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Mind-wandering in Younger and Older Adults: Converging Evidence from the Sustained Attention to Response Task and Reading for Comprehension

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Abstract

One mechanism that has been hypothesized to contribute to older adults' changes in cognitive performance is goal neglect or impairment in maintaining task set across time. Mind-wandering and task-unrelated thought may underlie these potential age-related changes. The present study investigated age-related changes in mind-wandering in three different versions of the Sustained Attention to Response task (SART), along with self-reported mind-wandering during a reading for comprehension task. In the SART, both younger and older adults produced similar levels of faster reaction times before No-Go errors of commission, whereas, older adults produced disproportionate post-error slowing. Subjective self-reports of mind-wandering recorded during the SART and the reading task indicated that older adults were less likely to report mind-wandering than younger adults. Discussion focuses on cognitive and motivational mechanisms that may account for older adults' relatively low levels of reported mind-wandering.

Keywords

mind-wandering; attention; aging; SART; reading

Recently there has been an exponential growth in the study of mind-wandering, which Smallwood and Schooler (2006) define as "a shift of attention away from a primary task toward internal information, such as memories" (p. 946). In this light, mind-wandering is an important function of executive attention, in which a primary task set must compete with task-irrelevant thoughts for limited cognitive resources (Smallwood & Schooler, 2006).

In order to investigate mind-wandering, researchers have recently relied on versions of the Sustained Attention to Response Task (SART), a go/no-go paradigm developed by Robertson et al. (1997), as an index of task-unrelated thought. The SART involves pressing a key in response to frequently presented nontargets (Go trials), and withholding the response to a very infrequent target (No-Go trials). The SART lends itself well to mind-wandering due to low attentional demands and a highly repetitive response. Errors on No-Go trials of the SART (i.e., responding to the target when one should withhold the response) are typically preceded by relatively fast Go trials, suggesting that the participant is simply responding automatically/rhythmically to the trial stimulus. SART errors have been shown to predict and be predicted by questionnaires related to absentmindedness and mind-wandering (Manly et al., 1999; Robertson et al., 1997; Smallwood, Davies et al., 2004; Smallwood & Schooler, 2006). Further, response latencies are associated with errors in SART, and the probability of errors occurring is related to blocks of trials in which mind-

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wandering is reported, but not by blocks of trials in which subjects report being on task (Smallwood et al., 2004). In addition to pre-error speeding, there is also post-error slowing which may reflect several task-related cognitive actions, such as reengagement of the task after the mind has wandered (Cheyne et al., 2009; Rabbit, 1966), a return of attention to the external environment (Smallwood et al., 2006), or even negative mood (Smallwood et al., 2009).

A second measure of mind-wandering used in this literature is a probed reading for comprehension task, which has been designed to explore the common experience of mind-wandering during reading. For example, Schooler, Reichle, and Halpern (2005) instructed subjects to read the first five chapters of Leo Tolstoy's *War and Peace*. While reading, subjects were asked to self-report any task-unrelated thoughts. Subjects were also periodically probed to determine if their minds were wandering. The authors classified mind-wandering with awareness, captured via the self-report method, as a *tune out*. Mind-wandering without awareness, captured by random probes in the task, was classified as a *zone out*, since the probe was necessary to catch these mind-wanderings. Schooler and colleagues noted that by using a combination of self-report and probe-report measures of mind-wandering in addition to more objective measures of performance, such as comprehension questions in a reading paradigm, it is possible to estimate an individual's awareness of their own attentive processes, that is, *meta-awareness*. For example, low meta-awareness is indicated by relatively few self-reported episodes of mind-wandering, low reading comprehension, and frequent reports of task-unrelated thought when probed.

Smallwood and Schooler (2006) argued that tasks that require controlled processing will be less likely to support mind-wandering because fewer executive resources are available to be diverted to task-unrelated thoughts. Therefore, tasks that require a high degree of cognitive control should be less susceptible to mind-wandering than tasks that require less cognitive control and indeed this has been reported (see, for example, Antrobus, 1968; Grodsky & Giambra, 1990–1991; Smallwood, Baracaia et al., 2003). However, when considering individual differences in working memory capacity, Kane and colleagues (2007; McVay & Kane, 2009; 2010) have found that more mind-wandering occurs in individuals with smaller working memory capacities. This also makes sense because failures in cognitive control, that is, failing to stay on task, may produce more mind-wandering (i.e., task-unrelated thoughts). Thus, it appears that both the extent to which a task demands cognitive control and the ability of an individual to stay engaged in a task will both contribute to mind-wandering.

The present study explored mind-wandering in healthy younger and older adults because – there are clear age-related differences in both attentional control and working memory capacity (see Balota, Dolan, & Duchek, 2000;Hasher, Zacks, & May, 2000, for reviews). Indeed, it has been suggested that older adults' decline in cognitive performance may reflect an inability to maintain task goals or context across time (e.g., Balota, Black, & Cheney, 1992; Hasher & Zacks, 1988; West, 1996), thereby influencing working memory capacity and attentional control. If individuals with higher working memory capacity are less likely to mind-wander, one might expect less mind-wandering in younger adults than older adults. However, as noted above, such an effect also depends on how much working memory capacity is allocated to a given task, as suggested by Smallwood and Schooler (2006). Specifically, if the task is relatively simple (not demanding) then individuals with more working memory capacity may be more likely to mind-wander. This might be found in the SART. In contrast, for a more demanding and natural task, such as reading for comprehension, one might find similar levels of mind-wandering for both younger and older adults, since both groups of subjects should appropriately titrate their resources to achieve the goals of understanding the passage (although see Grodsky & Giambra, 1990–1991).

There are also a number of motivational/personality factors that also may modulate mind-wandering. For example, individuals who are more conscientious may be more likely to stay on task and hence less likely to mind-wander. If older adults are more conscientious than younger adults, one might expect older adults to experience less mind-wandering than younger adults on the SART. Interestingly, there is recent accumulating evidence that personality variables are related to attentional control measures (see Duchek et al., 2007).

There is already an interesting literature that is relevant to mind-wandering in younger and older adults across different paradigms. For example, Singer and McCraven (1961) used self-report questionnaires to investigate daydreaming (a specific type of mind-wandering with high imagery). They found that middle-aged adults were less likely to daydream than younger adults. Giambra (1973) made use of cross-sectional surveys much in the fashion of Singer and McCraven (1961), and extended his sample to ages 17–77. Results were consistent with Singer and McCraven in that self-reports of daydreaming decreased with age. The same trend was replicated in longitudinal data, over spans of 7, 14, and 20 years by Giambra (2000). Giambra noted a paradoxical aspect of these results. That is, because of factors like reduced sensory function, one may have instead predicted that older adults would be less in touch with the external world and more internally driven, hence produce more, not less, mind-wandering, compared to younger adults (also see Smallwood, Davies et al., 2004).

The results of the studies reviewed above are based primarily on self-report questionnaires so it is possible that older adults may simply be less aware of mind-wandering or possibly have a bias not to report mind-wandering. Giambra (1989) used a vigilance task to investigate mind-wandering, in which a target appeared only 24 times within a 62-minute period. In addition to the vigilance task, subjects were probed at 25-second intervals asking whether they were thinking of something other than the task. Overall, there was a trend for older adults to report fewer incidences of mind-wandering than their younger counterparts, which the author attributed to fewer matters of concern (and hence less mind-wandering) in old age. Grodsky & Giambra (1990–1991) used both vigilance and reading tasks varying in difficulty and interest to investigate the generalizability of reported mind-wandering across the lifespan. In addition to replicating the negative correlation between mind-wandering and aging, the authors reported high correlations between the two types of tasks in task-unrelated thought.

Einstein and McDaniel (1997) argued that the age-related difference in mind-wandering frequency reported by Giambra (1973, 1989) may have been due to older adults' unwillingness or inability to report mind-wandering episodes, despite Giambra's (1973) evidence that older adults had a slightly more positive view of mind-wandering than younger adults. In the Einstein and McDaniel study, subjects were required to monitor a list of words presented every 2 seconds and were randomly probed for recall on the items. Lower proportions of recall relative to a baseline condition in which recall probes were fixed and predictable were considered a proxy of mind-wandering. Using these measures, there were no age differences in mind-wandering tendency. However, older adults recalled fewer words on average (in both baseline and experimental conditions) than younger adults, which could mask possible differences between younger and older adults.

