# Age-related differences in mind-wandering in daily life

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**Abstract:**

In recent years, several laboratory studies have indicated that healthy older adults exhibit a reduction in mind-wandering frequency compared with young adults. However, it is unclear if these findings extend to daily life settings. In the current study, using experience sampling over the course of a week in the daily life of 31 young and 20 older adults, we assessed age-related differences in: (a) mind-wandering frequency, (b) the relationship between affect and mind-wandering frequency, and (c) content of mind wandering. Older adults mind wandered less than young adults in daily life. Across age groups, negative affect was positively associated with mind-wandering occurrence. Finally, older adults reported that their thoughts were more pleasant, interesting, and clear compared with young adults, who had thoughts that were more dreamlike, novel, strange, and racing. Our results provide the first demonstration using thought sampling that older adults exhibit a reduction in mind-wandering frequency in daily life. Implications for current theories of age-related reductions in mind-wandering frequency are discussed.

**Keywords:** Aging | mind-wandering | affect | task-unrelated thought | stimulus-independent thought

## Article:

Mind wandering has been defined as a shift in content of thought away from an ongoing task to thoughts that are both task unrelated and stimulus independent (Smallwood & Schooler, 2006, 2015; Stawarczyk, Majerus, Maj, Van der Linden, & D'Argembeau, 2011). In recent years, laboratory studies have consistently indicated that older adults mind wander less than do young adults (for a review, see Maillet & Schacter, 2016a). This age difference seems robust. First, age-related reductions in mind wandering have been found across different tasks, including those indexing sustained attention (Giambra, 1989; Jackson & Balota, 2012; McVay, Meier, Touron, & Kane, 2013), reading comprehension (Frank, Nara, Zavagnin, Touron, & Kane, 2015; Jackson & Balota, 2012; Krawietz, Tamplin, & Radvansky, 2012), episodic encoding (Maillet & Rajah, 2013), and working memory (Jordano & Touron, 2017; McVay et al., 2013). Second, subjective mind-wandering reports appear to be as valid in older adults as in young adults: when reporting off-task versus on-task thoughts, young and older adults exhibit similar levels of task disruption (McVay et al., 2013), patterns of eye movement (Frank et al., 2015), and brain activation (Maillet & Rajah, 2016). Third, mind-wandering frequency is further reduced in early stage Alzheimer's patients (Gyurkovics, Balota, & Jackson, 2018) and in patients with Parkinson's disease (Geffen et al., 2017) compared with healthy older adults, suggesting that mind-wandering frequency may decrease with cognitive impairment.

Several explanations have been put forward to explain age-related reductions in mind-wandering frequency in the laboratory. First, older adults may be more motivated to perform well, or may be more interested than young adults in laboratory tasks (or both), which could, in turn, lead them to mind wander less (Krawietz et al., 2012). Indeed, older adults typically report being more interested than young adults in performing laboratory tasks, and after statistically accounting for interest, age-related reductions in mind wandering are reduced or even eliminated (Jackson & Balota, 2012; Jackson, Weinstein, & Balota, 2013; Krawietz et al., 2012; Shake, Shulley, & Soto-Freita, 2016). Second, age-related reductions in off-task mind wandering may be due to older adults being more concerned about their task performance compared with young adults (McVay et al., 2013). Consistent with this suggestion, some studies have distinguished between mind-wandering (task-unrelated thoughts) and task-related interference (thoughts, including worries, about one's task performance) and found that older adults exhibit more task-related interference despite exhibiting less mind wandering compared with young adults (Frank et al., 2015; McVay et al., 2013). However, the total amount of off-task thoughts (mind-wandering + task-related interferences) is still lower in older than young adults in these studies, suggesting that this explanation cannot fully account for age-related reductions in off-task thoughts. Third, older adults may mind wander less than young because the laboratory environment may contain goal- or concern-related cues that are more relevant to young versus older adults, and may thus trigger more mind-wandering episodes in young adults (McVay et al., 2013). A fourth suggestion is that older adults may produce less task-unrelated thoughts than young adults (e.g., Giambra, 1989; Maillet & Schacter, 2016b). Giambra (1989) suggested that the brain engages in nonconscious processing of unfinished business (unresolved goals) and that the result of this processing is pushed back into awareness as task-unrelated thoughts whenever the conscious mind has sufficient capacity to express it. Giambra (1989) further suggested that age-related reductions in task-unrelated thoughts may be attributable to fewer nonconscious processing products being available for intrusion into awareness. Relatedly, Maillet and Schacter (2016b) suggested that age-related reductions in mind wandering can be understood as part of a broader age-related reduction in the capacity to internally trigger and maintain representations that leads older adults to become increasingly environment dependent (Lindenberger & Mayr, 2014).

Age differences in mind-wandering frequency are widely demonstrated during laboratory tasks, but no study has measured in-the-moment mind wandering in young and older adults during daily life. This was the first goal of the current study. There are several reasons why assessing whether age-related reductions in mind wandering persist during daily life may help better understand this phenomenon. First, it may provide evidence relevant to current theories of age-related reductions in mind wandering. For instance, measuring mind-wandering frequency while young and older adults go about their daily routines minimizes the concern that the laboratory setting may be more relevant to young adults, thereby triggering a greater amount of thoughts in young versus older adults. It also minimizes the concern that older adults may be more motivated or concerned than young adults to perform laboratory tasks. Thus, finding an age-related reduction in mind wandering in daily life would provide evidence against these proposals. Assessing age-related differences in mind wandering in daily life is also important because there is evidence that mind wandering in people's daily life environment has different correlates than mind wandering measured in the lab. A recent study found that whereas neuroticism (but not openness to experience) predicted laboratory mind wandering, openness (but not neuroticism) predicted daily life mind wandering (Kane et al., 2017). Such findings make it unclear whether laboratory findings regarding mind wandering in older adults extend to daily life.

