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The effect of context on mind-wandering in younger and older adults

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ABSTRACT

Older adults report less mind-wandering (MW) during tasks of sustained attention than younger adults. The control failure × current concerns account argues that this is due to age differences in how contexts cue personally relevant task-unrelated thoughts. For older adults, the university laboratory contains few reminders of their current concerns and unfinished goals. For younger adults, however, the university laboratory is more directly tied to their current concerns. Therefore, if the context for triggering current concerns is the critical difference between younger and older adults' reported MW frequencies, then testing the two groups in contexts that equate the salience of self-relevant cues (i.e., their homes) should result in an increase in older but not younger adults' MW rates. The present study directly compared rates of MW and involuntary autobiographical memories (IAMs) in the home versus in the lab for younger and older adults using a within-subjects manipulation of context. Inconsistent with the control failure × current concerns account, no significant reduction in the age-gap in MW was found. Suggesting a lack of cues rather than an abundance of cues elicits MW, participants in both age groups reported more MW in the lab than at home. The number of IAMs recalled did not differ across contexts but was lower in older than younger adults. These findings suggest that a cognitive rather than an environmental mechanism may be behind the reduction in spontaneous cognition in aging.

1. Introduction

Mind-wandering (MW) refers to the generation of mental content unrelated to the task one is currently performing (Seli, Kane, et al., 2018; Smallwood & Schooler, 2006). There are multiple accounts in the literature attempting to explain various aspects of MW, the two most prominent of which are the cognitive resource account and the control failure × current concerns account. The cognitive resource account (Smallwood & Schooler, 2006) posits that MW involves decoupling attention from the external environment and devoting cognitive resources to maintaining a self-generated train of thought. In other words, this account views MW as a resource intensive process, and proposes that the more resources available to an individual, either in overall capacity or during any given task, the more likely they are to MW. The control failure × current concerns account (McVay & Kane, 2010), on the other hand, suggests that MW is a result of the cognitive control system's inability to defend goal-directed thought from competing thoughts brought on by

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current concerns (e.g., other, unfinished tasks) of the individual. According to this hypothesis, the more control an individual engages to defend goal-directed thought in a given situation, the less likely they are to MW.

The cognitive resource account can elegantly explain one of the best-established findings in the MW literature, namely that older adults report fewer instances of off-task thought than younger adults (e.g., Giambra, 1989, 2000; Gyurkovics, Balota, & Jackson, 2018; Jackson & Balota, 2012; Jackson, Weinstein, & Balota, 2013; Krawietz, Tamplin, & Radvansky, 2012; Maillet & Schacter, 2016a; Maillet et al., 2018; Seli, Maillet, Smilek, Oakman, & Schacter, 2017; Staub, Doignon-Camus, Bacon, & Bonnefond, 2014; Shake, Shulley, & Soto-Freita, 2015; Zavagnin, Borella, & De Beni et al., 2014). According to this account, the negative relationship between age and MW frequency can be explained as a decrease in available cognitive resources with age (e.g., Craik, Klix, & Hagendorf, 1986; Salthouse, 2009), leading to a reduced ability to maintain off-task thoughts while engaged in a task.

In contrast to the predictions made by the cognitive resource account, the control failure × current concerns account predicts that older adults should MW *more* than younger adults because of age-related declines in inhibitory control (e.g., Hasher & Zacks, 1988; Jurado & Rosselli, 2007). Specifically, older adults are hypothesized to have worse inhibitory control, and should consequently have more trouble maintaining and defending the goals of an ongoing task as compared to younger adults, thereby leading to more MW. The fact that older adults report less MW therefore appears to present a problem for the control failure × current concerns account. Anticipating this contradiction, McVay and Kane (2010) argued that older adults may report less MW than younger adults because of the context in which they are tested. For older adults, the university laboratory is outside their typical daily experience, with few reminders of unfinished goals they need to complete, and thus few unrelated thoughts to inhibit. For younger adults on the other hand, the laboratory is embedded in the broader university context that includes their dorms, classrooms, and study areas. Thus, when performing laboratory tasks of sustained attention, younger, but not older, adults are surrounded by cues for their uncompleted goals and other current concerns (homework, friends, relationships, etc.). If it is the case that testing context may trigger current concerns and contribute to the difference in MW between younger and older adults, then testing both younger and older adults in a context that equates the salience of self-relevant cues (i.e., their homes) should result in an increase in older but not younger adults' MW rates compared to the laboratory. Therefore, the critical prediction is that there should be an interaction between age group and testing context. Older adults' MW frequencies should increase at home where cues related to current concerns are more prevalent as compared to the lab where they are more scarce. In contrast, younger adults' MW frequencies should not differ between the home and lab since both are embedded in the same (broader) university context. If these predictions hold, then the age gap in MW should be reduced or completely absent in the home testing context (where salient, self-relevant cues are present for both age groups) compared to the lab (were salient, self-relevant cues are present for younger but not older adults).

Although the paper by McVay and Kane (2010) which proposed the control failures × current concerns account, has been cited well over 500 times since its publication, the central age group by testing location interaction aspect of this hypothesis has yet to be directly empirically tested. There is some evidence, however, to suggest that the age gap in MW is unlikely to close completely even in contexts where salient, self-relevant cues are present for both age groups. However, these findings come from studies that were not designed to directly test the prediction of the control failures × current concerns hypothesis' regarding the interaction between age and testing context. Specifically, Jackson et al. (2013) tested younger and older adults online using Amazon Mechanical Turk in environments of their own choosing (most likely non-lab contexts) and Maillet et al. (2018) assessed age differences in MW during everyday life, outside of the lab. Even though both younger and older adult participants were tested in non-lab contexts, both studies found reliable age differences in reported MW propensity. However, neither of these studies directly manipulated where participants completed the study, and therefore cannot address the question of whether age differences in MW vary as a function of context familiarity (i.e., whether older adults report more similar levels of MW to younger adults at home compared to in the lab, in other words, whether age and testing context interact as predictors). Thus, these studies do not directly test the cognitive failure × current concerns account. The present study, however, addresses these limitations by directly comparing rates of MW in the lab and at home for younger and older adults, using a within-subjects manipulation, and explicitly controlling the contexts in which participants completed the tasks. Thus, this experimental design is uniquely suited to address the age-related predictions of the control failure × current concerns account.

