, as the patterns can be explained solely by age differences occurring at the point of retrieval. Experiment 2 examined whether young adults show greater performance in relation to previously distracting information than older adults on an indirect task in which suppression is ruled out.

Experiment 2

A speeded perceptual identification task is likely to overcome suppression. In such a task there is a single, well-defined goal (to identify words as quickly as possible), so participants do not have flexibility in their performance strategy, and there is no reason for suppression of a response to occur. It is unlikely that participants would actively try to inhibit a response on this type of task, and indeed there would be very little time for any type of suppression to occur. The initial phases of the experiment were identical to Experiment 1, but at test participants performed the continuous identification with recognition (CID-R) task (e.g., Conroy, Hopkins, & Squire, 2005; Stark & McClelland, 2000; Ward, Berry, & Shanks, 2013a), which involves the concurrent trial-by-trial capture of priming and recognition. On each trial participants identified (named) a word as quickly as possible as it gradually emerged from a background mask (priming was indexed by reduced identification times for previously studied items (e.g., previously distracting words) compared to new items), before making a recognition judgement in relation to the word.

Ward et al. (2013a) showed that the CID-R task is sensitive to age-differences in priming[2], and that it is unaffected by the use of intentional memory strategies. Thus, it can be said to capture a pure or ‘uncontaminated’ measure of priming. This is important in the context of the present investigation because it is unlikely that participants would be able to suppress a primed response in relation to a previously distracting item. Therefore, if young adults tend to engage in greater suppression of previously distracting information than older adults on tasks with indirect instructions, they should show greater transfer of distraction than older adults when the possibility of suppression is eliminated (i.e., one would predict greater priming in young than older adults in the present task).

On the other hand, if the age-differential pattern is due to qualitatively distinct initial encoding of distraction by young and older adults, one would predict greater priming but lower recognition in older than younger adults on the CID-R task, which involves a highly perceptual priming task (most suitable for the encoding style argued to be used by older adults) and a conceptually driven recognition task (most suitable for the encoding style argued to be used by younger adults). The priming task draws strongly upon perceptual processing, and repetition priming effects are greatest when encoded representations match visually presented test stimuli (e.g., Roediger & Blaxton, 1987), thus, we would not expect conceptually encoded representations to benefit performance on the identification task.

Participants were made aware at the point of the test phase that some words appearing in the CID-R task also appeared in the study list. However, at no point were participants informed that some items appearing in the test had also appeared as distracting items in the stories. The rationale for including the recognition judgement was twofold: First, given the evidence that the presence of the recognition judgement alongside identification does not affect priming (i.e., the priming task is not subject to explicit contamination, see Ward et al. 2013a), we deemed it useful to capture such a measure. Second, although explicit, the recognition task was actually performed under the same conditions as the free recall task with indirect instructions in Experiment 1 – participants were not made aware that some items previously appeared as distraction in the stories – so we believed this to be a useful task against which to compare the earlier findings.

Method

Participants

Twenty-four young (four male; *M* age = 19.38 years, *SD* = 1.35) and 24 older (eight male; *M* age = 70.54 years, *SD* = 5.90) adults participated (see Table 2). Young adults were students from Middlesex University, who took part in the study in exchange for course credit, and the older adults were recruited through the U3A. All participants were native English speakers who reported good health. No participant reported awareness of the presence of previously distracting items in the final test (CID-R phase). Ward et al. (2013a) reported effect sizes in the region of $d = 0.83$ using the CID-R task to examine age differences in priming and recognition, thus 24 participants per group were once again needed to achieve 80% statistical power.

[Table 2 about here]

Design

The between-participants factor was age group (young/older adult), and the within-participants factor was word type (distracting/new). There were two dependent measures:

Response times (RT) in milliseconds in the identification task, and the proportion of hits (old items judged old) and false alarms (new items judged old) in the recognition task.

Materials and procedure

The materials and procedure were the same as in Experiment 1, except that participants performed the CID-R task instead of free recall. Immediately following presentation of the final item in the study list, participants were given instructions for the CID-R task. They were told that on each trial they would have to identify a word as it gradually emerged on the computer screen. They were informed that the word would be obscured by a grid and difficult to make out at first, but that it would gradually become clearer. They were instructed to press the Enter key as soon as they knew the identity of the word, and then type it into a box that would appear on the screen. Speed was emphasised, but participants were asked to try to be as accurate as possible, and not press the Enter key until they were confident that they would identify the word correctly. Participants were also instructed that some items were previously shown in the study list, and that after each identification they would be asked to decide whether or not they believed the word was shown in the study list. As in Experiment 1, at no point were participants informed that some of the words in the study list also appeared in the story reading task as distracting items.