In sum, previous work on mind-wandering in younger and older adults suggests that older adults are either less likely to mind-wander or that they mind-wander at similar rates as younger adults. However, much of this work is based on questionnaires and self-report measures. A major goal of the present study is to further investigate mind-wandering in younger and older adults with more recently developed experimental paradigms. Thus, the first three experiments involved variations of the SART and the final experiment investigated the probed reading for comprehension task.

Experiment 1

Experiments 1 – 3 were designed to examine the differences between younger and older adults on tasks of sustained attention. Using the SART, we expected to replicate the basic indices of mind-wandering reported recently (e.g., Carriere et al., 2010; Kane et al., 2007; Smallwood, Davies, et al., 2004). Specifically, one should find that response latencies decrease on Go trials immediately prior to No-Go errors (pre-error speeding) and increase immediately following No-Go errors (post-error slowing). The critical question is whether there are any age-related changes in these indices of mind-wandering. Indeed, if older adults have difficulty maintaining attentional control across time, then one might expect an increased probability of mind-wandering in these individuals, compared to younger adult controls. In order to further investigate the mechanism underlying such changes, we also included measures of working memory in Experiments 1 and 2.

Experiment 1 used the original version of the SART developed by Robertson et al. (1997), and also included infrequent unpredictable probes as a method of thought sampling (Smallwood, Davies et al., 2004). Figure 1 displays a sample sequence of events in the SART.

Method

Subjects—Fifty-four younger adults (29 female) and 62 older adults (40 female) took part in the study. For all four experiments, younger adults were recruited from an undergraduate research pool, and given credit in partial fulfillment of course requirements, whereas older adults were recruited via an older adult volunteer pool maintained by the Washington University Aging and Development program, and were paid $10/hour as compensation for participation. Demographic data are summarized in Table 1, and include age, education, Shipley vocabulary scores, conscientiousness and neuroticism scores taken from the NEO-FFI (Costa & McCrae, 1992), and the Operation Span complex working memory span task as a measure of working memory capacity[1] (Unsworth et al., 2005). Due to time constraints, NEO and Shipley data were not collected on 7 younger adult subjects, and Operation Span data were not collected from 4 younger adults and 22 older adults. Older adults were more highly educated than younger adults, $t(114) = 5.99$, $p < .001$, and had higher vocabulary scores than younger adults, $t(107) = 2.81$, $p = .006$. Based on the NEO-FFI, older adults were more conscientious, $t(107) = 3.94$, $p < .001$, and less neurotic, $t(107) = 2.92$, $p = .004$, than younger adults. As suspected, younger adults had much higher working memory capacities than older adults, $t(88) = -12.89$, $p < .001$, see Table 1.

Materials & design—Stimuli for the SART were single numbers 1–9, with the number 3 identified as the target stimulus (No-Go trials), and all others as nontarget stimuli (Go trials). Two hundred sixteen trials were presented over a period of approximately four minutes. Each digit was presented for 200 ms, followed by a 900 ms mask that consisted of a ring with a diagonal cross in the middle. The period from trial onset to trial onset was 1100 ms. Target trials occurred on 11.1% of trials, and were distributed evenly throughout the task such that there was 1 target trial on average for every 8 nontarget trials. Probes were given on 3.7% of trials, and were presented within the SART to promote an equal distribution of probes over the course of the task. Probes were delivered randomly, so on approximately

[1]Due to different scoring metrics employed for Operation span (Experiment 1) and Reading span (Experiments 2 and 4) tasks, working memory scores are reported in a z-score values based on overall means and standard deviations to facilitate comparison across experiments.

1.7% of probe trials across all subjects, probes appeared after targets. These probes were identified in the analysis stage and dropped from all results. Subjects were instructed to press the spacebar for nontarget trials, but to withhold their response on target trials (i.e., when the number 3 appeared on the screen).

Procedure—Each session was preceded by 3 short blocks of practice. The first block of practice consisted of 18 trials, 2 of which were targets. Subjects were given feedback but no random probes during practice. The second block of practice consisted of 18 trials with feedback, again with 2 target trials, as well as 2 random probes. The third block of practice was designed similarly to the second block, with the difference that no feedback was given.

Stimuli were presented at the center of the screen, and appeared in white against a black background in 20 pt Arial Rounded MT Bold font, via either CRT or LCD monitors. The experiment was controlled using E-Prime 1.2 software (Psychology Software Tools, Pittsburgh, PA).

On probe trials, subjects were instructed to report via a keypress whether they were mind-wandering or thinking about the task when they saw the following prompt: "At the time of the probe, my mind was on task." Subjects pressed the Y key to indicate an affirmative response, and the N key to indicate that they were mind-wandering. Several examples of mind-wandering were given across a range of activities, such as thinking about shopping, interacting with loved ones, or reflecting on one's own boredom, with the experimenter careful not to constrain the participant's interpretation. The term "mind-wandering" was avoided when explaining the tasks.

Subjects sat approximately 50 centimeters from the monitor. The experimenter left the room so as not to unduly influence subjects' responses. The SART was included as part of a two-hour experimental battery.

Results

All results are presented after testing for unequal variances between groups using Mauchly's test of sphericity for analyses of variance, and Levene's test for equality of variances for the *t*-test comparisons. Where necessary, lower-bound corrections were used for F-tests, and unequal-variance *t*-tests were used in place of Student's *t*-test to compensate for unequal variances between groups. An alpha of .05 was set to indicate significance. Mean response latencies and accuracies, broken down by experiment and age group, are displayed in Table 2. Also, as shown in Table 2, in order to control for any effects due to overall age-related slowing, all RTs were converted to z-scores based on the individual participant's mean and standard deviation (see Faust et al., 1999).

Accuracy—To examine the effects of age on accuracy, a 2 (Go trial vs. No-Go trial) × 2 (Younger/Older Adult) mixed-model analysis of variance (ANOVA) was conducted. As shown in Table 2, Go trials were significantly more accurate than No-Go trials, $F(1, 117) = 299.30$, $p < .001$. Neither the main effect of age nor the age by trial type interaction produced reliable effects, both *F*s < 1.

Response latencies—No-Go error trials were faster than Go trials, $F(1, 114) = 27.88$, $p < .001$, suggesting that these trials reflect a loss of control, possibly due to mind-wandering. Older adults had slower response latencies than younger adults, $F(1, 114) = 47.70$, $p < .001$. The age by trial type interaction did not reach significance, $F(1, 114) = 1.11$, $p = .294$. Under the *z*-score transform, No-Go error response latencies were again significantly faster than Go responses, $F(1, 114) = 72.09$, $p < .001$. Neither the main effect of age nor the age by trial type interaction approached significance, both *F*s < 1.

Pre-error speeding—Pre-error speeding and post-error slowing data are presented in Table 3. As noted, response latencies preceding No-Go errors are generally faster than those preceding correctly withheld No-Go or standard Go responses (McVay & Kane, 2009; Robertson et al., 1997; Smallwood, Davies, et al., 2004). The four response latencies immediately preceding a correctly withheld No-Go response were contrasted with the four trials immediately preceding a No-Go error in a 2 (No-Go Correct vs. No-Go Error) × 2 (Younger/Older Adult) mixed-model ANOVA. Trials preceding No-Go errors were faster than trials preceding a correctly withheld No-Go response, $F(1, 114) = 33.75$, $p < .001$. Older adults again had slower response latencies than younger adults, $F(1, 114) = 46.05$, $p < .001$. The age by trial type interaction did not approach significance, $F < 1$. The results from the z-score analyses yielded significant effects of pre-error speeding, $F(1, 114) = 145.55$, $p < .001$. Neither the main effect of age nor the age by preceding trial type interaction approached significance, both *F*s < 1.