Another important component of the present study is that we also tested for a key theoretical mechanism of MW initiation that stems from the control failure × current concerns account: context-specific memory retrieval. We did so by measuring the occurrence of involuntary autobiographical memories (IAMs) and querying participants about their current concerns and environmental distractions. IAMs are memories of personal experiences that come to mind spontaneously (Berntsen, 2010). Prior research has demonstrated that IAMs can be elicited during controlled paradigms that present potential memory cues in the context of a vigilance task (Schlagman & Kvavilashvili, 2008) and are sensitive to the surrounding context (Rubin & Berntsen, 2009; Staugaard and Berntsen, 2014)[1]. We therefore hypothesized that testing participants in familiar contexts with salient, self-relevant cues should increase IAMs, self-reported current concerns, and distractions. Moreover, with respect to our primary goal of examining whether the age gap in MW reports differs depending on testing context, a concomitant change in IAMs, current concerns, and distractions (e.g., more MW, more IAMs, and more current concerns for older adults when tested at home as compared to when tested in the lab) would provide evidence that context affects MW by cueing context-specific memories.

The present experiment measured rates of MW and IAMs in two contexts: at participants' homes and in a laboratory. Participants completed a Sustained Attention to Response Task (SART) and an IAM vigilance task twice, once in each context, and the relative rates

[1] Although the argument can be made that IAMs are merely a specific case of MW, Berntsen (2021) argues that "[b]ecause of their highly constrained, situation-dependent and automatic nature, involuntary autobiographical memories form a distinct category of spontaneous thought that cannot be equated with mind wandering."

of MW and IAMs were compared. It was hypothesized that if the home context possessed more cues for MW, then generally higher rates of MW and IAMs would be elicited. This increase was predicted to be more pronounced for older adults than for younger adults as the difference in the number of self-relevant cues across contexts is likely to be much larger for older rather than younger adults. Accordingly, we expected that there would be a smaller age gap in MW and IAM rates in the home context compared to the lab, consistent with the control failures × current concerns account (McVay & Kane, 2010). This would suggest previous research comparing rates of MW between younger and older adults has been confounded by the effect of testing context. Such a finding would also support the theorized role of environmental cues on MW and IAMs and would help to reconcile previous work with respect to the inhibitory deficit theory. Specifically, if there are few competing thoughts elicited by environmental distractors in a given context that need to be inhibited by older adults, then their inhibitory deficit should have a lesser impact on rates of MW than if they were tested in a highly distracting environment. If, however, the age effect in MW was of a similar magnitude across contexts, this would suggest that the reduced rates of MW in older adults likely cannot be explained solely by the differential effect of environmental cues on young and older adults, providing indirect support for the cognitive resource account of MW[2].

2. Method

2.1. Participants

Younger adults were recruited from the Washington University undergraduate student population while older adults were recruited from participant registries maintained by the Washington University Department of Psychological and Brain Sciences and the Washington University School of Medicine and consists of community-dwelling older adults in the St. Louis area. All participants were required to have normal or corrected to normal vision, computer and internet access at home (tablets or cell phones were not allowed, as tasks were incompatible with touchscreens), and a task-compatible web browser. Younger adults were required to be aged 18 to 25, living in the Washington University on-campus dormitories, and to be able to do the tasks at the desk that is furnished for each student in their bedrooms. Older adults were required to be age 60 or older, be comfortable operating a computer[3], and to be able to do the study at a computer on a tabletop (i.e., table or desk; using the computer in their laps was not allowed). All participants were asked to complete the home session while alone with all forms of distraction (phones, televisions, radios, etc.) turned off. Younger adults were compensated with credit they could apply to their courses while older adults were compensated with $25.

In total, 75 participants were enrolled in the study. At recruitment, four older adults were disqualified due to reporting low comfort or inexperience with computers. Due to a web browser update that occurred while the study was ongoing, data from four older adults and two younger adults failed to be recorded. Data from three additional older adults could not be used because of data lost to accidental overwrites (they either used their Session 1 hyperlink for Session 2 or were sent the wrong link by a researcher). Two older adults were excluded from analysis because too much time elapsed between sessions for one (greater than one week), and because of a failure to do both sessions at the same time of day for the other. One older adult was also excluded because a health change after recruitment meant they no longer met the inclusion criteria. Two older adults dropped out of the study while doing the SART during Session 1, both reporting that they felt the study was too boring and did not want to continue. Finally, one older adult misunderstood the SART instructions during Session 1 and was also excluded. The final sample was therefore 60 participants, consisting of 31 younger adults and 29 older adults. See Table 1 for descriptive statistics.

The sample size was initially determined based on practical constraints including funding and time restrictions. However, simulation-based post-hoc power analyses were run to estimate the smallest effect size reliably detectable with 0.80 power in a sample of 60 participants and 25 thought probes per individual. The code for these analyses is available on the OSF repository (https://osf.io/fqzar). Briefly, participant-level data was simulated with different cell means for the four cells of interest (younger/older adults in the lab/at home) across several iterations, and the observed incidence rate ratio (*IRR*) was calculated for the age by testing context interaction for each simulated sample that were equal in size to ours (see Supplementary Materials for details). An *IRR* of 1.00 would represent no difference between conditions, while an *IRR* of 2.00 or 0.50, for example, would represent a 200% difference between conditions. For the interaction, the *IRR* represents the ratio of the *IRR* for context in younger adults, and the *IRR* for context in older adults. The probability of observing a significant interaction effect using our analytic strategy is plotted as a function of the observed *IRR* in Supplementary Fig. 1. This curve indicates that we had 0.80 power with our sample of 60 participants to detect an *IRR* of ~ 2.5 (or a ~ 250% difference between conditions).