The second goal of this study was to assess age-related differences in the association between affective valence and mind-wandering frequency. Several studies have indicated that negative affect is positively associated with mind-wandering frequency in young adults (Kane et al., 2017; Killingsworth & Gilbert, 2010). Compared with young adults, older adults report more positive emotional experience (Carstensen et al., 2011) and exhibit a positivity bias (Mather & Carstensen, 2005). This naturally leads to the question of whether age-related reductions in mind-wandering frequency are related to age-related differences in affect. Supporting this assertion, older adults' more positive affect may partially mediate age-related differences in mind-wandering frequency during reading comprehension (Frank et al., 2015). We thus predicted that, in daily life, older adults would report increased positive affect and that this would partially account for age-related reductions in mind-wandering frequency.

The third goal of this study was to assess age-related differences in the content of thought. The characteristic of mind-wandering that has most often been assessed in the aging literature is temporality. Using retrospective estimates of daily life mind wandering, Giambra (2000) reported that older adults had fewer future-oriented thoughts than young adults. Across two experiments using sustained attention to response task, Jackson et al. (2013) found reduced mind-wandering frequency in older versus young adults but did not find age-related differences in temporality of mind wandering. In the first experiment (with no atemporal option), both young and older adults exhibited more future- versus past-oriented mind wandering, whereas in the second experiment (with an atemporal option), the prospective bias disappeared in both age groups. Maillet and Schacter (2016b) also did not find age-related differences in temporality of mind-wandering: in both young and older adults, thoughts triggered by task stimuli were more past- versus future-oriented, whereas internally triggered thoughts were more future- versus past-oriented. Although they did not measure mind wandering, a fourth study (Gardner & Ascoli, 2015) used an experience-sampling procedure to assess age-related differences in autobiographical memories and prospective memories in daily life. Surprisingly, they reported that, although there were no age-related differences in frequency of autobiographical memories, older adults reported experiencing an increase in prospective thoughts. Due to the inconsistency in previous results, we had no specific hypotheses regarding age-related differences in temporality of thought in the current study.

Apart from temporality, age-related differences in content of mind wandering have rarely been assessed. One exception is Giambra (2000) who conducted an extensive, longitudinal examination of age-related changes in daydreaming content and characteristics in daily life using a retrospective questionnaire: the Imaginal Process Inventory. Increasing age was associated with reduced frequency of daydreams on particular topics, including problem-solving, sexual, heroic, hostile, achievement-oriented, and guilt daydreams. A few types of daydreams showed other patterns. For example, bizarre-improbable daydreams showed a U-shaped age function, initially decreasing with increasing age until age 55–64, but then increasing again in the oldest subjects. Although interesting, these findings should be interpreted with caution as they were measured using a retrospective questionnaire. Many investigators have called into question the ability of participants to judge frequency or content of daily life thoughts in questionnaires, as these may be subject to memory errors and biases, a concern that is amplified in aging participants (Giambra, 1989; Maillet & Schacter, 2016a; McVay et al., 2013). In the current study, we conducted an exploratory analysis of age-related differences in the content of thought using in-the-moment thought probes that minimize demands on memory.

## Method

### Participants

The study was approved by the University of North Carolina at Greensboro (UNCG) Institutional Review Board. Thirty-five young adults and 29 older adults enrolled in the current study. Young adults were recruited via flyers posted around the UNCG campus as part of a larger project examining individual differences in mind wandering and creativity. Older adults were recruited from a database of participants who completed previous laboratory studies and expressed interest in participating in future studies. Participants were paid up to $100 for completion of all phases of the study. Four young adults and nine older adults were excluded due to having fewer than five thought-sampling responses (Bolger & Laurenceau, 2013; Cotter & Silvia, 2017). Thus, the final sample consisted of 31 young adults and 20 older adults. One of the included young adults had missing information for gender and age due to computer error. Young adults (19 female) had a mean age of 21.53 years (range = 18–34; *SD* = 3.65). Older adults (10 female) had a mean age of 70.70 years (range = 66–77; *SD* = 3.21). Older adults had a mean score of 29.45 (range: 25–30; *SD* = 1.28) on the Mini-Mental Status Examination (Folstein, Folstein, & McHugh, 1975), suggesting they were in good cognitive health.

### Procedure

The first phase of the study was conducted individually and involved completing consent forms and a series of behavioral measures; these measures were part of a larger project and are not reported here. The experimenter then described the experience-sampling phase of the study and procedure for responding to surveys over the course of the following week.

The surveys were administered via MetricWire, an app-based platform for experience-sampling data collection. Young and older adults with a smart phone (iPhone or Android) were asked to download MetricWire on their phones. Participants without a smart phone were given 7-in. Android tablets with MetricWire installed. An experimenter explained how to respond to the survey questions and completed a practice survey with participants. Previous studies support the feasibility of electronic daily life data collection with older adults (e.g., Scott, Sliwinski, Mogle, & Almeida, 2014).

MetricWire signaled participants to complete surveys from 8 a.m. to midnight for 1 week. The timing of survey notifications was randomly determined and programmed to occur at least 50 min apart. On Days 2–7, a total of 12 surveys per day were sent. The number of surveys sent on the first day varied depending on the time at which participants visited the lab. Participants were encouraged to respond to as many surveys as possible, but to avoid responding in situations that were unsafe (e.g., driving) or inappropriate (e.g., in class); they could also ignore the survey notifications if they were sleeping. Upon receiving the notification, participants were instructed to take stock of their current mental and emotional experiences, and to respond to survey questions based on their experiences at the time of the notification. This procedure has been used in previous studies (Kane et al., 2007; Kane et al., 2017). After clicking the notification, the visual display showed a series of survey questions, one at a time. Participants responded by clicking on sliding Likert scale icons, and responses were transmitted to a secure online server hosted by MetricWire.