The CID-R task was programmed in Matlab 6 using the Cogent 2000 Toolbox. Each trial consisted of a speeded masked-word identification in which RTs were measured, and a recognition judgement. Thirty two items were presented in total: The eight previously distracting items witnessed in the stories and the study list (old-distracting items); the eight items that were presented in the study list but not the stories (old-study items), and 16 completely new items. Each item was presented in Century 12-point font in the centre of a white screen background. The mask used in the identification task was a 400 x 400 pixel grid randomly filled with black and white noise.

Each CID-R trial was self-initiated by the participant, and began with the identification task: The mask was initially presented in the centre of the screen for 500 ms. A word (old-distracting, old-study, or new) was then presented for 17 ms, followed immediately by the mask for 233 ms (making a 250 ms block). These block presentations were repeated, with the duration of word presentations increasing by 17 ms on every alternate block while the total block duration remained constant. The effect is that the word appears to gradually emerge from behind the mask. Participants were required to identify (name) the word as quickly and accurately as possible as it emerges, pressing the ‘Enter’ key when they knew its identity. RTs were captured on the keypress, at which point the word disappeared and participants were prompted to type it into a box that appeared on the screen. The block presentations ceased at 7 sec (30 blocks) after initiation if identification had not taken place, and any such trials were discarded.

The recognition segment of the trial immediately followed each identification. The word was presented once more and participants were required to make a judgement as to whether they thought it had appeared in the study list using a 6-point scale where 1 = *very sure no*; 2 = *fairly sure no*; 3 = *guess no*; 4 = *guess yes*; 5 = *fairly sure yes*; 6 = *very sure yes*. No time limit was imposed on recognition judgements, and no feedback was provided. All trials were randomised, and upon completion of the experiment, participants were assessed for awareness that some of the words in the study list had been presented as distracting items in the stories. Finally, participants completed the WTAR, the WAIS-III subtests, and the MMSE (older adults only).

Results and Discussion

Reading task. As in Experiment 1, when analysed as a whole there were no significant age differences in reading times (1.61 min (*SD* = 0.46) and 1.69 min (*SD* = 0.42), for young and older adults, respectively), $t(46) < 1$, $p = .544$, or the number of errors produced (3.63 (*SD* = 4.03) and5.82 (*SD* = 4.07), for young and older adults, respectively), *t*(46) = 1.84, *p* = .073. However, older adults read the first two stories with distraction more slowly than younger adults, (1.57 min (*SD* = 0.31) and 1.80 min (*SD* = 0.42), for young and older adults, respectively), *t*(46) = 2.12, *p* = .039, *d* = 0.61.

Priming. Mean identification RTs for each item type for the two groups can be found in Table 3. Priming was calculated for old-distracting and old-study items by subtracting the mean studied item RT (old-distracting or old-study) from the participants' mean RT for new items, and this was expressed in proportion to the individuals' baseline (new item) RT, and averaged within each group (see Figure 2A). We planned to exclude trials associated with incorrect identifications, as well as those associated with RTs greater than 2.5SD from the mean, but there were no such cases.

Priming was significantly above chance (i.e., > 0 ms) for both word types in young adults (*t*(23) = 9.86, *p* < .001, *d* = 2.01, and *t*(23) = 6.87, *p* < .001, *d* = 1.39, for old-distracting and old-study items, respectively), and older adults (*t*(23) = 5.42, *p* < .001, *d* = 1.10, and *t*(23) = 3.89, *p* = .001, *d* = 0.79, for old-distracting and old-study items, respectively). A mixed ANOVA revealed a main effect of age group, *F*(1, 46) = 7.08, *p* = .011, η_p^2 = .13, no main effect of word type, *F*(1, 46) < 1, *p* = .383, and no significant interaction, *F*(1, 46) < 1, *p* = .571. Priming was greater in young than older adults for old-distracting items, *t*(46) = 2.94, *p* = .005, *d* = 0.83, but not old-study items, *t*(46) = 1.73, *p* = .090.