2.2. Materials

A single computer program was custom made using JavaScript that ran the entire experimental procedure. The program ran within participants' web browsers and was accessed by clicking on an internet hyperlink. The program and other materials are available for

[2] Further measures common in studies of MW in aging were also collected, such as self-reports of task engagement, motivation, and conscientiousness (e.g., in Jackson & Balota, 2012; Krawietz et al., 2012; Shake et al., 2015), to help us better characterize our sample, and to provide opportunity for hypothesis generation for future studies (i.e., regarding mechanistic explanations of the age by location interaction if it exists), but were not the focus of the present study.

[3] During recruitment, older adult participants were asked if they felt comfortable operating a computer and using the internet. Participants were disqualified during recruitment if they expressed low comfort or inexperience with computers.

Table 1
Participant Characteristics as a Function of Age.

Measure	Younger Adults	Older Adults
Age (SD)	19.61 (1.28)	72.79 (6.12)
Age Range (Min - Max)	18–23	64–86
Years of Education (SD)	13.42 (1.96)	16.05 (2.10)
Percent Female	71.00	62.10
Percent Caucasian	41.90	79.30
Blessed Test Score (SD)	—	0.81 (1.20)

Note. Values inside parentheses are standard deviations.

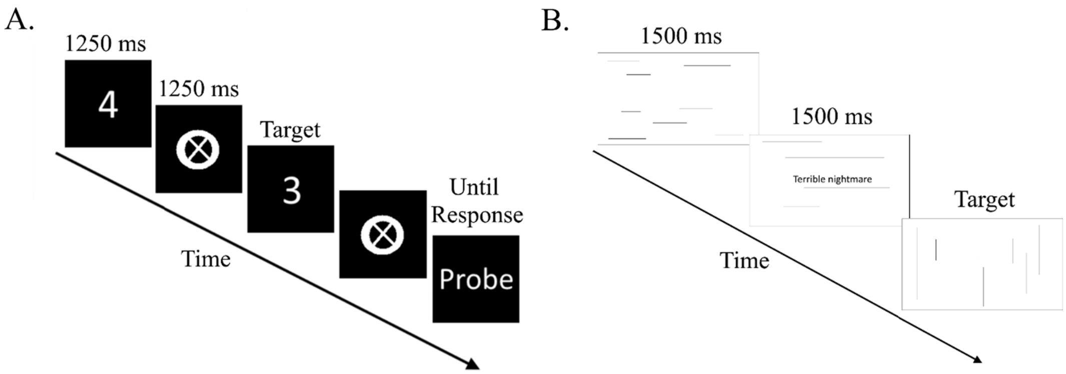

Fig. 1. *SART and IAM Tasks Note.* Sequence of two sample trials in the SART task (panel A) and three trials in the IAM task (panel B). Probe refers to the prompt asking participants to categorize their mental states at the time the probe appeared. Stimuli not shown to scale.

download along with all data on the Open Science Framework (https://osf.io/fqzar).

The SART presented random single digits (1 through 9) for three blocks of 200 experimental trials, lasting about 30 min (adapted from Jackson & Balota, 2012, Experiment 3, a version of the commonly used task which used a slower presentation speed in order to reduce difficulty and maximize MW reports). Short breaks were allowed after the first and second blocks. Participants were instructed to press the spacebar as quickly and accurately as possible in response to each digit (go trials) except the digit 3 (no-go trials), to which no response was required. Stimuli were presented in white on a black background at the center of the screen, scaled to be 30% of the size of the participants' screens in Calibri font. The digit 3, i.e., the no-go stimulus, was presented on about 11.1% of trials. Thought probes were presented after about 4% of trials (25 probes in total). Each trial began with the presentation of a digit that remained on screen for 1250 ms. The digit was then replaced by a visual mask for 1250 ms. Each trial lasted about 2.5 s (see Fig. 1 Panel A). Thought probes asked participants to characterize their mental state at the time the probe appeared, giving five options (Unsworth & Robison, 2016): 1) "I am totally focused on the current task" (an on task report), 2) "I am thinking about my performance on the task or how long it is taking" (a task-related interference report), 3) "I am distracted by sights/sounds/temperature or by physical sensations (hungry/thirsty)" (a report of external distraction), 4) I am daydreaming/my mind is wandering about things unrelated to the task" (a MW report), and 5) "I am not very alert/my mind is blank or I'm drowsy" (a report of an inattentive mind blank). Participants were able to respond to thought probes by pressing the 1 through 5 keys at the top of the keyboard. Dependent variables of interest from the SART included thought probe responses, go and no-go trial accuracy, and response times.

The IAM task presented a random pattern of horizontal black lines on a white screen for 1.5 s per trial (see Fig. 1 Panel B) (adapted from the infrequent cues condition of Vannucci, Pelagatti, Hanczakowski, Mazzoni, & Paccani, 2014, which was found to maximize the number of reported IAMs compared to a frequent cue condition and a multitasking condition). On nine of the total 450 trials, a random pattern of vertical lines was presented. These vertical line patterns, representing target trials that participants were instructed to respond to, were presented pseudo-randomly to assure 40 to 60 trials occurred between any two targets. The entire task lasted about 11 min. On 90 predetermined trials, phrases such as "relaxing on a beach" or "terrible nightmare" were presented in the middle of the horizontal line patterns in size 24 Calibri font. Phrases were chosen from a pool of 600 phrases (Schlagman & Kvavilashvili, 2008; Vannucci et al., 2014), assuring equal numbers of positive, neutral, and negative phrases were used. Two versions of the IAM task were created, each presenting unique phrases. It was thought possible that seeing the same phrase in Session 2 may lead to an IAM of seeing the phrase in Session 1. By using unique words in each session, this risk was eliminated. Both versions presented targets on the same trials. The dependent variable of interest from the IAM task was the number of IAMs reported.