**Table 1.** Survey Questions With Mean (SD)

| Survey questions | Young | Old |
|---|---|---|
| Content questions (1–7 Likert scale) | | |
| My thoughts were mostly about . . . | | |
| My thoughts were RELATED TO A CREATIVE PROJECT. | 2.47 (1.11) | 2.63 (.98) |
| My thoughts were PLEASANT. | 4.44 (.87) | 4.99 (.63) |
| My thoughts were RACING. | 2.80 (1.04) | 2.12 (.81) |
| My thoughts were DREAM-LIKE. | 2.62 (1.16) | 1.88 (.79) |
| My thoughts were CLEAR. | 4.49 (.82) | 5.55 (.76) |
| My thoughts were FUNNY. | 2.18 (.82) | 2.17 (.72) |
| My thoughts were STRANGE. | 2.06 (.90) | 1.46 (.52) |
| My thoughts were NOVEL. | 2.38 (1.10) | 1.99 (.82) |
| My thoughts were INTERESTING. | 3.75 (1.07) | 4.22 (.77) |
| At the time of the beep, my thoughts had VISUAL IMAGES & PICTURES | 4.17 (1.43) | 3.79 (1.32) |
| My thoughts had AUDITORY IMAGES & SOUNDS | 3.31 (1.30) | 2.36 (.85) |
| Affect questions (1–7 Likert scale) | | |
| At the time of the beep, . . . | | |
| I was feeling HAPPY. | 4.65 (.99) | 5.09 (.66) |
| I was feeling SAD. | 1.67 (.60) | 1.44 (.31) |
| I was feeling TIRED. | 3.44 (1.04) | 2.53 (.66) |
| I was feeling MOTIVATED. | 3.38 (1.04) | 4.19 (.65) |
| I was feeling FRUSTRATED. | 2.24 (.78) | 2.1 (.81) |
| I was feeling ANXIOUS. | 2.46 (1.02) | 2.07 (1.22) |
| I was feeling INTERESTED. | 3.76 (1.07) | 4.6 (.81) |
| I was feeling RELAXED. | 3.93 (.86) | 4.61 (.67) |
| I was feeling IN A STATE OF “FLOW” | 3.49 (1.27) | 3.65 (1.27) |
| I was feeling IRRITABLE. | 2.15 (.74) | 1.78 (.67) |
| I was feeling ENERGETIC. | 3.01 (1.11) | 4.04 (.75) |
| I was feeling GOOD AT WHAT I WAS DOING. | 3.92 (.95) | 4.93 (.53) |
| I was feeling INSPIRED. | 2.99 (1.14) | 3.45 (.91) |
| I was feeling FOCUSED. | 4 (1.00) | 4.83 (.65) |

*Note.* This table presents the subject-mean (standard deviation) score for the content and affect questions that were rated on a 1–7 Likert scale.

The survey (Table 1) began with a mind-wandering thought probe: “At the time of the beep, my mind had wandered to something other than what I was doing” (Kane et al., 2007; Kane et al., 2017). Whether they responded being on task or mind wandering, participants then received the same follow-up questions. First, participants indicated whether their thoughts were mostly about the past, present, or future. Then, the survey asked a series of questions related to thought content, with the aim of capturing a range of qualities related to mind-wandering and daydreaming experiences. Participants indicated the extent to which their current thoughts were characterized by each quality, using a 1 (*not at all*) to 7 (*very much*) scale. These items began with the stem, “My thoughts were mostly . . .” and ended with a content-related term (e.g., pleasant, racing, dreamlike, novel, interesting, etc.) The survey then asked participants to respond to a series of items related to affect, beginning with the stem, “I was feeling . . .” and ending with a mood-related term (e.g., sad, tired, motivated, anxious, relaxed, etc.). Finally, participants were asked to indicate their social context at the time of the survey (i.e., alone, by myself; with other people, but not interacting with them; interacting with other people); for completeness, exploratory analyses of these social-context items are presented in the online supplementary materials.

**Results**

Participants sometimes respond carelessly or randomly in self-report questionnaires. To identify potentially problematic responses, we calculated the variance across all probe questions in a given questionnaire that were rated on a 1–7 Likert scale. We assumed that low variance across these items reflected careless responding (this is especially likely to be the case because some questions should have produced divergent responses, such as feeling happy vs. sad). We dropped all questionnaires with variance scores more than 1.96 *SD*s below the mean (Kane et al., 2017). In total 16 questionnaires were dropped in young adults and one was dropped in older adults due to low variance. An additional three questionnaires, all in older adults, were dropped because of missing data for the on-task/mind-wandering question. In total, this left a total of 863 questionnaires in young adults and 625 questionnaires in older adults. Young adults had an average of 28 completed questionnaires (min = 5, max = 60, $SD = 13$), whereas older adults had an average of 31 (min = 10, max = 64, $SD = 14$). There were no group differences in average number of completed questionnaires, $t(1,49) = 0.92$, $p = .36$, $d = 0.26$.

We analyzed the distribution of responses over days to determine whether there were age-related differences in response rates over the course of the study. The first day was excluded from this analysis because subjects received a different number of probes on that day, depending on when their lab visit was scheduled. The mean (*SD*) response rate on Days 2–7 for young adults was: 0.41 (0.23), 0.35 (0.21), 0.40 (0.24), 0.34 (0.23), 0.26 (0.22), and 0.25 (0.20). For older adults, it was: 0.33 (0.23), 0.45 (0.24), 0.38 (0.17), 0.38 (0.21), 0.40 (0.24), and 0.38 (0.23). A repeated measures analysis of variance with response rate as the dependent variable and age group and day (Day 2, Day 3, Day 4, Day 5, Day 6, Day 7) as independent variables indicated an Age Group × Day interaction, $F(5, 245) = 4.78$, $p < .001$, $\eta p^2 = 0.09$. The interaction was due to there being no age differences in response rates in earlier days (2–5, all *p*s >0.1), but significant age differences on Day 6, $t(49) = 2.11$, $p < .05$, $d = 0.61$, and Day 7, $t(49) = 2.21$, $p < .05$, $d = 0.63$. Whereas older adults responded relatively consistently across days, young adults tended to respond less on later days.

Age-related differences in attention can change based on time of day (Anderson, Campbell, Amer, Grady, & Hasher, 2014; May, 1999), so we also analyzed age-related differences in the time at which young and older adults responded to the probes. Timing information was available for 1,430 out of 1,488 responses (96%). Young and older adults responded to probes that on average were sent at 4:44 p.m. ($SD$ = 1.31 hr) and 3:50 p.m. ($SD$ = 1.19 hr), respectively, $t(1,49) = 2.52$, $p < .05$, $d = 0.72$. We therefore partial out variance associated with time of day in our analyses of age-related differences in mind-wandering frequency in the following section.