[Figures 2a and 2b about here]

Recognition. Ratings 4-6 (*'yes'* – old) and 1-3 (*'no'* – new) on the 6-point scale were collapsed. For each participant, the proportion of hits (studied words judged as studied) and false alarms (new words judged as studied) were used to calculate *d′* for old-distracting items and old-study items (Figure 2B; See Table 4 for hits and false alarms). Discrimination was significantly greater than chance (i.e., d' > 0) for young and older adults for both old-distracting items, and old-study items (all *t*'s(23) > 13, *p*'s < .001, *d*'s > 2.79). There was a main effect of age group, $F(1, 46) = 5.16$, $p = .028$, $\eta_p^2 = .10$, no main effect of word type, $F(1, 46) < 1$, $p = .756$, and no interaction, $F(1, 46) < 1$, $p = .689$. Recognition was greater in young than older adults for both old-distracting items, $t(46) = 2.19$, $p = .034$, $d = 0.63$, and old-study items, $t(46) = 2.06$, $p = .045$, $d = 0.59$.

[Tables 3 and 4 about here]

Priming and recognition of previously distracting items were greater in young than older adults. Thus, we present new evidence that young adults can access previously distracting information for use on tasks with indirect instructions when suppression is ruled out. This also suggests that the superior performance in relation to previously distracting items often shown by older adults does not reflect a qualitatively distinct encoding style (e.g., shallow/perceptual) to that used by young individuals (e.g., deep/conceptual), which better equips them for indirect tasks. The fact that previously distracting items were clearly accessible to young adults on the CID-R task, which is not only highly perceptual but also rules out suppression, reinforces the notion that these individuals are better at suppressing output of such items when their use is not deemed relevant.

The findings with regards to recognition are interesting. As explained previously, although recognition is a standard explicit memory test, participants were not informed that some words in the test phase previously appeared in the stories as distraction, so it was performed under conditions akin to those in the indirect recall task in Experiment 1. The pattern of results, however, differed – there was a clear reduction in recognition with age for both word types. Thus, young participants did not suppress the previously distracting items in the recognition task. This is discussed further in the next section.

General Discussion

This study investigated whether age differences in the transfer of distraction to tasks with indirect instructions is due to greater suppression of seemingly irrelevant information by young adults, or to qualitatively distinct initial encoding of distraction by young and older adults. Experiment 1 showed differential retrieval of previously distracting and new items in young and older adults as a function of task instructions (direct versus indirect). Young adults' recall of new words (those that did not initially appear as distracting items in the story reading task) was greater than that of previously distracting words when task instructions were indirect, but they showed no difference in recall of new and previously distracting words when the instructions were direct. In contrast, retrieval of previously distracting and new words did not vary in older adults as a function of the task instructions. Young adults may have limited their retrieval to words from the study list in the indirect instruction condition, suppressing the previously distracting items from the stories. Indeed, in Experiment 2, when suppression was ruled out by using a speeded perceptual identification task, young adults showed significantly greater priming for such items compared to older adults.

The study provides evidence that young adults can access previously encoded distracting information when suppression is ruled out. It is well established that young adults are better than older adults at constraining their retrieval to relevant sources (e.g., Jacoby, Shimizu, Velanova, & Rhodes, 2005), and that they are better at suppressing no-longer-relevant information (e.g., Biss, Ngo, Hasher, Campbell, and Rowe, 2013; Hasher et al. 1999). Such control over retrieval may be useful when task switching, but also explains young adults' failure to transfer previously encoded distracting information to subsequent tasks in which its use is not explicitly called upon. In the present Experiment 1, young adults may have limited their retrieval solely to the studied list of words in the indirect condition, successfully suppressing the seemingly irrelevant distracting information that was encoded during the story reading phase. Although the distracting words in the stories were also presented in the study list (unbeknownst to participants), suppression of the unwanted items from the reading phase may have been strong enough to prevent more of these items from being recalled. By contrast, when the recall instructions pointed to the story reading phase as another relevant source of information (the direct condition), young adults may have been able to relax their control over retrieval in order to output the distracting information encoded during this phase. Due to a deficit in such retrieval control, older adults may not be as good at suppressing previously distracting items in the indirect condition, and so their recall may reflect a wider search of memory based on the studied list of words as well the distracting words from the stories.