A modified version of the Personal Concerns Inventory (Cox & Klinger, 2011) was used to measure differences in everyday current concerns. Participants were instructed to view current concerns as "not just problems" and were informed that they may have concerns about "pleasant things that they want to get, obtain, or accomplish" or about "unpleasant things that they want to get rid of, prevent, or avoid." Then they were allowed to list as many current concerns they had in 12 different areas: home and household, employment and finances, partner and family concerns, friend and acquaintance concerns, love and intimacy/sexual concerns, self-change concerns, education, health and medical, spiritual, hobbies and recreation, body and exercise/ lifestyle, and other concerns. They were then instructed to think about their most important concern and to answer four questions regarding that concern. The first asked "How important is it to me for things to turn out the way I want regarding this concern? (0 = not important at all, 10 = very important)" Second, "Do I know what steps to take to make things turn out the way I want? (0 = not knowing at all, 10 = knowing exactly)" Third, "How pressing or immediate is dealing with this concern to me? (0 = not pressing at all, 10 = very pressing)" And fourth, "Does the concern deal with an attempt to avoid something negative or to attain something positive? (0 = avoid negative consequences, 10 = attain positive consequences)".

Participants also completed a battery of questionnaires that allowed us to better characterize the sample and/or each testing session. These included a debriefing questionnaire that asked how distracting they found their environment (1 = very little distraction; 9 = very great distraction), if any salient events occurred external to the task that demanded their attention (e.g., a phone ringing), and if they multitasked while they were doing the experiment (yes or no)[4].

Finally, older adults were administered the eight questions on the Short Blessed Test (SBT) to screen for potential cognitive impairment (Katzman, Brown, & Fuld, 1983). Questions assessed basic memory functioning such as orientation, registration, and attention.

2.3. Procedure

There were two experimental sessions, one conducted online in participants' homes and one conducted in the lab separated by a minimum of 2 days and a maximum of 3 days. Both sessions were conducted at the same time of day (if Session 1 was at 11 am, then Session 2 was also conducted at 11 am two to three days later) since there is evidence time of day affects inhibitory functioning (May 1999; Rowe, Valderrama, Hasher, & Lenartowicz, 2006). Whether the home session or the lab session was conducted first was counterbalanced across participants within each age group[5]. To maintain similarity with the home session, research assistants left participants alone in individual testing rooms after assuring the program was successfully accessed. In both sessions, the task program was accessed through an internet hyperlink sent by email. After clicking on the link, participants were first presented with a consent letter and gave their consent by clicking a button reading "I agree".

The SART then began by instructing participants how to perform the task ("Press the spacebar every time a digit appears, except when that digit is a 3"), emphasizing to participants to give equal importance to accuracy and speed. After instructions, participants completed a practice block of 18 trials, with two trials being targets, receiving feedback after each trial. A second set of instructions was then presented on how to respond to the thought probes. Each response option was defined, giving examples of thoughts that would fit into each category (cf., Unsworth & Robison, 2016). A second practice block was then completed that included two random thought probes. Last, a third practice block was completed in which no feedback was provided. Once finished, participants began the experimental blocks after a screen that reiterated the task instructions.

After completing the SART, the program moved to the IAM task. Participants were instructed to watch the patterns of lines being presented on screen (the majority of which were made of horizontal lines), and to press the spacebar whenever they saw a vertical line pattern. The instructions also informed them that they would occasionally see word phrases on the screen, but that they were not supposed to do anything with them. Each participant was told that they were in a condition that was "looking at how people are able to keep their concentration on the patterns" and that "in another condition participants will have to concentrate on the words" (in reality this condition was never run; Vannucci et al., 2014). Participants were then told that they may find themselves thinking about other things unrelated to the task, and to press the enter key whenever they experience any "task-unrelated mental contents (thoughts, plans, considerations, past events, images, etc.) that pop into their mind during the task". Whenever they pressed the enter key, the task stopped and allowed them to type in what their thought was. They were instructed to write descriptively enough so that they would be able to remember the specific thought when it was shown to them again at the end of the experiment. They were also asked to indicate if the thought was triggered by internal thoughts, an element of their environment, or by a phrase presented on the screen. After reading the instructions, they completed 20 practice trials with two targets and 20 phrases not presented during the rest of the experiment. After practice, participants were reminded how to perform the task, and began the experimental trials. Once the task was complete, each memory a participant recorded during the task was presented one-by-one back to the participant, asking them to rate their memories on a number of dimensions unrelated to the current study.

After completing the IAM task, participants completed the debriefing questionnaire followed by the modified personal concerns inventory. At the end of the home session only, participants completed the conscientiousness scale of the NEO Five-Factor Inventory (McCrae & Costa, 2004). In the lab session only, older adults were administered the Short Blessed Test (Katzman, Brown, & Fuld,

[4] Additionally, participants were asked about their motivation, interest, drowsiness, "peak" time of day, and completed a personality inventory. This information is included in the Supplementary Materials.

[5] Although order effects were controlled for methodologically by ensuring that half of the participants in the age group were run at home first and half in lab first, we additionally ran a no-intercept logistic regression to test for potential order effects. This model yielded significant Context by Order and Age Group by Context by Order interactions indicating that older, but not younger, adults were more likely to MW at home when they completed the lab session first as compared to if they had completed the home session first. However, these results should be interpreted with caution for two reasons. First, this was an unplanned, post-hoc analysis. Second, because this was an unplanned analysis, the sample size was substantially smaller than what would likely be required to detect a complex three-way interaction such as this. Nevertheless, the presence of these interactions does not change the conclusions of the current study.