## Age-Related Differences in Mind-Wandering Frequency

Our first goal was to determine whether older adults exhibit a reduction in mind-wandering in daily life. Averaged across subjects, young adults reported mind wandering on 41% ($SD$ = 22%) of probes, whereas older adults reported mind wandering on 28% ($SD$ = 16%) of probes, $t(1,49) = 2.30$, $p < .05$, $d = 0.66$. An analysis of covariance (ANCOVA) indicated that this age-related difference in mind-wandering frequency remained significant after partialing out variance associated with average time of day of responses, $F(1, 48) = 6.96$, $p = .01$, $\eta p^2 = 0.13$.

We also assessed age-related differences in mind-wandering frequency using a mixed logistic model analysis (treating in-the-moment mind-wandering vs. on-task thought as a dichotomous variable). In contrast with a *t* test that gives equal weight to each participant, the mixed logistic model analysis accounts for some participants having more responses than others. Mixed-model analyses were conducted using the lme4 package in R (R Core Team, 2013). Young adults reported mind wandering on 365 out of a total of 863 probe responses (42%), whereas older adults reported mind wandering on 149 out of a total of 625 probe responses (24%). The logistic mixed-model analysis, with age group as a fixed effect and participant as a random effect, revealed a reduction in mind-wandering frequency in older versus young adults ($b = -0.75$, $SE = 0.29$, $Z = -2.57$, $p = .01$). We repeated this analysis including time of day of each response, and the Time of Day × Age Group interaction. There was no significant interaction, $p = .35$. In a model with only the main effects of age group and time of day, only age group was significant, ($b = -0.86$, $SE = 0.29$, $Z = -2.94$, $p < .005$) whereas time of day was not, $p = .17$.

One potential caveat of the current results is that the mind-wandering rate of the young sample was higher than those obtained in prior studies using a similar procedure but larger samples (30% in Kane et al., 2007; 30% in McVay, Kane, & Kwapil, 2009; 32% in Kane et al., 2017). One possibility for the discrepancy is that the present result is due to recruitment procedures. Because one of the goals of the broader project was to examine the relationship between creativity and mind wandering in younger adults, we attempted to recruit artists, musicians, and their friends. These individuals may be more open to experience than a traditional sample, which may have contributed to higher mind-wandering rates (Kane et al., 2017). In contrast, there was no such emphasis on recruiting artists for the older adult sample. Apart from four young adults, all current participants had data for the six facets of Openness to Experience (McCrae, Costa, & Martin, 2005). We calculated an average score of these six facets (27 young adults, $M = 3.74$, $SD = 0.43$; 20 older adults, $M = 3.46$, $SD = 0.45$) and used it as a covariate in an ANCOVA assessing age-related differences in mind-wandering. The ANCOVA indicated that age-related reductions in mind wandering were still significant after partialing out variance associated with Openness to Experience, $F(1, 44) = 5.17$, $p < .05$, $\eta p^2 = 0.11$, or after partialing out variance associated with both Openness and average time of day of response, $F(1, 43) = 6.06$, $p < .05$, $\eta p^2 = 0.12$. Similarly, in a mixed model with mind-wandering frequency as the dependent variable, age group, time of day, and Openness as fixed factors, and participant as a random factor, only age group was significant ($b = -0.90$, $SE = 0.32$, $Z = -2.85$, $p < .005$).

## Age-Related Differences in the Association Between Affect and Mind-Wandering Frequency

**Between-subjects analyses.** Our second goal was to assess age-related differences in the association between affect and mind-wandering frequency. We first assessed whether there was an age-related difference in affect. Toward this end, we performed a principal component analysis (PCA) using varimax rotation on the 13 affect variables to reduce them to a smaller number of components (with each subject contributing a mean value for each variable from across the questionnaires). For all PCAs reported in this paper, we based our decision about the number of components to keep on: (a) the scree plot, (b) the total amount of variance explained by all components, and (c) the interpretability of components. The rotated component matrices for all of the PCAs are presented as heat maps in Figures 1 and 2. The raw numbers used to generate these images can be found in the online supplementary materials.