Post-error slowing—In contrast to pre-error speeding, response latencies on the trial immediately following No-Go errors are generally slower than those following correctly withheld No-Go responses. Post-error slowing analyses excluded trials in which probes succeeded errors, in order to avoid the inclusion of probe-induced slowing. Post-error slowing was examined in a 2 (No-Go Correct vs. No-Go Error) × 2 (Younger/Older Adult) mixed-model ANOVA. Trials following No-Go errors were slower than trials following a correctly withheld No-Go response, $F(1, 114) = 91.24$, $p < .001$. Older adults again had slower response latencies than younger adults, $F(1, 114) = 43.14$, $p < .001$. Importantly, the age by trial type interaction was highly significant, $F(1, 114) = 41.92$, $p < .001$, displayed in Figure 2, where older adults were much more slowed by errors relative to younger adults. Standardized response latencies yielded the same results, with significant effects of post-error slowing, $F(1, 114) = 38.80$, $p < .001$, a main effect of age, $F(1, 114) = 5.49$, $p = .021$, and a reliable interaction of trial type and age, $F(1, 114) = 23.02$, $p < .001$.

Thought reports—Mean proportions of thought reports are summarized in Table 4. Consistent with past self-report studies of mind-wandering, younger adults were reliably more likely to report mind-wandering compared to older adults, $t(74.41) = 5.13$, $p < .001$, with proportions of .21 versus .04 for the younger and older adults, respectively.

Discussion

The results from Experiment 1 are clear. Although there was a robust predicted pattern in accuracy, overall response latencies, and pre-error speeding, these effects were all age-equivalent after correcting for general slowing, via z-score transformations. Thus, if one relies only on the relatively fast error responses and the pre-error speeding, one would conclude that older adults are mind-wandering at the same rates as younger adults. This age-invariance, coupled with infrequent reports of older adults' mind-wandering, may even suggest that older adults are engaging in less mind-wandering than younger adults. Interestingly, however, there was a significant interaction between age and post-error slowing, such that older adults were subsequently slowed more by No-Go errors than younger adults. As noted, post-error slowing has been hypothesized to indicate re-engaging in task set after mind-wandering (Cheyne et al., 2009; but see Smallwood et al., 2006, 2009, for alternative views). The results from Experiment 1 indicate that older adults have more difficulty reengaging in the task set after such an error is made.

One limitation of Experiment 1 was the nature of the thought probes. Despite explanations and examples of mind-wandering, it is possible that older adults did not fully understand the term, and did not fully disclose instances of mind-wandering. Additionally, the binary classification of mind-wandering in Experiment 1 (i.e., the "yes" and "no" options for reporting mind-wandering) glossed over potentially interesting distinctions between several types of mind-wandering experiences that may further distinguish between younger and older adult performance. Indeed, it is possible that just by giving individuals a more finely-grained distinction amongst different types of mind-wandering, subjects may be encouraged to be more self-reflective about their current cognitive state.

In order to address these issues, and attempt to replicate the interesting age-related difference in post-error slowing, in Experiment 2 we modified the probes in the SART to reflect three types of mind-wandering. *Tune outs*, as defined by Smallwood, McSpadden, and Schooler (2007), reflect mind-wandering that occurs with awareness. In other words, an individual that is tuning out is fully cognizant of the fact that his or her mind is no longer on the task at hand. *Zone outs*, on the other hand, reflect mind-wandering without awareness. In this state, individuals can only be expected to recognize such occurrences of mind-wandering when directly probed. In these instances, however, an individual may have some insight as to the content of where the mind has wandered. For example, one's mind may drift to autobiographical events while reading (see Experiment 4). The third type of mind-wandering were coded as *space outs*, which are instances in which the participant is probed and realizes they are not thinking about the task and are unaware of thinking about anything specifically.

It is also possible that there are differences in the way in which younger and older adults approached the SART. Perhaps older adults are more highly motivated to maintain attention in the simple SART, and in so doing achieve age-equivalent task performance while suppressing mind-wandering. Indeed, the results from the NEO in Experiment 1 indicated that older adults were more conscientious than the younger adults, and the SART performance measures did not differ after excluding the 7 younger adult subjects who did not complete the NEO. Because conscientiousness involves maintaining appropriate goals, this may have increased the older adults' likelihood of staying on task. Indeed, Grodsky and Giambra (1990–1991) reported that when subjects found a task difficult, they tend to report less frequent mind-wandering. To help shed light on this possibility, Experiment 2 included a post-experiment questionnaire, asking each subject to rate task difficulty and task interest.

Experiment 2

Method

Subjects—Thirty-two younger adults (18 female) and 38 older adults (31 female) took part in the study. Subjects were either given credit or paid as in Experiment 1. Due to time constraints, NEO data was not collected on 5 older adult subjects. Older adults were once again more highly educated than younger adults, $t(68) = 2.51$, $p < .001$, and had lower working memory as measured by a reading span task, $t(52.907)$, $p < .001$. Older adults were also again more conscientious, $t(63) = 4.01$, $p < .001$, and less neurotic, $t(63) = 5.91$, $p < .001$, than younger adults.

Materials & design—Stimuli and timing for the SART were as described in Experiment 1. An increased number of trials and more frequent probes were given in Experiment 2 to provide subjects with more opportunities to report mind-wandering. Two hundred seventy-five trials were presented over a period of approximately five minutes. Probes were given on 4% of task trials and were again presented to promote an equal distribution of probes throughout the SART.

On probe trials, subjects were instructed to report their attentional state via a keypress when they saw the following prompt: "Please choose the one option below which best describes your experience with the task just now." The 1 key indicated "I was thinking about the task," to reflect on-task thought; the 2 key indicated "My mind was blank," to reflect a space out; the 3 key indicated "My mind drifted to things other than the task, but I wasn't aware of it until you asked me," to reflect a zone out; the 4 key indicated "While doing the task I was aware that thoughts about other things popped into my head" to reflect a tune out.

Following the completion of the task, subjects were asked to rate how difficult and interesting they found the task. Permissible responses for the difficulty question ranged from 1 to 5, with 1 indicating "Very easy," 2 indicating "Moderately easy," 3 indicating "Neither easy nor difficult," 4 indicating "Moderately difficult," and 5 indicating "Very difficult." Similarly, a rating of 1 on the subjective interest question corresponded to "Not at all interesting," 2 corresponded to a rating of "A little interesting," 3 corresponded to "Somewhat interesting," 4 corresponded to "Pretty interesting," and 5 corresponded to "Highly interesting."

Procedure—The procedure was executed as in Experiment 1.

Results

Accuracy—Accuracy and response latency results are summarized in Table 2. Go trials were significantly more accurate than No-Go trials, $F(1, 68) = 192.95$, $p < .001$. Neither the main effect of age nor the age by trial type interaction produced reliable effects, both *F*s < 1.

Response latencies—No-Go error responses were faster than Go responses, $F(1, 67) = 41.62$, $p < .001$. Older adults had slower response latencies than younger adults, $F(1, 114) = 11.04$, $p = .001$. The age by trial type interaction did not approach significance, $F < 1$. Likewise, the z-score analysis indicated that No-Go errors were significantly faster than Go responses, $F(1, 67) = 52.45$, $p < .001$. Neither the main effect of age nor the age by trial type interaction approached significance, both *F*s < 1.

Pre-error speeding—Pre-error and post-error response latencies can be found in Table 3. Trials preceding No-Go errors were faster than trials preceding a correctly withheld No-Go response, $F(1, 67) = 22.33$, $p < .001$. Older adults were slower than younger adults, $F(1, 67) = 16.04$, $p < .001$. The age by trial type interaction did not approach significance, $F < 1$. The z-score analyses yielded significant effects of pre-error speeding, $F(1, 67) = 35.34$, $p < .001$. Older adults were also marginally slower than younger adults, $F(1, 67) = 3.90$, $p = .053$, although there was no significant interaction of age and trial type, $F < 1$.