As mentioned, we use the term ‘suppression’ to label the process that attempts to restrict the retrieval of previously distracting items on tasks in which they are not deemed relevant, but it is beyond the scope of this article to explain the mechanisms of such suppression. However, this is an important area of exploration for future studies. One possibility is that the suppression functions to prevent previously distracting items from coming to mind while performing a seemingly unrelated task – a front-end control process such as source-constrained retrieval (e.g., Jacoby et al., 2005) that is inferior in older adults meaning that more of such items are retrieved. This is also consistent with the deletion function explained within inhibitory theory (e.g., Lustig, Hasher, & Zacks, 2007). Since young adults are better at constraining their retrieval to relevant sources of information, they may not have brought as many previously distracting items to mind in the indirect condition. Another possibility is that distracting items do come to mind while performing tasks with indirect instructions, but young adults are more likely than older adults to disregard them due to their apparent lack of relevance (post-retrieval monitoring, e.g., Koriat & Goldsmith, 1996). Post-retrieval monitoring allows the individual to select the most appropriate (or preferred) response among a number of retrieved candidates, and because in the present Experiment 1 the goal of the task was to recall items from the *study list*, young participants may have disregarded previously distracting items coming to mind due to uncertainty about where they were encountered (the stories or the study list). On at least some occasions they may have incorrectly attributed a retrieved item's familiarity wholly to the reading task, and dismissed it as irrelevant. This is not to suggest that older adults have better source memory, but they may be more likely to output any recently encountered item that comes to mind.

Such a mechanism could also operate in other commonly used implicit tasks, such as WFC. For example, in Gopie et al. (2011), participants were instructed to complete word fragments with the first word that came to mind (some solutions had appeared as distraction in a previous phase), but it is possible that young participants did initially generate previously distracting items as solutions, but simply opted for alternative solutions because the task is framed as unrelated to the previous one, and/or because they are concerned that they are supposed to have ignored such items previously. Of course, this would mean that participants are not strictly following instructions to complete the fragments with the first word that comes to mind, but this problem and the fact that such tasks allow considerable flexibility in terms of response strategy, has been raised in the past (see Buchner & Wippich, 2000; Ward et al.,2013a; Ward, Berry, & Shanks, 2013b). It must be conceded that failing to produce a target on a test with indirect instructions does not necessarily mean that it was not retrieved from memory, and inferring an absence of 'implicit access' to previously distracting items on this basis should be approached with caution.

It has been also suggested that the age-differential pattern of retrieval of previously distracting information on direct and indirect tasks is due to qualitatively distinct initial encoding of such information by young and older adults. Gopie et al. (2011) argued that older adults process distracting information in a shallow/perceptual manner, and young adults in a deep/conceptual manner, thus the differential performance by the two age groups on explicit and implicit tasks can be explained by transfer-appropriate processing (because implicit tests usually rely on perceptual processing and explicit tests on conceptual processing). Given the findings of the present Experiment 2, there is no reason to believe that young and older adults differ in their initial encoding of distraction. If differential encoding had occurred in the way in which Gopie and colleagues describe, then older adults would have been better equipped for the identification task, which is highly perceptual, yet priming was significantly greater in young adults. Since repetition effects on perceptual tasks are greatest when encoded representations match the visually presented test stimuli (e.g., Roediger & Blaxton, 1987), conceptually encoded representations (i.e., in young adults) would not have resulted in greater priming in the present task. Gopie et al. (2011) reported lower explicit than implicit memory in young adults for distracting words that they were initially exposed to under conditions of divided attention (Experiment 3). They argued that divided attention forced participants to encode distracting items superficially (akin to the processing style of older adults), and it was this that provided a benefit to the subsequent implicit task and detriment to the explicit task. An alternative explanation is that the weak encoding made successful suppression more difficult in the indirect condition.

As well as elucidating the suppression mechanisms, it will also be important for future studies to examine the neurological underpinnings. It has been suggested that post-retrieval monitoring reflects activity of the dorsolateral prefrontal cortex (Achim & Lepage, 2005), which is implicated in activating goal-relevant knowledge. Activation of the ventrolateral prefrontal cortex has also been shown to be involved in a post-retrieval selection process that deals with competition between simultaneously active memory representations (Badre & Wagner 2007). Changes in the integrity of these structures with age, and the resulting effects on the suppression of task irrelevant information, is a much needed area of exploration. Age-related changes in medial prefrontal cortex activation have been linked to changes in the ability to suppress unwanted information (Chadick, Zanto, & Gazzaley, 2014).

The findings from Experiment 2 with regards to recognition are interesting. Because participants were not informed that some items in the CID-R task also appeared in the stories as distraction, it was performed under conditions akin to those in the indirect recall task in Experiment 1, yet the pattern of results differed. Young adults' recognition of previously distracting words was reliably greater in comparison to that of older adults, while there was no such age difference in recall. Thus, although young adults suppressed previously distracting items in the indirect recall task in Experiment 1, they did not do so while performing the recognition task. One explanation is as follows: In a situation where a previously distracting word is presented in a recognition task, young participants may be more likely to make a positive judgement (hit) than they are to dismiss it (miss), given the greater overall familiarity of the item compared to new items (see Jacoby, 1991, for a discussion on the role of familiarity in recognition). In contrast, if a previously distracting word comes to mind in a free recall task, participants may be more inclined to dismiss it due to uncertainty about where it was initially encountered. In other words, being faced with a familiar word in the context of a recognition task may reinforce the mentality that it must have been presented in the study list (because participants were not made aware that distracting items from the stories are present), leading to a positive recognition judgement.