1983). Again, these secondary measures were included to better characterize our participant sample and because they are common in MW and aging studies but are not central to the main hypothesis and are therefore presented in the Supplementary Materials.

3. Results

3.1. Statistical analyses

All data, along with analysis output and processing code is available on the Open Science Framework (https://osf.io/h2pku/). Analyses of continuous and categorical data were conducted using JASP (version 0.9.0.1; JASP team, 2018), in all cases using an alpha of 0.05 for significance, and partial eta squared, Cramer's *V*, or Cohen's *d* as measures of effect size where appropriate. Bayesian versions of the tests relevant to the central hypothesis (i.e., the age group by testing location interaction) were also conducted to acquire inclusion Bayes factors (BF_{inc}) for corresponding analyses, calculated across matched models (van den Bergh et al., 2020). BF_{inc}s quantify evidence for including a given term in a model (van den Bergh et al., 2020). Typically, a *BF* of 3 or above, or 1/3 or below, is considered substantial evidence supporting the inclusion or exclusion of a term, respectively (Jeffreys, 1961). JASP's default priors were used for all analyses. Error data and thought probe response data, due to being discrete count data and not normally distributed, were analyzed with multilevel Poisson (error data), or logistic regression (thought probe data) using the 'lme4′ (version 1.1–17; Bates, Maechler, Bolker, & Walker, 2015), 'DHARMa' (version 0.2.0; Hartig, 2018), and 'multcomp' (version 1.4–8; Hothorn, Bretz, & Westfall, 2008) packages in R (R Core Team, 2019). Confidence intervals for the mean differences output from these analyses are log counts in Poisson regression and log odds in logistic regression. *IRR* were calculated by exponentiating mean differences and represent the percent difference between conditions.

3.2. Mind-Wandering probe responses and involuntary autobiographical memories

To test our central hypothesis, multilevel logistic regression was used to analyze the probability of reporting MW thought probe responses (response option number 4) over non-MW responses (all other response options collapsed)[6]. Logistic regression was used due to severe violations of the normality assumption. The model was a no-intercept model with one fixed effect for each condition and separate random intercepts for the home condition and lab condition grouped by participant. A no-intercept model was run to enable subsequent general linear hypothesis testing of model terms. All predictors were dummy coded. Both main effects of Age Group, $z =$ -4.46, $p < .001$, 95% CI[-5.79, −1.76], IRR = 5.22, and Context were significant, $z =$ -3.31, $p = .003$, 95% CI[-3.17, −0.52], IRR = 2.26. Critically, when testing the primary hypothesis, no interaction was found between Age Group and Context on the probability of MW responses, $z =$ -0.36, $p = .976$, 95% CI[-0.18, 1.03], IRR = 1.41. Older adults were overall less likely to report MW (M = 2.91, Mdn = 1, SD = 3.79) than younger adults (M = 8.00, Mdn = 7, SD = 6.49), and MW was generally more likely in the lab context (M = 6.65, Mdn = 5, SD = 6.25) than in the home context (M = 4.43, Mdn = 3, SD = 5.39), see Table 2. For completeness, analyses of the other four thought probe responses can be found in the Supplementary Materials. Notably, the Age Group × Context interaction did not reach significance for any probe response.

Inclusion Bayes factors (BF_{inc}s) for the central terms of interest in our study were based on an analogous mixed ANOVA using the default prior settings in JASP (JASP team, 2018). Using a traditional 2 (Age Group) × 2 (Context) mixed-design ANOVA on the percentages of reported MW, the results remained the same as only main effects of Age Group, $F(1, 58) = 19.96$, $MSE = 0.06$, $p < .001$, $\eta^2_{\mathrm{p}} = .256$, $BF_{\mathrm{inc}} = 534.54$, and Context were found, $F(1, 58) = 8.56$, $MSE = 0.03$, $p = .005$, $\eta^2_{\mathrm{p}} = .129$, $BF_{\mathrm{inc}} = 8.62$, with no corresponding interaction, $F(1, 58) = 1.08$, $MSE = 0.03$, $p = .304$, $\eta^2_{\mathrm{p}} = .018$, $BF_{\mathrm{inc}} = 0.39$. The $BF_{\mathrm{inc}} = 0.39$ for the Age Group by Context interaction, the central effect of interest in the present study, can be interpreted as evidence, albeit not substantial evidence, in favor of excluding the interaction term from the model.

Multilevel Poisson regression was used to analyze the number of IAMs reported by each age group in each context utilizing a no-intercept model with one fixed effect for each condition and random effects of the home condition and lab condition grouped by participant (see Table 3). A main effect of Age Group was found, $z =$ -3.37, $p = .002$, 95% CI[-3.76, 0.65], IRR = 1.47, due to older adults reporting fewer IAMs (M = 2.62, Mdn = 0, SD = 4.70) than younger adults (M = 4.55, Mdn = 4, SD = 3.77). However, the main effect of Context, $z =$ -0.71, $p = .843$, 95% CI[-1.28, 0.69], IRR = 1.05, and the interaction, $z =$ -0.03, $p = .999$, 95% CI[-0.84, 0.77], IRR = 1.04, were non-significant.

3.3. Performance on the SART

Next, we analyzed behavioral performance on the SART, to examine whether commonly observed behavioral and age-related effects were present in our sample too. Reaction times less than 200 ms and greater than 3 standard deviations above an individual's overall mean were trimmed to control for outliers. Reaction time on the SART was analyzed to compare performance between contexts and age groups using a 2 (Context) × 2 (Age Group) mixed-design ANOVA.

Reaction Time. Descriptive statistics for overall reaction times are available in Table 4. On go trials, the main effect of Context, *F*(1,

[6] In the analysis of thought probe data, the probability of reporting a given thought probe was always contrasted with the probability of reporting any of the other thought probes, i.e., in our model, the outcome variable was the count of the occurrence of a given category vs the count of all other categories.