Post-error slowing—Trials following No-Go errors produced longer response latencies than trials following a correctly withheld No-Go response, $F(1, 67) = 32.11$, $p < .001$. Older adults had slower response latencies than younger adults, $F(1, 67) = 6.47$, $p = .013$, and were again much more slowed by errors relative to younger adults, $F(1, 67) = 15.97$, $p < .001$, as shown in Figure 3. The results from the z-score analysis yielded a significant effect of post-error slowing, $F(1, 67) = 18.07$, $p < .001$, and though there was no main effect of age, $F < 1$, there was again the important reliable interaction, $F(1, 67) = 9.90$, $p = .002$, indicating that older adults produced disproportionately more slowing on post-error trials than younger adults.

Thought Reports—Mean proportions of thought reports are summarized in Table 4. Younger adults were more likely to report tune outs, $t(68) = 4.85$, $p < .001$, zone outs, $t(57.15) = 2.15$, $p = .036$, and space outs, $t(33.28) = 4.32$, $p < .001$, compared to older adults.

Subjective difficulty and interest—As predicted, younger adults rated the task as less difficult, $t(68) = 2.71$, $p = .009$, and less interesting, $t(68) = 4.15$, $p < .001$, than older adults.

Discussion

Experiment 2 yielded results very similar to Experiment 1, with no reliable age differences in accuracy, standardized reaction time, or pre-error speeding. More importantly, however, older adults showed disproportionate post-error slowing. Overall reports of task-unrelated thought nearly doubled in Experiment 2 compared to Experiment 1 for both age groups, which may reflect a better understanding and classification of various types of mind-wandering. Importantly, older adults again reported fewer instances of mind-wandering compared to younger adults. Finally, older adults reported that the task was more difficult and interesting than younger adults, which may also contribute to decreased self-report of mind-wandering in older adults.

The SART parameters used in Experiments 1 and 2 were taken directly from Robertson et al. (1997). It is possible that rapid presentation of stimuli and use of a stimulus mask in this version of the task may make the SART more difficult for older adults, thereby requiring more sustained attention over the course of the task. If older adults find the task more difficult than younger adults (also reflected by self-report data), they may be less likely to mind-wander than younger adults (Grodsky & Giambra, 1990–1991). Further, a slower task presentation has been shown to increase reports of mind-wandering (e.g., Smallwood, Davies et al., 2004). Thus, in Experiment 3 we altered the SART to include a slower stimulus presentation rate, allowing subjects more time to process the stimuli and make responses. We also removed the stimulus mask to allow for prolonged processing of the go/no-go stimuli. By slowing the presentation rate and removing visual interference, we reduced task demands to very low levels and encouraged an even more prepotent Go response, and potentially more mind-wandering.

Experiment 3

Method

Subjects—Thirty-one younger adults (16 female) and 49 older adults (29 female) took part in the study. Subjects were either given credit or paid as described in Experiment 1. We did not include all of the additional individual differences measures in this sample taken from the same populations as the previous studies, but note that older adults and younger adults did not reliably differ in years of education, $t(78) = 1.64$, $p = .11$.

Materials, design, & procedure—Stimuli for the SART were the same as in Experiments 1 and 2, with the exception of the mask. Two hundred twenty-five trials were presented over a period of approximately ten minutes. Each digit was presented for 1250 ms, followed by a 1250 ms intertrial interval. Target trials occurred on 11.1% of trials, and probes were presented on 4% of trials, and were distributed as indicated in Experiments 1 and 2. All other aspects of the procedure were the same as those described in Experiment 1, with exception of the probes, which were the same as described in Experiment 2.

Results

Accuracy—As shown in Table 2, Go trials were significantly more accurate than No-Go trials, $F(1, 78) = 97.34$, $p < .001$. There was also a main effect of age, $F(1, 78) = 13.00$, $p < .001$, and an interaction of age and trial type, $F(1, 78) = 16.45$, $p < .001$. The results indicate that older adults were more accurate than younger adults on No-Go trials, and that this age difference was larger than on Go trials.

Response latencies—No-Go trials were faster than Go trials, $F(1, 68) = 13.38$, $p < .001$. Older adults had slower response latencies than younger adults, $F(1, 68) = 10.62$, $p = .002$. The age by trial type interaction did not reach significance, $F < 1$. The results from the *z*-

score analyses also indicated that No-Go error response latencies were reliably faster than Go responses, $F(1, 68) = 15.28$, $p < .001$. Neither the main effect of age nor the age by trial type interaction produced reliable effects, both *F*s < 1.

Pre-error speeding—As shown in Table 3, trials preceding No-Go errors were faster than trials preceding a correctly withheld No-Go response, $F(1, 68) = 7.43$, $p = .008$. Older adults were slower than younger adults, $F(1, 68) = 14.14$, $p < .001$. The age by trial type interaction did not reach significance, $F < 1$. Standardized response latencies did not yield a significant effect of trial type, $F(1, 68) = 1.88$, $p = .175$. The main effect of age and the age by trial type interaction both failed to produce reliable effects, both *F*s < 1.

To further examine the age by trial type interaction in pre-error speeding with additional power, we combined Experiments 1 to 3. The age by trial type did not approach significance in either the mean latencies, $F < 1$, or in the standardized analyses, $F(1, 253) = 1.07$.

Post-error slowing—There was no reliable effect of trial type, $F(1, 68) = 1.50$, $p = .224$. There was a main effect of age, $F(1, 68) = 20.79$, $p < .001$, and again a reliable interaction, $F(1, 68) = 6.56$, $p = .013$, indicating that older adults produced much more post-error slowing relative to younger adults (Figure 4). Standardized response latencies yielded reliable main effects of trial type, $F(1, 68) = 8.29$, $p = .005$, and a marginally reliable main effect of age, $F(1, 68) = 3.71$, $p = .058$. Most importantly, there was again a reliable age by trial type interaction, $F(1, 68) = 10.22$, $p = .002$.

Thought Reports—Mean proportions of thought reports are summarized in Table 4. Younger adults were again more likely to report tune outs, $t(78) = 3.46$, $p = .001$, and space outs, $t(78) = 2.77$, $p = .007$, compared to older adults. Younger adults were also marginally more likely to report zone outs than older adults, $t(41.14) = 1.95$, $p = .059$.

In order to further explore differences in the type of response reported to probes across Experiments 2 and 3, we conducted a 2 (Experiment) × 2 (Age Group) × 3 (Type of Mind-wandering) ANOVA. These data are displayed in Figure 5. There was a main effect of type of mind-wandering, $F(2, 292) = 58.46$, $p < .001$, and Bonferroni-corrected pairwise comparisons revealed that tune outs were reported more frequently than space outs, which in turn were reported more frequently than zone outs, all *p*s < .001. Younger adults reported more mind-wandering than older adults, $F(1, 146) = 67.40$, $p < .001$, although the proportion of the difference varied by type of mind-wandering, demonstrated by an age by type of mind-wandering interaction, $F(2, 292) = 6.98$, $p = .009$. There was a main effect of experiment, $F(1, 146) = 45.62$, $p < .001$, and a reliable interaction between type of mind-wandering and experiment, $F(2, 292) = 31.00$, $p < .001$, such that while overall mind-wandering was reported more frequently in Experiment 3, tune outs were reported far more often in Experiment 3 than Experiment 2. There was no age by experiment interaction, $F < 1$, and the interaction of age, experiment, and type of mind-wandering failed to reach significance, $F(2, 292) = 2.74$, $p = .103$.

Subjective difficulty and interest—While younger adults and older adults both rated the task equally difficult, $t(78) = .35$, $p = .73$, younger adults found the task less interesting, $t(73.71) = 5.67$, $p < .001$.

Discussion

As predicted, the slower-paced SART in Experiment 3 increased mind-wandering in both younger and older adults. These results are consistent with Smallwood et al. (2004), who reported an increase in off-task thought in slow SART conditions relative to fast SART conditions, as well as an accuracy advantage for older subjects. Further, although there was an overall increase in mind-wandering, the patterns observed in Experiments 1 and 2 were also found in Experiment 3. Specifically, both groups produced equivalent pre-error speeding, whereas, older adults produced disproportionate post-error slowing.