The lack of a significant difference in priming between previously distracting and new words in Experiment 2 warrants consideration. In line with previous studies (e.g., Grant & Logan, 1993), one would expect priming to be greater for repeated compared to unrepeated items. Given that distracting items were shown 20 times in the story reading task and new items just once in the study list, one might wonder why priming was only numerically greater for previously distracting items in both age groups. However, it is important to note that although the distracting items were repeated, they were ignored (unattended) during the reading task. Only while studying the list of words (half previously distracting) did participants attend to these items. To our knowledge no study has compared priming for repeated but weakly encoded/unattended items to priming for unrepeated but strongly encoded/fully attended items, but one might not predict a robust difference.

Finally, prior studies have demonstrated greater slowing in older adults' reading times when distracting words are present (e.g., Connelly et al., 1991; Duchek et al. 1998; Dywan & Murphy, 1996; Thomas & Hasher, 2012), yet the absence of such an age difference on the whole in the present study suggests that older adults were not more disrupted by the presence of distracting items (but note that older adults read more slowly compared to younger adults when the first two stories with distraction were analysed separately, similarly to Thomas and Hasher, 2012). Kim, Hasher, and Zacks (2007) also reported no age-differential slowing caused by distracting items when age differences in processing speed were controlled for. They suggested that there may be no age differences in the susceptibility to distraction during reading, and that young and older adults may initially process distraction in a similar way. The present findings suggest that encoding of distraction was equivalent between groups (at least, exposure to distracting items was equal since reading times did not differ as a whole), so the age-differential pattern of recall of previously distracting items must be due to age differences occurring at the point of retrieval.

To conclude, this study sheds light on the mechanisms of the age-differential pattern of retrieval of previously distracting information. The evidence suggests that young adults engage in greater suppression of previously distracting information when task instructions do not refer to its relevance, but can access this information when explicitly guided to do so. A key implication is that both younger and older adults benefit from previously encoded distracting information that later becomes relevant, but in different ways. Young adults are more likely to benefit from prior distraction when its relevance to the current task goals is explicit, whereas older adults benefit from previously encoded distracting information in the absence of explicit cues to use the information. Thus, although distraction in the current environment can have negative consequences for cognitive processing in older adults, under some circumstances this can bolster memory performance on future tasks.

References

Abbenhuis, M. A., Raaijmakers, W. G. M., Raaijmakers, J. G. W., & Van Woerden, G. J. M. (1990). Episodic memory in dementia of the Alzheimer type and in normal aging: Similar impairment in automatic processing. *The Quarterly Journal of Experimental Psychology, 42*, 569–583.

Achim, A.M., & Lepage, M. (2005). Neural correlates of memory for items and for associations: An event-related functional magnetic resonance imaging study. *Journal of Cognitive Neuroscience, 17,* 652-667.

Badre, D. & Wagner, A.D. (2007.) Left ventrolateral prefrontal cortex and the cognitive control of memory. *Neuropsychologia, 45,* 2883–2901.

Biss, R. K., Ngo, K. J., Hasher, L., Campbell, K. L., & Rowe, G. (2013). Distraction can reduce age-related forgetting. *Psychological Science,* 24, 448–455.

Bowers, J. S., & Schacter, D. L. (1990). Implicit memory and test awareness. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 404–416.

Brown, A. S., Jones, T. C., & Mitchell, D. B. (1996). Single and multiple test repetition priming in implicit memory. *Memory, 4,* 159–173.

Brown, A. S., Neblett, D. R., Jones, T. C., & Mitchell, D. B. (1991). Transfer of processing in repetition priming: Some inappropriate findings. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 514–525.

Campbell, K. L., Hasher, L., & Thomas, R. C. (2010). Hyper-binding: A unique age effect. *Psychological Science, 21,* 399–405.

Chadick, J.Z., Zanto, T.P., & Gazzaley, A. (2014). Structural and functional differences in medial prefrontal cortex underlie distractibility and suppression deficits in ageing. *Nature Communications, 30,* 4223.