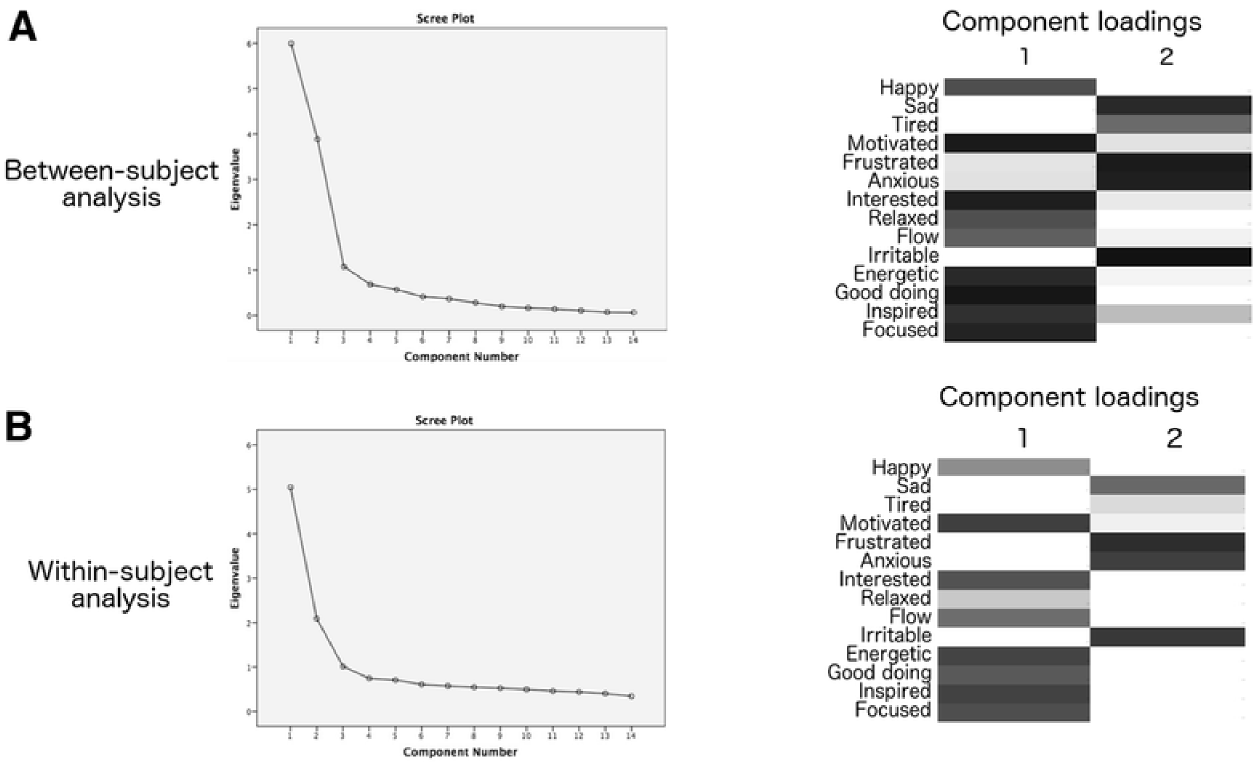


**Figure 1.** Scree plots and component loadings for the principal components analysis on the affect variables. Results are presented both when the analysis was performed at (A) a between-subjects level, and (B) a within-subject level.

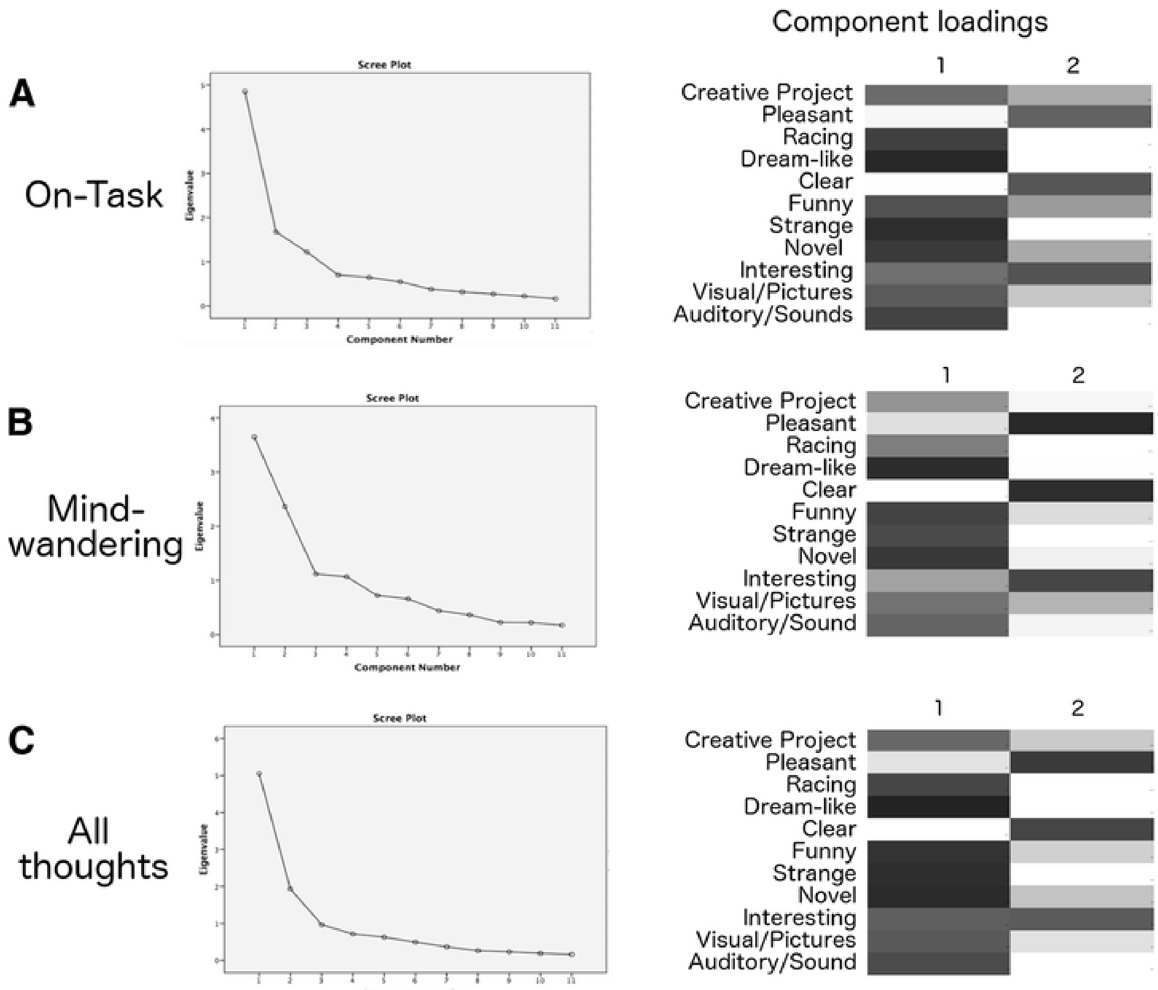


**Figure 2.** Scree plots and component loadings for the principal components analysis on the content variables. Results are shown when the analysis was performed on (A) on-task responses only, (B) mind wandering only, and (C) all thoughts.

The PCA indicated that two components accounted for 71% of the total variance (see Figure 1A for scree plot and component loadings). The first component (positive affect) loaded strongly on the variables motivated, interested, inspired, energetic, feeling good at what one is doing, and focused. The second component (negative affect) loaded strongly on the variables irritable, frustrated, anxious, and sad. Independent-samples *t* tests indicated that older adults had higher scores compared with young for positive affect, $t(1,48.44) = 3.80$, $p < .001$, $d = 1.03$. Older adults had numerically but nonsignificantly lower loadings than young for the negative affect component $t(1,49) = 1.92$, $p = .06$, $d = 0.55$.

Next, we assessed whether differences in affect were associated with mind-wandering frequency. Correlations across all participants (young and old) indicated that mind wandering was positively correlated with negative affect, $r = .40$, $p < .005$ but not with positive affect, $r = .05$, $p > .05$. Partial correlations partialing out variance associated with age group similarly indicated that mind-wandering frequency was positively correlated with negative affect, $r = .35$, $p = .01$, but not with positive affect, $r = .13$, $p > .05$.