Regarding self-reported mind-wandering, younger adults reported task-unrelated thought on nearly 3 in 4 probes, and older adults' mind-wandering rates were less than half of younger adults'. Interestingly, although both groups produced a higher number of tune outs in Experiment 3 compared to Experiment 2, this increase was greater in younger adults (52%) than in older adults (27%). Of course, tune outs may be viewed as a type of controlled mind-wandering (i.e., the participant can continue the task, while thinking of something else), and so it is not surprising that younger adults may report relatively more of these, if indeed it is particularly less demanding for these individuals.

To investigate the impact personality in the SART, we correlated conscientiousness with SART performance measures across experiments 1 – 3, and found modest negative correlations between conscientiousness and number of No-Go errors ($r = -.185$, $p = .009$), and between conscientiousness and overall reports of mind-wandering ($r = -.227$, $p = .001$). The correlation between conscientiousness and post-error slowing was marginally significant ($r = .138$, $p = .066$). This appears to establish a link between conscientiousness and evidence of mind-wandering on the SART.

To investigate the relative impact of self-reported difficulty and interest across the SART, we correlated difficulty and interest with the number of No-Go errors, overall reported mind-wandering, pre-error speeding, and post-error slowing. Difficulty was robustly correlated with the number of No-Go errors, ($r = .397$, $p < .001$), while interest was only marginally significant ($r = .151$, $p = .065$). Both difficulty ($r = -.246$, $p = .002$). and interest ($r = -.512$, $p < .001$). were reliably and negatively correlated with overall reports of mind-wandering. Finally, neither difficulty nor interest were reliably correlated with pre-error speeding or post-error slowing, all *p*s > .16.

Additionally we considered the relationship of participant age, and correlated this measure with SART performance measures. We found reliable correlations between age and post-error slowing ($r = .366$, $p < .001$), number of No-Go errors ($r = -.139$, $p = .023$), and self-reported mind-wandering ($r = -.413$, $p < .001$). When we controlled for subjective interest in the SART, the magnitude and direction of the age-performance correlations remained largely unchanged, with reliable correlations between age and post-error slowing ($r = .343$, $p < .001$), number of No-Go errors ($r = -.227$, $p = .005$), and self-reported mind-wandering ($r = -.251$, $p = .002$). We also controlled for subjective difficulty in the SART, with correlations between age and post-error slowing ($r = .369$, $p < .001$), number of No-Go errors ($r = -.198$, $p = .016$), and self-reported mind-wandering ($r = -.402$, $p < .001$). These combined results appear to demonstrate that while conscientiousness indeed has a measurable link with measures of mind-wandering, the age differences reported in the manuscript cannot be accounted for via reported task difficulty and interest, which presumably indicates subjects' ratings of how inherently engaging they found the task. Conscientiousness instead may impact age differences in mind-wandering via completion of the task in a disciplined or persistent fashion, two common subtraits of conscientious individuals.

Experiment 4

Although the SART is one of the most commonly used tasks to investigate mind-wandering, the use of a reading for comprehension task may reflect a more naturalistic setting to explore task-unrelated thought. Individuals often report the experience of mind-wandering during reading, and indeed report having to go back and reread passages after they recognize their mind has wandered off the passage. Reading comprehension is relatively well-preserved in older adults (De Beni, 2007; Curiel & Radvansky, 1998), and so this provides a useful additional assay to investigate age-related changes in mind-wandering. Because reading is a common activity for both younger and older adults, a reading task may afford a more natural paradigm to investigate age-related changes in mind-wandering compared to the SART.

In Experiment 4, we replicated and extended the reading paradigm of Schooler, Reichle, and Halpern (2005) by requiring younger and older adults to read an extended excerpt from Leo Tolstoy's *War and Peace*. Our aim was to determine if the pattern observed in Experiments 1 – 3 (i.e., lower levels of self-reported mind-wandering in older than younger adults) generalize to a more natural reading task, which was reported by Grodsky and Giambra (1990–1991), using similar vigilance and reading paradigms. Of course, because there are no detectable errors in the reading task, we cannot evaluate pre-error speeding and post-error slowing. Further, we sought to better understand age differences in the frequency of reported mind-wandering by including both self-caught and probe-caught mind-wandering cues, as in a recent study by Sayette, Reichle, and Schooler (2009) investigating mind wandering during reading in younger adults under the influence of alcohol or a placebo.

Method

Participants—Thirty-two younger adults (18 female) and 38 older adults (31 female) participated in the reading task. Subjects in Experiment 4 also performed the SART (reported in Experiment 2; demographic information also reported in Experiment 2).

Materials, design, & procedure—Subjects were given 30 minutes to read up to the first five chapters of a computer-presented version of Leo Tolstoy's *War and Peace* at their own pace. Each page of text consisted of approximately 65 words, with no chapter or section breaks indicated. Subjects were instructed to press the spacebar to move to the next page. Revisiting previous pages was not permitted. Although subjects were not informed of their progress, the computer recorded how many "pages" each participant completed reading.

Thought reports were assessed using two methods. The self-caught method allowed subjects to report mind-wandering as they became aware of it. Subjects were instructed to press the 2 key whenever they realized their minds were no longer attuned to the reading. At this time, subjects were asked to categorize the episode they had just experienced. Options available for self-caught categorization included pressing the A key to indicate their "mind was blank" or the B key to report a tune out, indicating that "while reading I was aware that thoughts about other things popped into my head."

In addition to self-caught reports of mind-wandering, we also assessed mind-wandering using infrequent probes. The probes were distributed throughout the task, occurring at randomly-determined intervals between 2 and 4 minutes in length. Options available for probe-caught categorization were consistent with Experiments 2 and 3. Tune out and space out options were presented as described for the self-caught reports. Additionally, probe reports included an option for reporting zone outs, in which the participant was "thinking of other things, but not aware of it until you asked me." Random probes also included an option to report that "my mind was on the task." Subjects indicated their response by pressing the A, B, C, or D keys to indicate tune outs, space outs, zone outs, and on-task thought, respectively, and had no time limit in which to record their responses, apart from the overall limit to the reading period. At the end of the reading period, 14 true/false comprehension questions were presented regarding the reading. Subjective measures of interest and difficulty were also recorded. Due to computer error, these later subjective measures were only obtained on 22 younger adults and 28 older adults. The experiment was carried out using E-Prime 1.2 software via a widescreen LCD display. The reading appeared in white against a black background, in 20 pt Arial Rounded MT Bold font.

Results

Reading rate and comprehension—Reading rate, comprehension, and mind-wandering results for the reading task are reported in Table 5. Reading progress was measured by recording the final page number for each participant. Younger adults read reliably faster than older adults on a per-word basis, $t(65) = 4.13$, $p < .001$. Because the task was self-paced, subjects' accuracy on the comprehension questions was calibrated to include only those questions with subject matter pertinent to the reading that each participant completed. Younger adults performed slightly better than older adults on the reading comprehension questions, $t(65) = 2.13$, $p = .037$.

Self-caught mind-wandering—Overall, older adults reported fewer self-caught mind-wanderings than younger adults, $t(41.61) = 4.01$, $p < .001$. Younger adults reported more tune outs than older adults, $t(31.34) = 3.52$, $p = .001$, and marginally more space outs than older adults, $t(65) = 1.87$, $p = .066$.

Probe-caught mind-wandering—Overall, younger adults were more likely to report mind-wandering in responses to probes than older adults, $t(65) = 3.00$, $p = .004$. Planned comparisons indicated that the age differences in probe-caught tune outs was not reliable, $t(57.24) = .25$, $p = .80$. Younger adults, however did report reliably more zone outs than older adults, $t(39.63) = 4.28$, $p < .001$, and marginally more space outs than older adults, $t(56.13) = 1.81$, $p = .076$.

Subjective difficulty and interest—Younger adults did not reliably differ from older adults in their ratings of difficulty, $t(48) = 1.50$, $p = .141$, nor in their ratings of task interest, $t(48) = 1.08$, $p = .286$, although the direction of the means is consistent with the previous experiments[2].