Table 2
Probability of Mind-Wandering (MW).

Age Group	Lab	Home
Younger Adults	0.33	0.18
Older Adults	0.08	0.03

Note. Model predicted probabilities of reporting MW in the lab and at home for younger and older adults.

Table 3
Number of Involuntary Autobiographical Memories (IAMs) Reported.

Age Group	Lab M	Lab SD	Home M	Home SD
Younger Adults	5.0	4.4	4.1	3.0
Older Adults	2.9	5.0	2.3	4.4

Note. Number of IAMs reported as a function of age and testing context.

58) = 6.95, MSE = 2556, $p = .011$, $\eta_p{}^2 = 0.107$, and Age Group, $F(1, 58) = 19.72$, MSE = 14423, $p < .001$, $\eta_p{}^2 = 0.254$, were significant while the interaction was not, $F(1, 58) = 0.51$, MSE = 2556, $p = .480$, $\eta_p{}^2 = 0.009$. Older adults (M = 593, SD = 92) were generally slower than younger adults (M = 495, SD = 92), and reaction times were generally slower at home (M = 556 ms, SD = 98 ms) than in the lab (M = 532 ms, SD = 86 ms).

Errors. Error rates are displayed in Table 4. Multilevel Poisson regression was used to analyze the number of go trial errors and no-go trial errors committed by each age group in each location utilizing a no-intercept model with one fixed effect for each condition and random effects of the home condition and lab condition grouped by participant. On go trials, while the main effect of Context was not significant, $z = -0.49$, $p = .946$, 95% CI[-2.16, 1.43], IRR = 1.11, the main effect of Age Group, $z = -3.13$, $p = .005$, 95% CI[-5.50, −0.75], IRR = 2.42, and the interaction were significant, $z = -2.58$, $p = .029$, 95% CI[-2.99, −0.12], IRR = 2.54. Older adults (M = 1.19, Mdn = 0, SD = 1.89) were generally more accurate than younger adults (M = 13.18, Mdn = 1, SD = 42.26), with the interaction suggesting older adults were slightly more likely to commit an error in the lab (M = 1.55, Mdn = 1, SD = 2.25) than at home (M = 0.83, Mdn = 0, SD = 1.39), while younger adults were less likely to commit an error in the lab (M = 6.32, Mdn = 1, SD = 14.21) than at home (M = 20.03, Mdn = 2, SD = 56.24). On no-go trials, the main effect of Age Group was significant, $z = -5.78$, $p < .001$, 95% CI[-2.84, −1.19], IRR = 1.11, while the main effect of Context, $z = 1.89$, $p = .161$, 95% CI[-0.07, 0.64], IRR = 0.99, and the interaction were non-significant, $z = -0.15$, $p = .998$, 95% CI[-0.34, 0.30], IRR = 1.01, suggesting that older adults (M = 6.41, Mdn = 6, SD = 4.57) generally committed fewer errors on no-go trials than did younger adults (M = 17.29, Mdn = 14, SD = 11.51). This age effect is typical of SART performance in the lab (Jackson & Balota, 2012; Maillet et al., 2020).

3.4. Current concerns

A multilevel Poisson regression was used to analyze the number of current concerns reported by each age group in each location utilizing a no-intercept model with one fixed effect for each condition (younger adults at home, younger adults at lab, older adults at home, older adults at lab) and random effects of the home condition and lab condition grouped by participant. Separate 2 (Context) × 2 (Age Group) mixed-design ANOVAs were conducted on the four Likert ratings of participants' top concerns. Regarding the number of current concerns reported, both older (M = 14.56, Mdn = 12, SD = 9.46) and younger (M = 13.90, Mdn = 10, SD = 9.20) adults listed similar numbers of current concerns, as the main effects of Age Group, $z = 0.98$, $p = .693$, 95% CI[-0.43, 1.03], IRR = 0.99, Context, $z = -1.98$, $p = .138$, 95% CI[-0.58, 0.05], IRR = 1.01, and the interaction were non-significant, $z = -0.001$, $p = 1.00$, 95% CI[-0.28, 0.28], IRR = 0.99. Both older (M = 8.39, SD = 1.92) and younger (M = 8.52, SD = 1.29) adults also rated their top concern with similar importance regardless of which context they were in, as both the main effects of Age Group, $F(1, 53) = 0.10$, MSE = 4.83, $p = .753$, $\eta_p{}^2 = 0.002$, and Context, $F(1, 53) = 0.25$, MSE = 0.41, $p = .619$, $\eta_p{}^2 = 0.005$, as well as the interaction were non-significant, $F(1, 53) = 3.11$, MSE = 0.41, $p = .084$, $\eta_p{}^2 = 0.055$. The same was found for reports of feeling they knew the steps to achieve their top concern (older adults: M = 6.98, SD = 2.40; younger adults: M = 6.50, SD = 1.47), as the main effects of Age Group, $F(1, 53) = 1.10$, MSE = 5.78, $p = .300$, $\eta_p{}^2 = 0.020$, Context, $F(1, 53) = 0.01$, MSE = 1.99, $p = .928$, $\eta_p{}^2 < 0.001$, and the interaction were again non-significant, $F(1, 53) = 0.65$, MSE = 1.99, $p = .425$, $\eta_p{}^2 = 0.012$. Likewise, feelings of immediacy of their top concern (older adults: M = 7.00, SD = 2.496; younger adults: M = 6.98, SD = 1.89) was not different between age groups, $F(1, 53) < 0.01$, MSE = 7.73, $p = .974$, $\eta_p{}^2 < 0.001$, contexts, $F(1, 53) = 1.19$, MSE = 2.54, $p = .281$, $\eta_p{}^2 = 0.022$, nor was there an interaction, $F(1, 53) = 0.70$, MSE = 2.54, $p = .406$, $\eta_p{}^2 = 0.013$.