We performed a hierarchical regression analysis to determine whether age group accounted for any additional variance after partialing out variance associated with the two affect factors. That is, in a regression predicting mind-wandering frequency, at the first level, we entered positive affect and negative affect as independent variables. At the second level, we entered age group. The Level 1 model was significant, $F(2, 48) = 4.64$, $p = .01$, $R^2 = 0.16$. negative affect was the only significant predictor, unstandardized $b = 0.08$ ($SE = 0.27$), $p = .004$. The Level 2 model was also significant, $F(3, 47) = 4.70$, $p < .01$, $R^2 = 0.23$. Both negative affect, unstandardized $b = 0.07$ ($SE = 0.03$), $p < .05$, and age group, unstandardized $b = -0.13$ ($SE = 0.06$), $p < .05$, were significant predictors. Thus, age group significantly predicted mind-wandering frequency even after accounting for affect.

**Within-subject (mixed linear model) analyses.** Our between-subjects analysis found that people with higher scores for negative affect over the week exhibited more mind wandering than did those with lower scores. Here, we conducted a mixed logistic model analysis to assess the association between affect and mind-wandering occurrence using within-person centering to partial out the between-subjects variance. This analysis indicates whether occasions of mind wandering are associated with more negative affect within-participant compared with occasions of on-task thinking, and whether there is any age-related difference in this association.

Toward this end, we performed a PCA at the probe level (rather than at the subject level in the paragraph above) on within-person centered data (for similar applications of PCA at the thought probe level, see Engert, Smallwood, & Singer, 2014; Medea et al., 2016; Ruby, Smallwood, Engen, & Singer, 2013; Ruby, Smallwood, Sackur, & Singer, 2013). A two-component solution explaining 51% of the total variance was obtained (see Figure 1B for scree plot and component loadings). Similar to the between-subjects analysis, the first factor (positive affect) loaded strongly on the variables motivated, interested, feeling good at what one is doing, inspired, and focused and the second factor (negative affect) loaded strongly on the variables irritable, frustrated, anxious, and sad.

We performed a series of mixed logistic model analyses to assess the within-person relationship between mind-wandering and momentary affect. In all models, the dependent variable was mind wandering, the fixed effects were negative affect and positive affect, and for random effects, we had participant intercept and participants as a random slope by the main effect of each affect factor. In the first model, negative affect in the moment positively predicted mind-wandering occurrence ($b = 0.25$, $SE = 0.07$, $Z = 3.85$, $p < .001$), whereas positive affect negatively predicted it ($b = -0.19$, $SE = 0.08$, $Z = -2.37$, $p < .05$). In a second model, with age group as an additional fixed effect, negative affect positively predicted mind wandering in the moment ($b = 0.26$, $SE = 0.07$, $Z = 3.93$, $p < .001$), positive affect negatively predicted it ($b = -0.19$, $SE = 0.08$, $Z = -2.40$, $p < .05$), and age group also negatively predicted it ($b = -0.80$, $SE = 0.30$, $Z = -2.65$, $p < .01$). The model with age group explained significantly more variance than the model without this variable ($p = .01$). In a final model, we entered the interaction between age group and each of the affect factors to determine if whether age moderated the association between affect and mind-wandering frequency. None of the interactions were significant (all $p$s $> .40$), suggesting that the relationship between affective valence and mind-wandering occurrence is similar in young and older adults.

In summary, as predicted, we found that older adults reported more positive affect compared with young adults. Moreover, we found that negative affect similarly predicts mind-wandering occurrence in young and older adults, both at a between-subjects and a within-subject level. In addition, at both between-subjects and within-subject levels, age group was a significant predictor of mind-wandering frequency even after accounting for affect. Finally, although people with greater positive affect did not mind wander less than those with less positive affect, occasions on which people had more positive affect produced less mind wandering than did those on which people had less positive affect.

## Age-Related Differences in Content of Thought

The third goal of this study was to assess age-related differences in the content of thought. The temporality data was analyzed separately from the other content variables because we had a particular interest in this variable, and because it was a categorical variable (unlike all the other variables that were measured on a 1–7 scale). We performed three mixed logistic analyses. The first two compared “past” responses and “future” responses to “present” responses, whereas the third compared future with past response outcomes (Table 2 displays descriptive statistics of the temporality variable). The fixed effects were age group (young or old), thought type (on-task or mind-wandering), and the Age Group × Thought Type interaction. For random effects, we had intercepts for participants and also included participants as a random slope by the main effect of thought type. These analyses assess whether there are thought-type (mind-wandering vs. on-task) or age-related differences (young vs. old) in the temporal orientation of thought.

**Table 2.** Temporality Data

| | On-task | | | | Mind-wandering | | | |
|---|---|---|---|---|---|---|---|---|
| Age group | Past | Future | Present | Total | Past | Future | Present | Total |
| Young | 6 (1%) | 35 (7%) | 457 (92%) | 498 | 33 (9%) | 165 (45%) | 167 (46%) | 365 |
| Old | 23 (5%) | 68 (14%) | 381 (81%) | 472 | 25 (17%) | 66 (45%) | 57 (39%) | 148 |

*Note.* This table presents the number of thoughts (and percentage) for each category of the social context and temporality variables in young and older adults.

For the past versus present logistic analysis, there as a main effect of thought type ($b = -1.65$, $SE = 0.52$, $Z = -3.19$, $p = .001$). No other effects were significant (all $p$s $>0.15$). For on-task thoughts, the predicted probability of being about the past versus the present was 0.05 ($SE = 0.29$, 95% CI [0.03, 0.09]) in older adults and 0.01 ($SE = 0.45$, 95% CI [0, 0.03]) in young adults. For mind wandering, it was 0.22 ($SE = 0.43$, 95% CI [0.11, 0.40]) in older adults and 0.13 ($SE = 0.33$, 95% CI [0.08, 0.23]) in young adults. The predicted probabilities indicate that in both age groups, mind wandering was more likely to be about the past vs. the present compared with on-task thoughts.