Overall, the results from the reading task are quite clear. Consistent with Experiments 1, 2, and 3, older adults were both less likely to report mind-wandering when directly probed during reading and also less likely to spontaneously report mind-wandering during reading. Thus, the general pattern of decreased mind-wandering observed in the SART, via both self-report and probe-initiated methods, extends to a more natural reading paradigm.

General Discussion

The primary goal of the present study was to explore age differences in mind-wandering in the SART and reading for comprehension paradigms. The results across four experiments were quite clear in indicating that, consistent with past literature, older adults do not exhibit more mind-wandering than younger adults and if anything produce less mind-wandering. First, consider the SART experiments. Responding on a No-Go trial in the SART has been viewed as a reflection of mind-wandering or task disengagement. Older adults produced numerically fewer No-Go responses during the SART compared to younger adults in each experiment, although this was reliable only in the third experiment. Each of these

[2]Because subjective difficulty and interest were not collected on the full sample, analyses were performed on the subsample that reported this data. Planned comparisons revealed no differences between the subsample and the full sample on accuracy, reading rate, overall self-caught mind-wandering, self-caught tune outs, probe-caught tune outs, and probe-caught zone outs. Neither the marginal age difference of self-caught space outs ($t(48) = .980$, $p = .33$) nor probe-caught space outs ($t(48) = 1.23$, $p = .23$) in the full sample were reliable in the subsample. Additionally, although younger adults reported numerically more probe-caught mind-wandering episodes, this age difference was not reliable in the subsample, $t(48) = 1.49$, $p = .142$. It is important to stress, however, that these analyses are bounded by a reduction in power, and the lack of reliability is at least partially due to this limitation.

experiments also produced the expected pre-error speeding, i.e., faster response latencies on the trials preceding an error compared to those preceding a correctly withheld response. Pre-error speeding has been viewed as suggesting that the mind is disengaged from the primary task leading up to an error because it indicates inattention to the task or "going through the motions" without specific regard to a particular trial's stimulus (e.g., Cheyne et al., 2009; Smallwood, Davies et al., 2004), although it is important to bear in mind that various indices of mind-wandering may not necessarily reflect isomorphic processes (McVay, Kane, & Kwapil, 2009). Subjects responding mindlessly are likely to have shorter response latencies on externally-paced tasks like the SART because they are likely to respond at the trial onset, rather than maintaining task set and evaluating a given trial's stimulus for the appropriate response. Older adults produced comparable pre-error speeding to younger adults. Turning to the probe report data, older adults consistently reported less mind-wandering than younger adults. Indeed, this is quite dramatic across experiments, with younger adults reporting overall mind-wandering at a rate of 44%, whereas older adults reported mind-wandering at a rate of 16%. Interestingly, the relative difference in age-related reports of mind-wandering occurred even though manipulations of the presentation rate across experiments dramatically influenced the rates of probed mind-wandering (i.e., Experiment 1, 12%, Experiment 2, 25%, and Experiment 3, 53%).

One concern about the SART paradigm is that this task is relatively novel and more interesting for the older adults, compared to the younger adults. Indeed, the results from the interest and difficulty ratings were consistent with this notion. If this were the case, then older adults may have allocated more of their resources to the task, thereby decreasing the likelihood of mind-wandering. The SART is also relatively short task (at most 10 minutes in the present versions), and possibly the older adults did not have enough time in the novel experimental task environment to disengage from the task and develop higher rates of mind-wandering. This is why the converging evidence from the reading for comprehension experiment is particularly important. Reading is a more natural task that both younger and older adults engage in on a regular basis. In the present study instead of performing the task for 10 minutes or less, as in the case of the SART, subjects performed the reading task for 30 minutes. The results here are quite telling and consistent with the results from the SART. Specifically, older adults were less likely to report mind-wandering based on either the random probes or via the self-caught method even in the reading task. It is noteworthy that numerically the older adults found the reading task more interesting and difficult than the younger adults; however, neither difference reached significance. Thus, overall, the results indicate that older adults were less likely to mind-wander than younger adults.

Recently, Carriere and colleagues (2010) also reported a study investigating the relationship between SART and aging, and found results very similar to those reported here. Namely, there was a decrease in SART No-Go errors and increase in mean response latency across the lifespan. The authors suggest that sustained attention remains largely stable past adolescence while a slowing of response time may be a strategic move to minimize overt errors. While the results of Carriere et al. (2010) corroborate those reported here, their study used a version of the SART consistent with Robertson et al. (1997), and thus can only be directly compared with Experiment 1 of the present study. Furthermore, Carriere et al. (2010) did not include additional speeded tasks to determine if the slowing across the lifespan to minimize errors is specific to the SART or is a more general phenomenon. The current study also extended these findings to additional manipulations of the SART (e.g., pre-error speeding and post-error slowing) as well as a reading for comprehension task.

Although the present results are clearly in line with early research by Giambra (1973, 1989, 2000; Grodsky & Giambra, 1990–1991) and more recent work by Carriere et al. (2010), we shall now turn to the unique aspects of the present results series of studies.

Disproportionate Age-Related Post-Error Slowing

One of the most intriguing patterns in the present experiments is that older adults produced disproportionate post-error slowing compared to younger adults. The fact that this effect is still highly reliable in standardized reactions times across each of the three experiments makes these results particularly noteworthy. Specifically, the effects in the standardized data provide evidence of a qualitatively distinct age-related effect that does not simply follow the widespread general slowing pattern commonly found in studies of cognitive aging (e.g., Faust, et al., 1999; Myerson et al., 1992).

Post-error slowing has often been attributed to the process of redirecting attention to the primary task after an error is detected (e.g., Robertson et al., 1997; Smallwood, Davies, et al., 2004; but see Notebaert et al, 2009; Smallwood et al., 2009). In this light, there are at least two possible accounts of disproportionate age-related post-error slowing. First, this may reflect impairment in older adults' ability to reengage the task set after the set has been lost leading to the error. There has been considerable interest in models of error monitoring, the correcting influence of error detection on task representations, and the underlying neural systems for these processes (e.g., Botvinick et al., 2001; Braver, Gray, & Burgess, 2007). The post-error performance may reflect the extent to which the system re-establishes cognitive control after detecting an error response to a low-frequency probe. It is possible that this reestablishment of cognitive control declines in older adults.

Second, Smallwood, Davies et al. (2004) and others (e.g., Cheyne et al., 2009) have suggested that post-error slowing may reflect a type of task related mind-wandering. Here, the notion is that when an error is detected, the participant engages in a type of reactive thought process which may include self-evaluation of performance. These additional "mind-wanderings" are task relevant but are more reflective of one's evaluation of their own performance instead of performing the task itself. Because older adults found the SART more interesting than younger adults, they may be more likely to engage in task-related reactive thought processes after realizing they made an error. Converging with this possibility are the personality measures indicating that older adults were more conscientious, and hence be more likely to take the task seriously. Thus, disproportionate post-error slowing may also indicate that older adults engage in more self-reflection of their performance, thereby producing more reactive mind-wandering and disproportionate post-error slowing. Given the convergence of measures across the experiments, we believe the disproportionate post-error response latencies in older adults likely involves qualitative differences in older adults' degree of engagement in the SART, and the increased self-referential processes when an error is detected.

Theoretical Implications

As noted in the Introduction, there are two general perspectives on mind-wandering. Smallwood and Schooler (2006) argued that tasks that require controlled processing will be less likely to support mind-wandering because fewer executive resources are available to be diverted to task-unrelated thoughts. Therefore, tasks like the SART that require relatively little cognitive control should be more susceptible to mind-wandering. In this light, if the SART and the reading for comprehension task were more engaging for older adults, it is reasonable that they would report less mind-wandering than younger adults. Interestingly, Kane and colleagues (2007; McVay & Kane, 2009; 2010) have found that more mind-wandering occurs in individuals with less cognitive control, as reflected by working memory capacity. At first glance, this would appear to be inconsistent with the present results, since there was clear evidence of working memory differences in Experiments 1 and 2, consistent with the extent literature (e.g., McCabe et al., 2010). Hence, one would expect older adults to produce more mind-wandering because of having difficulty staying on task.