3.5. Environmental distractions

Due to the lack of control during the home session as compared to the lab session, participants were asked to describe potential sources of distraction in their environment in both sessions. These data are explored below to determine whether task adherence and distractibility differed between age groups and contexts. Participants who had missing data for a particular analysis were excluded

Table 4
Means and Standard Deviations of Overall Reaction Times and Error Rates on the SART.

Measure	Age Group	Lab		Home	
		M	SD	M	SD
Go Reaction Times (ms)	Younger Adults	480	85	511	99
	Older Adults	584	87	601	97
No-Go Reaction Times (ms)	Younger Adults	422	100	475	132
	Older Adults	494	101	491	95
Go Error Rates	Younger Adults	0.012	0.027	0.038	0.105
	Older Adults	0.003	0.004	0.002	0.003
No-Go Error Rates	Younger Adults	0.246	0.177	0.272	0.167
	Older Adults	0.092	0.069	0.100	0.069

Note. Means and standard deviations of overall reaction times and error rates on the SART as a function of age group and testing context. SART = Sustained Attention to Response Task.

from the following analyses.

Two 2 (Multitasked: yes, no) × 2 (Age Group: younger, older) Chi-square tests were conducted separately for the home and lab sessions on the number of participants who reported that they had or had not multitasked while doing the experiment. During the lab session, there was no difference in the proportion of participants reporting multitasking across the two groups, $\chi^2(1, N = 56) = 1.16$, $p = .281$, Cramer's $V = 0.149$. During the home session, significantly more younger adults than older adults engaged in multitasking in some manner, χ^2 (1, N = 56) = 6.72, $p = .010$, Cramer's $V = 0.346$. Two more 2 (Experienced a Salient Distractor: yes, no) × 2 (Age Group) Chi-square tests were conducted to test for differences in unexpected distracting events while doing the experiment (e.g., a phone ringing). Again, in the lab context, no difference was detected between age groups, χ^2 (1, N = 60) = 2.01, $p = .156$, Cramer's $V = 0.183$. However, in the home context, younger adults experienced more salient distractions than older adults, χ^2 (1, N = 57) = 6.70, $p = .010$, Cramer's $V = 0.343$.

These findings were corroborated by the subjective ratings of the distractibility of participants' contexts. A 2 (Context) × 2 (Age Group) mixed-design ANOVA indicated significant main effects of Context, $F(1, 55) = 12.50$, MSE = 1.71, $p < .001$, $\eta_p^2 = 0.185$, and Age Group, $F(1, 55) = 13.72$, MSE = 3.04, $p < .001$, $\eta_p^2 = 0.200$, and a significant interaction, $F(1, 55) = 23.96$, MSE = 1.71, $p < .001$, $\eta_p^2 = 0.303$. During the lab session, younger (M = 1.9, SD = 0.92) and older (M = 1.9, SD = 1.78) adults reported the lab equally distracting. During the home session, younger adults reported their homes to be more distracting (M = 4.0, SD = 2.13) than older adults (M = 1.6, SD = 0.93). As the Age Group × Context interaction present in environmental distractions was not mirrored by a similar interaction in MW frequency, these findings suggest that environmental distractions are unlikely to be driving the effects of age and context on MW frequency.

4. Discussion

The present study investigated the effects of testing context on the reported frequency of MW in younger and older adults to directly test the key prediction of the control failures × current concerns account of MW. This account argues that the gap in reported MW between age groups, which was replicated here, may be partially (or completely) due to the context in which MW was measured in prior reports (McVay & Kane, 2010). Many prior investigations of MW across age groups took place in a lab, where the theory suggests younger adults are more prone to MW due to the lab's poor separation from their everyday current concerns. If it is the case that testing context may trigger current concerns and contribute to the difference in MW between younger and older adults, then testing both younger and older adults in a context that equates the salience of self-relevant cues (i.e., their homes) should result in an increase in older but not younger adults' MW rates, reducing or even closing the typical age gap. This prediction relies upon a mechanism whereby stimuli or distractions in one's environment may cue IAMs and/or current concerns which in turn may increase MW frequency. To empirically test this hypothesis, younger and older adults completed MW and IAM tasks both in the lab and at home. No previous studies to date have used such a design to experimentally test the age-related predictions of the control failures × current concerns account. Ultimately, our results failed to provide support for the control failures × current concerns account such that the effect of testing context on rates of MW did not interact with age. Bayesian analyses provided evidence weakly in favor of excluding the interaction term from our model. While these findings cannot be taken as evidence for the lack of an effect of testing context on age-related changes in MW frequency, they do suggest that if such an effect exists, it is quite small. Therefore, it is more parsimonious to suppose that the age gap in MW frequency may be due to age-related changes in the cognitive resources available for MW as proposed by the cognitive resource account (Smallwood & Schooler, 2006).

Importantly, however, testing context did have an unexpected effect on MW frequency overall, irrespective of age: more MW was found in the lab for both age groups compared to the home session, which is opposite the pattern that would be expected based on an environmental cueing mechanism that initiates MW and goes against the predictions of the control failures × current concerns account, especially with respect to older adults. This observation cannot be attributed to context-induced differences in the number of IAMs, current concerns, or a selection of subjectively rated qualities of participants' top concerns, as no significant location differences were found for these measures.

While the finding that participants reported more MW in the lab than at home may seem surprising at first, we provide a speculative explanation as to why this may be the case. Specifically, these findings may suggest that the relative lack of stimuli (e.g., in a lab testing room), and not the presence thereof, induces higher reports of MW. The differential effects of context on MW compared to IAMs is consistent with this explanation. In the case of the IAM task, no difference in IAMs was found between contexts. Importantly, in the IAM task, completely different stimuli were presented in Sessions 1 and 2 thus equating the novelty of eliciting stimuli across contexts. In contrast, due to the nature of our research question, self-relevant cues that could elicit MW were not similarly equated across contexts. This could explain why MW but not IAMs differed between the two contexts. Nevertheless, due to the unexpected nature of this finding, it must be replicated before definitive conclusions can be drawn.