Chiarello, C, & Hoyer, W. J. (1988). Adult age differences in implicit and explicit memory: Time course and encoding effects. *Psychology and Aging, 3,* 358–366.

Conroy, M. A., Hopkins, R. O., & Squire, L. R. (2005). On the contribution of perceptual fluency and priming to recognition memory. *Cognitive, Affective, and Behavioural Neuroscience, 5,* 14–20.

Connelly, S. L., Hasher, L., & Zacks, R. T. (1991). Age and reading: The impact of distraction. *Psychology and Aging, 6,* 533–541.

Craik, F.I.M. (1983). On the transfer of information from temporary to permanent memory. *Philosophical Transactions of the Royal Society B: Biological Sciences, 302,* 341–359.

Craik, F.I.M. (1986). A functional account of age differences in memory. In F. Klix & H. Hagendorf (Eds.), *Human memory and cognitive capabilities, mechanisms and performances* (pp. 409–422). Amsterdam, The Netherlands: Elsevier.

Craik, F. I. M., Moscovitch, M., & McDowd, J. M. (1994). Contributions of surface and conceptual information to performance on implicit and explicit memory tasks. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 864–875.

Darowski, E. S., Helder, E., Zacks, R. T., Hasher, L., & Hambrick, D. Z.(2008). Age-related differences in cognition: The role of distraction control. *Neuropsychology, 22,* 638 – 644.

Davis, H. P., Cohen, A., Gandy, M., Colombo, P., Van Dusseldorp, G., Simolke, N., & Roman, J. (1990). Lexical priming deficits as a function of age. *Behavioral Neuroscience, 104,* 288–297.

Duchek, J. M., Balota, D. A., & Thessing, V. C. (1998). Inhibition of visual and conceptual information during reading in healthy aging and Alzheimer's disease. *Aging, Neuropsychology, and Cognition, 5,* 169–181.

Dywan, J., & Murphy, W. E. (1996). Aging and inhibitory control in text comprehension. *Psychology and Aging, 11,* 199–206.

Fleischman, D. A., & Gabrieli, J. D. E. (1998). Repetition priming in normal ageing and Alzheimer's disease: A review of findings and theories. *Psychology and Aging, 13,* 88–119.

Gazzaley, A., Cooney, J. W., Rissman, J., & D'Esposito, M. (2005).Top-down suppression deficit underlies working memory impairment in normal aging. *Nature Neuroscience, 8,* 1298–1300.

Gerard, L., Zacks, R. T., Hasher, L., & Radvansky, G. A. (1991). Age deficits in retrieval: The fan effect. *Journal of Gerontology, 46*, 131–136.

Gopie, N., Craik, F. I. M., & Hasher, L. (2011). A double dissociation of implicit and explicit memory in younger and older adults. *Psychological Science, 22*,634–640.

Grant, S. C. & Logan, G. D. (1993). The loss of repetition priming and automaticity over time as a function of degree of initial learning. *Memory & Cognition, 21*, 611–618.

Hamm, V. P., & Hasher, L. (1992). Age and the availability of inferences. *Psychology and Aging, 7,* 56–64.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and ageing: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 22, pp. 193–225). San Diego, CA: Academic Press.

Hasher, L., Zacks, R.T., & May, C.P. (1999). Inhibitory control, circadian arousal, and age. In D. Gopher & A. Koriat (Eds.), Attention and Performance XVII: Cognitive regulation of performance: Interaction of theory and applications, 653–675. Cambridge, MA: MIT Press.

Hay, J. F., & Jacoby, L. L. (1996). Separating habit and recollection: Memory slips, process dissociations and probability matching. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*,1323–1335.

Hay, J. F., & Jacoby, L. L. (1999). Separating habit and recollection in young and elderly adults: Effects of elaborative processing and distinctiveness. *Psychology and Aging, 14,* 122–134.

Hultsch, D. F., Masson, M. E. J., & Small, B. J. (1991). Adult age differences in direct and indirect tests of memory. *Journal of Gerontology: Psychological Sciences*, *46*, 22–30.

Jacoby, L. L. (1983). Perceptual enhancement: Persistent effects of an experience. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *9,* 21–38.

Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language*, *30*, 513–541.

Jacoby, L. L., Shimizu, Y., Velanova, K., & Rhodes, M. G. (2005). Age differences in depth of retrieval: Memory for foils. *Journal of Memory and Language*, *52*, 493– 504.