McVay and Kane (2010) have more recently developed a Control Failures × Current Concerns framework, based on work by Klinger (1971; 1999; 2009). This work is largely consistent with work by Giambra (1989), in which he suggested that "situational determinants, as well as the variability of the press of unfinished business in any person's life situation at any time, can act to greatly change the person's likelihood of having TUTs" (p.143). The notion here is that mind-wandering is influenced by an interaction of multiple dimensions including cognitive control, the experimental task, and the extent to which the task environment triggers relevant concerns. In this way, reported mind-wandering for both younger and older adults may be influenced by simply setting a cognitive task in an environment that triggers a relevant current concern. This seems particularly relevant in the present study, since older adults appeared more engaged in the present tasks. Hence, the act of older adults coming to a novel experimental context in a University setting, and subsequently experiencing fewer triggered concerns, may contribute to their reported decreased mind-wandering.

In a response to the Control Failures × Current Concerns framework, Smallwood (2010) posited that resources are needed to generate and sustain off-task thought, because mind-wandering is a complex experience which cannot be produced in a resource-free manner. Hence any group, including older adults, with fewer cognitive resources to dedicate to a task would experience less mind-wandering than a group with more cognitive resources. The resource framework could conceivably account for older adults' lack of reported mind-wandering, as well as their worse performance in Experiment 4. Because older have fewer executive resources, as reflected by lower working memory scores, compared to younger adults, they presumably would not experience mind-wandering to the same degree in the SART experiments, and would suffer slower and less accurate reading in Experiment 4. At this level, both perspectives can provide insight into the present results.

Because working memory measures were available in our sample, it is useful to examine if there is any direct relation between working memory and measures of mind wandering. Indeed, in both Experiments 1 and 2, working memory measures were positively correlated with measures of probed reported mind-wandering, $r = .417$, $p < .001$, and $r = .516$, $p < .001$, respectively. However, these correlations were eliminated when one controls for age. In Experiment 4, robust correlations were found between working memory and self-reported mind-wandering, $r = .520$, $p < .001$. Moreover, there was an interesting relationship between personality, working memory, and mind wandering that persisted even after age had been partialed out. Specifically, low-conscientiousness individuals (based on median split) produced a reliable negative correlation between self-reported mind-wandering and working memory, $r = -.454$, $p = .034$. In contrast, high-conscientiousness individuals produced a positive correlation between working memory and self-reported mind wandering, $r = .748$, $p < .001$. Although these results are preliminary, they do suggest that in addition to the difficulty of the task, the task environment, and the degree of interest in the task, as discussed by McVay and Kane (2010) and Smallwood (2010), the relationship between working memory and mind wandering may also be modulated by personality characteristics.

General Implications Regarding Cognitive Studies in Younger and Older Adults

Although the primary goal of the present study was to investigate age-related changes in mind-wandering in recently developed paradigms, we believe the present results have potentially broader implications regarding cognitive aging studies. Specifically, in contrast to the predicted increase in mind-wandering in older adults due to declines in cognitive control, we actually found evidence for less mind-wandering in older adults. The important modifying mechanisms in the present results may be that older adults were higher in conscientiousness, had higher levels of interest in the task, and perceived the task as more difficult. Because in the vast majority of cognitive studies, older adults produce deficits in cognitive performance (see for example, Craik & Salthouse, 2008), it is often implicitly assumed that they have difficulty maintaining the appropriate task set across trials. In contrast, the present results consistently indicated that older adults were at some level performing better than younger adults. That is, accuracy was numerically higher across the SART studies, and they reported less task disengagement, mind-wandering. Moreover, the older adults were higher in conscientiousness and reported these tasks as being more interesting and difficult based on self-report measures. The present study of mind-wandering along with the self-report measures allowed us to detect possible differences in how young and older adults approach such tasks. Just as there are age-related differences in circadian rhythms (e.g., May & Hasher, 1998) and age-stereotypes (e.g., Hess et al., 2003) that may modulate performance in cognitive tasks, one should also consider the degree to which the subjects find the task engaging and interesting. This is another important dimension to better understanding the changes in cognitive performance across the adult spectrum.

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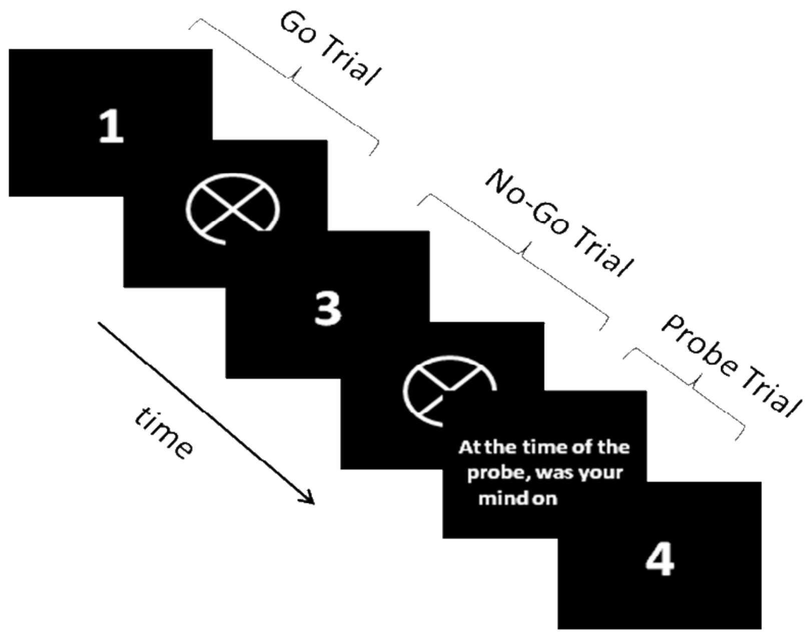

Figure 1.
Sample run of SART trials.

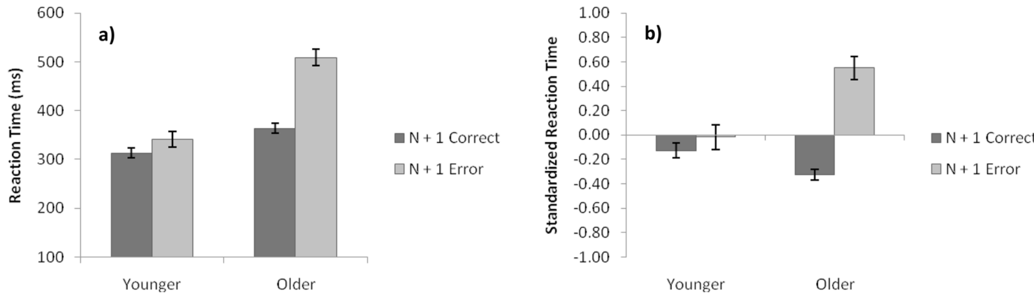

Figure 2.
SART post-error slowing as a function of No-Go trial type and age in Experiment 1. Displayed are a) raw response latencies, and b) standardized response latencies.

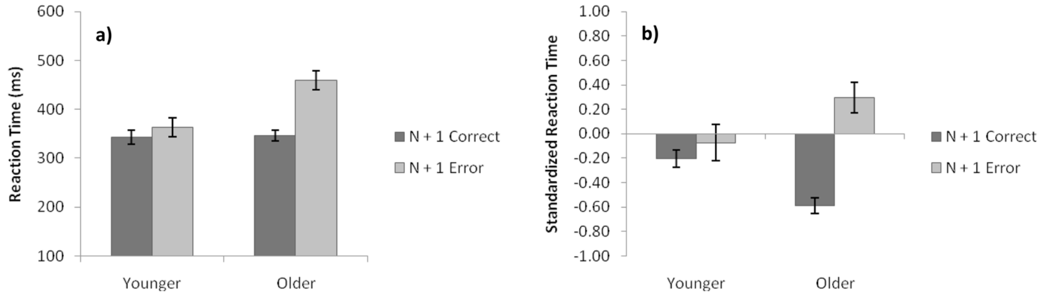

Figure 3.
SART post-error slowing as a function of No-Go trial type and age in Experiment 2. Displayed are a) raw response latencies, and b) standardized response latencies.