For the future vs. present logistic analysis, there was a main effect of thought type ($b = -2.00$, $SE = 0.37$, $Z = -5.44$, $p < .001$). No other effects were significant (all $p$s $>0.15$). For on-task thoughts, the predicted probability of being about the future versus the present was 0.13

($SE$ = 0.24, 95% CI [0.08, 0.19]) in older adults and 0.06 ($SE$ = 0.26, 95% CI [0.04, 0.09]) in young adults. For mind wandering it was 0.52 ($SE$ = 0.28, 95% CI [0.38, 0.65]) in older adults and 0.47 ($SE$ = 0.21, 95% CI [0.37, 0.57]) in young adults. The predicted probabilities indicate that in both age groups, mind wandering was more likely to be about the future vs. the present compared with on-task thoughts. Finally, for the future vs. past logistic analysis, there were no main effects or interactions (all $p$s >0.30). Taken together, these results indicate that temporality of thought was similar in young and older adults. That is, in both age groups, mind wandering was more likely to be about the past or future than the present compared with on-task thought.

**Age-related differences in other content variables.** We performed a PCA, at the between-person level, on the 11 content variables that were each rated on 1–7 Likert scales. We performed this analysis separately for on-task thoughts and mind-wandering questionnaires. Thus, for the on-task PCA, for each subject, we calculated the mean rating for each of the 11 content variables for the on-task questionnaires only. These 11 mean values per subject were then entered into the PCA. We repeated this procedure for mind-wandering responses.

The PCA for on-task thought yielded a two-component solution that accounted for 59% of the total variance (see Figure 2A for scree plot and component loadings). The first component loaded on many variables, but most strongly on the variables dreamlike, racing, strange, novel, and auditory sounds. The second loaded most strongly on the variables clear, pleasant, and interesting. Independent-samples $t$ tests indicated that young adults had higher scores compared with older adults on the first component (young: $M = 0.27$, $SD = 1.05$; old: $M = -0.41$, $SD = 0.77$, $t(1,48) = 2.49$, $p < .05$, $d = 0.72$) whereas older adults had higher scores compared with young adults for the second component (young: $M = -0.45$, $SD = 0.82$; old: M = 0.67, $SD = 0.87$, $t(1,48) = 4.58$, $p < .001$, $d = 1.32$).

The PCA for mind wandering similarly yielded a two-component solution that accounted for 55% of the total variance (see Figure 2B for scree plot and component loadings). The first loaded most strongly on the variables strange, novel, funny, auditory sounds, visual pictures, and racing. The second loaded most strongly on the variables pleasant, clear, and interesting. Independent-samples $t$ tests indicated that young adults had higher scores compared with older adults on the first component (young: $M = 0.24$, $SD = 1.12$; old: $M = -0.36$, $SD = 0.65$, $t(1,47.28) = 2.38$, $p < .05$, $d = 0.65$), whereas older adults had higher scores than young on the second component (young: $M = -0.29$, $SD = 0.91$; old: $M = 0.44$, $SE = 0.98$, $t(1,48) = 2.71$, $p < .01$, $d = 0.78$).

The analyses presented above indicate that age-related differences in content of thought are very similar for on-task thought and mind wandering: young adults tend to have thoughts that are more dreamlike, racing, strange, and novel than older adults, whereas older adults tend to have thoughts that are more pleasant, clear, and interesting. Because of these similarities in age-related differences in content of on-task thought and mind wandering, we repeated the PCA collapsing across both types of thought. A two-component solution was obtained, accounting for 63% of the variance (see Figure 2C for scree plot and component loadings). The first component loaded most strongly on the variables dreamlike, strange, racing, novel, funny, and auditory sounds. The second loaded most strongly on the variables pleasant, interesting, and clear. Consistent with prior analyses, independent samples $t$ tests indicated that young adults had higher scores on the first component (young: $M = 0.22$, $SD = 1.09$; old: $M = -0.33$, $SD = 0.74$, $t(1,48.85) = 2.14$, $p <$

.05, $d = 0.59$), whereas older adults had higher scores on the second component (young: $M = -0.47$, $SD = 0.81$; old: $M = 0.72$, $SD = 0.83$, $t(1,49) = 5.07$, $p < .001$, $d = 1.45$).

**Discussion**

The current study assessed age-related differences in mind-wandering frequency, mind wandering's association with affect, and mind-wandering content, using experience sampling in daily life. Extending results from laboratory paradigms, we found that older adults exhibited less mind wandering during everyday activities than did younger adults. Second, we found that, across groups, negative affect was positively associated with mind-wandering frequency, at both between-subjects and within-subject levels. Third, we found that in both age groups, mind wandering was more likely to be oriented toward the future or past than were on-task thoughts, but there were no age-related differences in temporality of thought. Fourth, whereas young adults reported more thoughts characterized by variables such as dreamlike, strange, racing, and novel, older adults' thoughts were more frequently characterized as pleasant, clear, and interesting.

Older Adults Exhibit Reduced Mind-Wandering Frequency in Daily Life

Many laboratory studies have indicated that older adults mind wander less than do young adults (Maillet & Schacter, 2016a). We extend these findings by demonstrating an age-related reduction in mind-wandering frequency during daily life, albeit in a small sample. If this result replicates in larger-*N* studies, it would be difficult to reconcile with several laboratory-specific explanations provided to explain age-related reductions in mind wandering. For instance, one suggestion is that older adults may exhibit less mind wandering than young adults because the laboratory environment is more familiar to young versus older adults and therefore triggers more goal- or concern-related off-task thoughts for younger adults (McVay et al., 2013). In the current study, there is no reason to assume that young adults responded to the thought probes in environments that were more familiar to them than those of older adults, and so our results appear inconsistent with this suggestion. Similarly, Jackson et al. (2013) found age-related differences in mind wandering during an Amazon Turk study and suggested that this result should be viewed as inconsistent with McVay et al.'s (2013) suggestion. However, we note that a more direct test of this hypothesis would require questions regarding environment familiarity. Another proposal is that older adults are more motivated and/or interested than young adults to perform experimental tasks (Krawietz et al., 2012). At the minimum, this suggestion would need to be modified to argue that older adults are also more motivated than young to perform everyday activities. On one hand, consistent with such an idea as well as with reports that older adults report better emotional well-being than young (Carstensen et al., 2011) and exhibit a positivity bias (Mather & Carstensen, 2005), older adults had higher scores on the positive affect component, which was driven by variables including motivated and interested. On the other hand, the finding that age still predicts mind wandering with affect included in the models suggests that age-related differences in motivation and interest did not fully explain age-related differences in mind wandering in the current study.