Jonides, J., Marshuetz, C., Smith., E.E., Reuter-Lorenz, P.A., Koeppe, R.A., & Hartley, A. (2000). Age differences in behaviour and PET activation reveal differences in interference resolution in verbal working memory. *Journal of Cognitive Neuroscience*, *12*, 188–196.

Kim, S., Hasher, L., Zacks, R.T. (2007). Aging and a benefit of distractibility. *Psychonomic Bulletin & Review*, *14,* 301–305.

Koriat, A., & Goldsmith, M. (1996). Monitoring and control processes in the strategic regulation of memory accuracy. *Psychological Review*, *103*, 490–517.

Kray, J. & Lindenberger, U. (2000). Adult age differences in task switching. *Psychology and Aging*, *15*, 126–147.

Lien, M.C., Ruthruff, E., & Kuhns, D. (2008). Age-related differences in switching between cognitive tasks: Does internal control ability decline with age? *Psychology and Aging, 23,* 330–341.

Lustig, C., Hasher, L., & Zacks, R.T. (2007). Inhibitory deficit theory: Recent developments in a “new view”. In D.S. Gorfein & C.M. MacLeod (Eds.), *The place of inhibition in cognition,* 145–162. Washington, DC: American Psychological Association.

Lustig, C., May., C.P., & Hasher, L. (2001). Working memory span and the role of proactive interference. *Journal of Experimental Psychology: General, 130,* 199–207.

May, C. P. (1999). Synchrony effects in cognition: The costs and a benefit. *Psychonomic Bulletin & Review, 6,* 142–147.

May, C. P., Hasher, L., & Kane, M. J. (1999). The role of interference in memory span. *Memory & Cognition, 27,* 759 –767.

Mayr, U. (2001). Age differences in the selection of mental sets. The role of inhibition, stimulus ambiguity, and response-set overlap. *Psychology and Aging*, *16,* 96–109.

Mitchell, D. B., & Bruss, P. J. (2003). Age differences in implicit memory: Conceptual, perceptual, or methodological? *Psychology and Aging, 18,* 807–822.

Morris, C.D., Bransford, J.D., & Franks, J.J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior*, *16*, 519–533.

Rowe, G., Hasher, L., & Turcotte, J. (2008). Age differences in visuospatial working memory. *Psychology and Aging, 23,* 79–84.

Rowe, G., Valderrama, S., Hasher, L., & Lenartowicz, A. (2006). Attention disregulation: A long-term memory benefit for implicit memory. *Psychology and Aging, 21,* 826–830.

Roediger, H. L., & Blaxton, T. A. (1987). Effects of varying modality, surface features, and retention interval on priming in word-fragment completion. *Memory & Cognition*, *15,* 379–388.

Roediger, H. L., III, & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences, 15,* 20–27.

Roediger, H.L., III, Weldon, M.S., & Challis, B.H. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H.L. Roediger & F.I.M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 3–41). Hillsdale, NJ: Erlbaum.

Schneider, J. (2002). Near vision test card. Retrieved from http://www.i-see.org/block letter eye chart.pdf.

Stark, C. E. L., & McClelland, J. L. (2000). Repetition priming of words, pseudowords, and nonwords. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 945–972.

Thomas, R.C., & Hasher, L. (2012). Reflections of distraction in memory: Transfer of previous distraction improves recall in younger and older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38,* 30-39.

Ward, E. V. and Berry, C. J. and Shanks, D. R. (2013a). An effect of age on implicit memory that is not due to explicit contamination: Implications for single and multiple-systems theories. *Psychology and Aging, 28*, 429-442.

Ward, E. V. and Berry, C. J. and Shanks, D. R. (2013b). Age effects on explicit and implicit memory. *Frontiers in Psychology, 4,* 1-11.

Weeks, C.J., & Hasher, L. (2014). The disruptive and beneficial effects of distraction on older adults' cognitive performance. *Frontiers in Psychology, 5*, 1-6.

Footnotes

[1] The terms ‘direct’ and ‘explicit’, and ‘indirect’ and ‘implicit’ are frequently used interchangeably. Here, the terms ‘direct’ and ‘indirect’ are used to describe task instructions (whether or not they refer to the relevance of specific previously studied information), and the terms ‘explicit’ and ‘implicit’ to describe types of test. For example, recall and recognition are explicit memory tests that call upon participants to retrieve previously studied information, and perceptual identification is an implicit test that does not call upon participants to retrieve previously studied information. The implicit test therefore involves indirect instructions, and the explicit tests involve direct instructions. (In some conditions, however, the explicit tests involve indirect instructions where the use of previously distracting information is concerned).