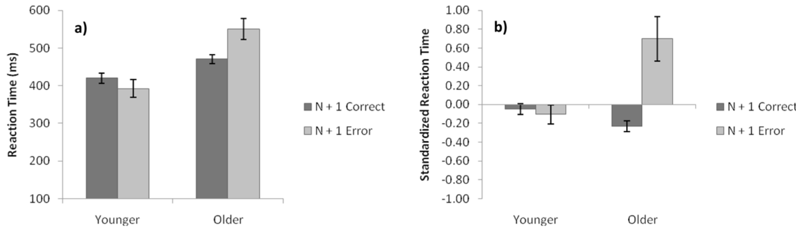

Figure 4.
SART post-error slowing as a function of No-Go trial type and age in Experiment 3. Displayed are a) raw response latencies, and b) standardized response latencies.

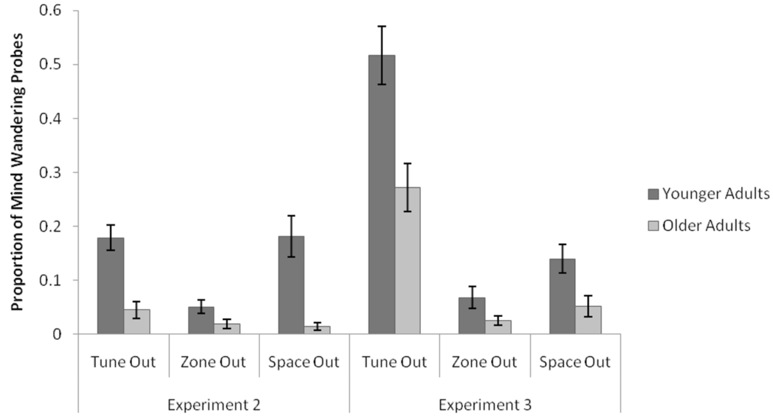

Figure 5.
Comparison of reported mind-wandering between Experiments 2 and 3 as a function of age and type of mind-wandering

Table 1

Mean (SDs) demographic data for younger and older adults for the SART and reading tasks.

	Experiment 1		Experiment 2/4*		Experiment 3	
Measure	**Younger**	**Older**	**Younger**	**Older**	**Younger**	**Older**
N (Female)	54 (29)	62 (40)	29 (18)	38 (31)	31 (16)	49 (29)
Age	19.0 (0.9)	77.3 (6.9)	19.4 (0.8)	75.8 (6.5)	20.9 (1.4)	76.3 (6.4)
Years of Education	13.0 (0.9)	15.0 (2.5)	13.4 (1.1)	14.7 (2.8)	14.9 (1.5)	15.8 (2.6)
Shipley Vocabulary Score	18.8 (0.9)	19.3 (1.1)	---	---	---	---
NEO Conscientiousness	28.4 (9.2)	34.3 (6.1)	27.1 (6.1)	33.6 (7.0)	---	---
NEO Neuroticism	22.2 (10.2)	16.9 (8.1)	25.0 (6.8)	13.8 (8.4)	---	---
Standardized Working Memory†	0.80 (0.6)	−0.78 (0.6)	0.71 (0.9)	−0.71 (0.5)	---	---

*Experiments 2 and 4 were conducted on the same sample.

†Working memory capacity was evaluated using the Operation Span task in Experiment 1 and the Reading Span task in Experiments 2/4

Table 2

SART response latencies and means (SDs) as a function of trial type and age.

Measure	Experiment 1		Experiment 2		Experiment 3	
	Younger	Older	Younger	Older	Younger	Older
Accuracy						
Go Accuracy	.96 (.05)	.96 (.05)	.95 (.07)	.96 (.05)	.99 (.01)	.99 (.02)
No-Go Accuracy	.70 (.14)	.73 (.16)	.68 (.17)	.70 (.17)	.84 (.11)	.93 (.08)
Reaction Time						
Go RT	341 (71)	441 (96)	370 (74)	426 (78)	438 (76)	513 (73)
No-Go (Error) RT	299 (89)	378 (91)	316 (74)	377 (93)	367 (94)	455 (194)
Go zRT	.01 (.02)	.01 (.02)	.02 (.02)	.01 (.02)	.01 (.01)	.01 (.01)
No-Go (Error) zRT	−.46 (.51)	−.49 (.68)	−.53 (.56)	−.42 (.54)	−.55 (.54)	−.45 (1.32)

Table 3

SART pre-error and post-error response latencies (SDs) as a function of trial type and age.

	Experiment 1		Experiment 2		Experiment 3	
Measure	**Younger**	**Older**	**Younger**	**Older**	**Younger**	**Older**
Pre-Error Speeding						
N − 4 No-Go Error RT	315 (69)	411 (103)	325 (63)	386 (67)	397 (82)	466 (119)
N − 4 No-Go Correct RT	345 (66)	443 (82)	361 (68)	417 (74)	426 (69)	498 (71)
N − 4 No-Go Error zRT	−.23 (.36)	−.23 (.33)	−.35 (.44)	−.18 (.37)	−.18 (.35)	−.01 (1.06)
N − 4 No-Go Correct zRT	.19 (.16)	.24 (.17)	.07 (.18)	.08 (.14)	.04 (.12)	.05 (.11)
Post-Error Slowing						
N + 1 No-Go Error RT	341 (113)	509 (129)	363 (112)	460 (117)	392 (127)	550 (180)
N + 1 No-Go Correct RT	313 (72)	364 (81)	343 (78)	346 (69)	420 (78)	471 (84)
N + 1 No-Go Error zRT	−.02 (.73)	.55 (.75)	−.07 (.84)	.30 (.77)	−.10 (.53)	.70 (1.51)
N + 1 No-Go Correct zRT	−.13 (.44)	−.33 (.37)	−.20 (.41)	−.58 (.41)	−.06 (.31)	−.25 (.41)

Table 4

SART thought report mean proportions (SDs) as a function of age and experiment.

	Experiment 1		Experiment 2		Experiment 3	
Measure	**Younger**	**Older**	**Younger**	**Older**	**Younger**	**Older**
Thought Reports – Random Probes						
Overall Mind-Wandering	.21 (.23)	.04 (.11)	.41	.08	.72 (.29)	.35 (.32)
Tune Outs	---	---	.18 (.14)	.05 (.09)	.52 (.30)	.27 (.31)
Zone Outs	---	---	.05 (.07)	.02 (.05)	.07 (.11)	.02 (.06)
Space Outs	---	---	.18 (.22)	.01 (.04)	.14 (.15)	.05 (.13)
Interest	---	---	2.19 (1.18)	3.34 (1.15)	1.42 (.56)	2.53 (1.17)
Difficulty	---	---	2.41 (1.29)	3.21 (1.19)	1.61 (.76)	1.55 (.79)

Table 5

Reading task mean proportions (SDs) as a function of age and experiment.

	Experiment 4	
Measure	**Younger**	**Older**
Comprehension Accuracy	.87 (.10)	.79 (.14)
Reading Time Per Word (ms) *	339 (55)	465 (159)
Thought Reports – Random Probes		
Overall Mind-Wandering	.30 (.20)	.14 (.22)
Tune Outs	.10 (.08)	.09 (.17)
Zone Outs	.15 (.13)	.03 (.07)
Space Outs	.05 (.08)	.02 (.07)
Thought Reports – Self Caught		
Overall Mind-Wandering	8.90 (8.29)	2.00 (4.71)
Tune Outs	6.24 (7.63)	1.11 (2.13)
Space Outs	2.66 (2.84)	.89 (4.40)
Zone Outs	---	---
Interest	2.67 (1.24)	3.00 (1.18)
Difficulty	2.76 (1.14)	3.29 (1.27)

*For Experiment 4, per-word reading times were calculated by dividing each subject's per-page reading time by 65, the average number of words on each page.