Another interesting finding from the current study is that older adults consistently reported fewer IAMs than younger adults (see Berntsen and Rubin, 2002; Schlagman et al., 2007 & 2009; Maillet & Schacter, 2016a; however, see also Berntsen, Rubin, & Salgado, 2015 & Berntsen, Rasmussen, Miles, Nielsen, & Ramsgaard, 2017; Moulin et al., 2014; Rubin and Berntsen, 2009; Warden e t al., 2019), and this was true regardless of context. Thus, it appears that declines in IAMs with age, like declines in MW, may reflect a cognitive rather than environmental mechanism, although Berntsen (2021) argues that IAMs should not be equated with MW. Nevertheless, this context-general reduction in IAMs may point to a decline in spontaneously arising memories in old age, which may similarly function as a potential mechanism for older adults' reduced reports of MW (see Maillet & Schacter, 2016a) across contexts. Consistent with a spontaneous memory decline hypothesis, the closely related construct of unintentional MW also declines with age in both state and trait measures (Seli et al., 2017; however, see Berntsen et al., 2015 & 2017; Moulin et al., 2014; Rubin and Berntsen, 2009; Warden et al., 2019 for evidence suggesting age invariance in IAMs).

Finally, the current experiment is consistent with prior reports that found that motivation (Antrobus et al., 1966; Frank et al., 2015; Seli et al., 2015), interest (Jackson & Balota, 2012; Krawietz et al., 2012; though see Maillet & Schacter, 2016b), and conscientiousness (Jackson & Balota, 2012; though see Jackson, Weinstein, & Balota, 2013) differ between age groups, and remain factors warranting further consideration in understanding the age-related gap in reported MW. Before any cognitive mechanisms for the gap can be confirmed, differences in these dimensions need to be equated either statistically (which will require larger sample sizes and validated self-report measures), or preferably methodologically (selective sampling of younger adults or broader sampling of older adults, incentives manipulations, etc.). Interestingly, despite motivation being negatively associated with MW in the literature (see Seli, Cheyne, Xu, Purdon, & Smilek, 2015; Seli, Maillet, Smilek, Oakman, & Schacter, 2017), both higher motivation and higher rates of MW were found for older adults in the lab relative to at home, suggesting that motivation, at least, cannot entirely explain the present results (when measured by a single question)[7]. These issues highlight the need to collect broader and larger samples of each age group or to develop more robust measures that may increase the variance of the variable of interest (e.g., motivation).

It should be noted that the present experiment does not invalidate the core ideas of the control failure × current concerns theory. The theory rests primarily on its claims regarding the opposing effects of cognitive control and current concerns on the frequency of MW, and both factors have good empirical support (see Klinger, 2013; McVay & Kane, 2010; Robison, Gath, & Unsworth, 2017). These core claims are not fundamentally incompatible with the cognitive resource account of MW, and framework accounts that have attempted to reconcile the two accounts (e.g., Seli et al., 2018; Smallwood, 2013). Additionally, more controlled versions of the current experiment are conceivable, such as conducting the home session by an experimenter during a home visit. This could help equate the number of salient distractors and the amount of time spent multitasking across different age groups, as both of these variables suggested that in the present sample young adults' homes were more distracting than older adults'. This could have affected the validity of young adults' thought reports in the home context.

The current experiment also assumes participants' home environments were richer in MW cues than the lab environment. This unfortunately was not measured but potentially could be by future studies, such as by having participants describe or photograph the location where they do the home session. The current experiment also warrants replication at other sites. Older adults were recruited through a participant registry that has been maintained for many years which increases the likelihood that many older adults in the current sample have been to the university campus where the study took place multiple times. If so, this may decrease the novelty associated with a lab visit, perhaps making it less distinct from the rest of their everyday lives. However, this limitation would not explain why more MW was found in the lab than at home for both age groups. Lastly, of course, the study is limited by practical constraints on sample size, and consequently, by limited statistical power (see *Method: Participants* for details). Larger sample replications using the posted materials (https://osf.io/fqzar) are strongly encouraged.

An important strength of our study is its unique experimental design that allows us to directly test the effects of testing context and age on MW. Our findings represent an important first step in understanding the role these factors play in spontaneous thought. Furthermore, on a methodological level, our results speak to the feasibility of online aging research, an area that has rapidly gained traction in recent years due to the growing popularity - and necessity - of online studies (Krantz & Reips, 2017).

In conclusion, the current experiment did not find evidence for and presented some evidence against a prediction of the control failure × current concerns theory that the gap in reported MW between age groups is due to differences in the ability to inhibit task-unrelated thoughts cued by the environment. Instead, the current evidence is more in line with the notion that a lack of environmental cues may lead to more MW in general across age groups, given the observation of more MW in the lab context compared to the home context. The current evidence also found that the age-related decrease in IAMs was context general, raising the possibility that a deficit in spontaneous memories in old age may explain both age-related reductions in IAMs and MW. Further research is needed to explore this possibility as well as the role of various well-documented differences between age groups on motivation, interest, and

[7] It is important to note that more elaborate analyses could not be done on the present data to covary out the influence of the dispositional differences between age groups due to issues of high multicollinearity. The whole sample correlations are confounded by the influence of age group and separating out each age group necessarily leads to a loss of power.

conscientiousness.

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CRediT authorship contribution statement

Nathaniel T. Diede: Conceptualization, Methodology, Formal analysis, Investigation. **Máté Gyurkovics:** Formal analysis. **Jessica Nicosia:** Formal analysis. **Alex Diede:** Software. **Julie M. Bugg:** Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2021.103256.

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