Negative Affect Is Associated With Mind-Wandering Occurrence in Young and Older Adults

Previous studies in young adults have found a link between negative affect and mind wandering (Kane et al., 2017; Killingsworth & Gilbert, 2010). We provide further support for this association here. Individuals with higher subject loadings on a PCA component strongly associated with the variables irritable, frustrated, anxious, and sad over the course of a week exhibited higher mind-wandering frequency after partialing out variance associated with age group, suggesting that this relationship is independent of age. We obtained similar results at a within-participant level (after removing between-subjects variance), suggesting mind-wandering experiences were more likely during negative moods.

## Age-Related Differences in Content of Thought

Consistent with some prior studies (Jackson et al., 2013; Maillet & Schacter, 2016b), we found no age-related differences in temporal orientation of thought. Both age groups reported more temporally oriented thoughts (past and future) when mind wandering versus being on task. However, although not significant, we note that older adults had numerically more temporally oriented thoughts than young adults *when on task*. We point this out because these results may be related to those of Gardner and Ascoli (2015) who reported an age-related increase in prospective memories in daily life. These authors suggested that older adults may be more likely than young to deliberately and repeatedly rehearse thoughts pertaining to a future intention or a future event to ensure that they are completed in a timely manner. It is possible that prospective memories were primarily classified as on-task thoughts in the current study, particularly if they do, in fact, reflect deliberate rehearsal by older adults. This possibility highlights a key difference between laboratory studies, where the ongoing task is typically present oriented (i.e., a go/no-go task), and daily life where being on task may include temporally oriented activities. The relationship between aging, prospective memory, and mind wandering should be further investigated in future studies (see also Maillet & Schacter, 2016a).

We analyzed the other content variables using PCA. We performed these analyses separately for on-task thoughts and mind wandering, and also across both thought types. Results were similar for all analyses. Compared with young adults, older adults had lower scores on components associated with the variables dreamlike, strange, racing, and novel, whereas older adults had higher scores on components associated with the variables pleasant, clear, and interesting. Given the paucity of prior evidence regarding age-related differences in content of thought and our small sample size, the content analyses in the present experiment were exploratory, and should be interpreted with care. The finding that older adults rated their thoughts as more pleasant and interesting than young adults may be related to their having more positive affect compared with young adults. The finding that young adults report more racing and dreamlike thoughts whereas older adults report clearer thoughts is intriguing. It has recently been suggested that “freedom of thought” (i.e., the tendency to jump from thought to thought) may be an important dimension of thought that is relatively independent from task relatedness (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Mills, Raffaelli, Irving, Stan, & Christoff, 2017). One possibility is that young adults jump from thought to thought at a faster pace than older adults (both when on task and mind wandering), resulting in higher ratings for the variable racing in young adults and higher ratings for clear in older adults.

## Explaining Age-Related Reductions in Mind-Wandering Frequency

The finding of age-related reductions in mind-wandering frequency in laboratory settings is consistent and robust, and the current experiment adds to the literature by providing initial evidence that it generalized beyond laboratory settings. However, the mechanisms underlying this effect remain unclear. Giambra (1989) suggested that the brain engages in nonconscious processing of unfinished business (unresolved goals), and that the result of this processing is pushed back into awareness as task-unrelated thoughts whenever the conscious mind has sufficient capacity to express it. Giambra (1989) further suggested that age-related reductions in task-unrelated thoughts may be attributable to fewer nonconscious processing products being available for intrusion into awareness. Maillet and Schacter (2016a, 2016b) suggested that age-related reductions in mind wandering may be related to older adults being less able than young to internally trigger thoughts that are independent of ongoing events, rendering them more environment dependent. They found that older adults are more likely than young adults to report that their ongoing thoughts were triggered by task stimuli, whereas young adults were more likely to report internally triggered thoughts. Reductions in the ability to internally trigger and maintain representations with age have been proposed to account for age-related impairments in many cognitive domains including episodic memory, action management, and perceptual tasks (Craik & Byrd, 1982; Lindenberger & Mayr, 2014) and it is possible that a similar mechanism is involved in age-related reductions in mind-wandering frequency. Several other factors including motivation/interest (Krawietz et al., 2012), affect, and personality (Frank et al., 2015) may also be involved in age-related reductions in mind-wandering frequency and it will be important for future studies to clarify the relative importance of these mechanisms in different situations.

## Limitations

To our knowledge, this study was the first to assess age-related differences in mind-wandering frequency in daily life using experience sampling. Nonetheless, our study had several limitations. One is that we had a relatively small sample size, and future studies with larger samples should be conducted to replicate and extend our results. As well, future studies would benefit from a more fine-grained classification of thoughts than the on-task/mind-wandering distinction used here. Many studies in the aging literature have found that older adults exhibit a greater amount of task-related interferences (e.g., thoughts about one's task performance) compared with young adults (Frank et al., 2015; Jordano & Touron, 2017; McVay et al., 2013). We did not measure this thought type in the current study, and it would be interesting to see if this age-related difference found in laboratory settings extends to daily life. In addition, it would be helpful to distinguish between mind wandering and external distractions (Stawarczyk, Majerus, Maj, et al., 2011; Stawarczyk, Majerus, Maquet, & D'Argembeau, 2011). Zavagnin, Borella, and De Beni (2014) have reported that older adults report reduced frequency of both external distractions and mind wandering. Therefore, the extent to which age-related reductions in mind wandering in the current study are attributable to reductions in external distractions is unclear. It would also be of interest to collect additional information about the activities participants were engaged in when they were probed (Killingsworth & Gilbert, 2010; Schlagman, Kvavilashvili, & Schulz, 2007) and to investigate age-related differences in other aspects of daily life mind-wandering not measured here, such as intentionality of thought (Seli, Maillet, Smilek, Oakman, & Schacter, 2017; Seli, Risko, Smilek, & Schacter, 2016), and whether thought triggers are external or internal (e.g., Maillet & Schacter, 2016b; Schlagman et al., 2007; Song & Wang, 2012). Such studies may help to further clarify the mechanisms involved in age-related reductions in mind-wandering frequency.

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