[2] The idea that implicit memory is age-invariant has come to be widely accepted, yet many studies have demonstrated significantly reduced priming in older compared to younger adults (e.g., Abbenhuis, Raaijmakers, Raaijmakers, & Van Woerden, 1990; Chiarello & Hoyer, 1988; Davis, Cohen, Gancy, Colombo, & Van Dusseldorp, 1990, Hultsch, Masson, & Small, 1991; Ward et al., 2013a). Moreover, in published studies that claim to have revealed preserved priming in older individuals, performance has most often been numerically reduced (see Fleishman & Gabrieli, 1998), and it has been argued that there is a genuine decline in priming with age that may sometimes go undetected due to inadequate statistical power to detect small but real age effects in priming (a detailed discussion is provided in Mitchell & Bruss, 2003; Ward et al., 2013a; 2013b).

Table 1

Participant characteristics for Experiment 1

	Young (n = 24)	Older (n = 24)
	M (SD)	M (SD)
Age (years)	20.25 (2.16)	70.25 (6.10)
Education (years)	15.04 (0.98)	15.75 (2.37)
Visual acuity *	31.00 (5.38)	42.67 (21.16)
WAIS-III Vocabulary *	43.20 (10.65)	62.88 (5.83)
WAIS-III Digit Symbol (processing speed) *	79.11 (13.41)	67.73 (13.99)
Wechsler Test of Adult Reading (WTAR) *	41.80 (4.66)	47.19 (4.12)
Mini Mental State Exam (MMSE)	-	29.63 (0.64)

* Significant difference between groups, $p < .05$

Note. Visual acuity measured using the Near Vision Test Card (Schneider, 2002), viewed at a distance of 16 inches whilst wearing corrective glasses. Participants indicated the smallest set of letters that they could comfortably read, and scores on this test can range from 16 (highest acuity) to 160 (lowest acuity). The WAIS-III (Wechsler Adult Intelligence Scale III) subtests Vocabulary and Digit Symbol Substitution have maximum scores of 66 and 133, respectively, and the maximum score on the WTAR is 50. The maximum score on the MMSE is 30. A score of 23 or lower indicates probable cognitive impairment, however no participants in the experiments reported here scored below 27. Age differences in vocabulary, vision, processing speed, and WTAR score did not predict the outcomes of the main analysis in Experiment 1 – the significant interaction between age group and word-type in the indirect instruction condition, but not the direct instruction condition, remained when these variables were controlled for.

Table 2

Participant characteristics for Experiment 2

	Young (n = 24)	Older (n = 24)
	M (SD)	M (SD)
Age (years)	19.38 (1.35)	70.54 (5.90)
Education (years) *	14.63 (0.69)	15.71 (2.46)
Visual acuity *	31.67 (5.52)	38.33 (12.59)
WAIS-III Vocabulary *	39.55 (15.20)	61.63 (7.72)
WAIS-III Digit Symbol (processing speed)	75.82 (15.46)	67.04 (15.86)
WTAR *	35.45 (8.57)	45.35 (7.54)
MMSE	-	29.50 (0.78)

* Significant difference between groups, $p < .05$

Note. Age differences in education, vision, vocabulary, and WTAR score did not predict outcomes of the main analysis in Experiment 2. When these variables were controlled for, the statistical outcomes of the analyses did not differ to those reported.

Table 3

Mean response times (RT) in milliseconds in young and older adults in the identification task in Experiment 2.

	Young	Older
Word type	*M* (*SD*)	*M* (*SD*)
Old distracting	2651 (560)	3193 (989)
Old study	2724 (654)	3198 (982)
New	3064 (623)	3445 (1031)

Table 4

Mean proportions of hits and false alarms in young and older adults in the recognition task in Experiment 2.

	Young	Older
	M (*SD*)	*M* (*SD*)
Hits		
Old distracting	.90 (.07)	.76 (.17)
Old study	.88 (.10)	.76 (.19)
False Alarms	.13 (.07)	.11 (.15)

Figure captions

Figure 1. A: Mean number of previously distracting and new items recalled by young and older adults in the indirect instruction condition in Experiment 1. B: Mean recall of previously distracting and new items in young and older adults in the direct instruction condition in Experiment 1. Error bars in indicate standard error of the mean (SEM).

Figure 2. A: Priming in young and older adults for old-distracting items (RTnew – RTold-distracting / RTnew) and old-study items (RTnew – RTold-study / RTnew) in Experiment 2. B. Recognition in young and older adults in Experiment 2. Error bars indicate SEM.