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Research Article

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Self-Referential Memory Encoding and Mind-Wandering in Younger and Older Adults

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Abstract: Self-referencing, the relating of information to oneself, is a successful encoding strategy that improves memory across the lifespan. Mind-wandering, the shifting of thoughts from a task to self-focused information, is characterised by decreased cognitive performance and is reported by older adults less frequently than by younger adults. In the present study, we investigated a hypothetical relationship between mind-wandering and self-referential memory and whether this relationship decouples in healthy aging. Younger and older adults rated adjectives on how descriptive they were of themselves, Albert Einstein or assessed the commonness of the adjective. Participants were interrupted during the encoding task with randomly timed mind-wandering prompts and then completed a surprise free recall test. Results replicated prior demonstrations of enhanced memory for self-referenced information, whereas age and self-focus decreased reports of mind-wandering. In terms of effects of interest, we found that encoding condition as well as age impacted the number of words recalled and reports of mind-wandering. However, a single mechanism does not appear to account for both of these effects, and there was no compelling evidence for age differences in the relationships amongst the factors. Future research should further examine the relationships amongst self, memory, and mind-wandering across the lifespan.

Keywords: self, memory, aging, mind-wandering, cognition

Self-Referential Memory and Mind-Wandering in Younger and Older Adults

Strategies have long been demonstrated to improve the effectiveness of memory encoding in younger as well as older adults. From the classic levels of processing effects (Craik & Tulving, 1975), in which thinking about the meaning of a word enhances memory, to more recent work on the testing effect (Karpicke & Roediger, 2008) or training in mnemonic strategies (e.g. Kirchhoff, Anderson, Barch, & Jacoby, 2012; Kirchhoff, Anderson, Smith, Barch, & Jacoby, 2012; Kirchhoff, Gordon, & Head, 2014), strategies can improve the amount or quality of information that is remembered. Self-referencing, the relating of information to oneself, has been repeatedly demonstrated to be an effective encoding strategy in younger and older adults (Glisky & Marquine, 2009; Gutchess, Kensinger, & Schacter, 2007; Gutchess, Kensinger, Yoon, & Schacter, 2007; Mueller, Wonderlich, & Dugan, 1986; Rogers, Kuiper, & Kirker, 1977; Yang, Truong, Fuss, & Bislimovic, 2012). This includes findings that self-referencing not only improves memory for items but also enhances memory for details (Hamami, Serbun, & Gutchess, 2011; Leshikar & Duarte, 2014; Serbun, Shih, & Gutchess,

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2011), actions (Rosa & Gutchess, 2011; Truong, Chapman, Chisholm, Enns, & Handy, 2016), recollection (Leshikar, Dulas, & Duarte, 2015), and prospective memory (Grilli & McFarland, 2011) in healthy younger and older adults as well as patients with memory impairments (Grilli & Glisky, 2010, 2011; Rosa, Deason, Budson, & Gutchess, 2016). The strategy could be effective because the self is highly developed and frequently recruited during cognition, supporting more successful organisation and formation of memories (Symons & Johnson, 1997), perhaps through superordinate schemas (Wagner, Haxby, & Heatherton, 2012) or integration across processing stages (Sui & Humphreys, 2015).

The neural correlates suggest that unique processes support a self-referencing strategy as compared to other types of memory strategies. The medial prefrontal cortex is engaged when making judgments about the self and during the successful encoding of self-referenced information as compared to referencing another person or semantic judgments (Gutchess & Kensinger, 2018; Kelley et al., 2002; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004). Self-referential encoding effects seem to be supported by the medial prefrontal cortex across the lifespan, with younger and older adults engaging the region similarly for item and source memory (Gutchess, Kensinger, & Schacter, 2007; Gutchess et al., 2015; Leshikar & Duarte, 2014).

One interesting question is the extent to which a self-referencing strategy impacts other aspects of cognition, including mind-wandering. Mind-wandering involves the shifting of thoughts from an external task (e.g. reading, attending to one's environment) to more internal, self-focused information. The default mode network (Raichle et al., 2001), which encompasses the medial prefrontal cortex and the posterior cingulate cortex, is engaged during the related constructs of stimulus-independent thought, mind-wandering, and rest (e.g. Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Mason et al., 2007; Whitfield-Gabrieli et al., 2011). Given that the topic of mind-wandering tends to center on spontaneous self-related thoughts, it is unsurprising that the default mode network is also activated by self-generated cognition (Andrews-Hanna, Smallwood, & Spreng, 2014). In a review of different functional subdivisions of the medial prefrontal cortex, reflecting on the self and mind-wandering converge in the same subregion of the medial prefrontal cortex (Dixon, Thiruchselvam, Todd, & Christoff, 2017).

Unlike the benefits of self-referential processing on memory, mind-wandering seems to interfere with concurrent information processing. Some examples of the impact of mind-wandering on cognitive performance include disrupted success on implicit learning tasks (Franklin, Smallwood, Zedelius, Broadway, & Schooler, 2016; Thomson, Besner, & Smilek, 2013), zoning out while reading a written narrative (Kane & McVay, 2012; Smallwood, McSpadden, & Schooler, 2008), diminished recognition and recall after mind-wandering during recall (Smallwood, Baracaia, Lowe, & Obonsawin, 2003), and a general decoupling of attention required to complete the task at hand (McVay & Kane, 2009; Smallwood, McSpadden, & Schooler, 2007) . Although there are conflicting arguments regarding whether mind-wandering recruits cognitive resources (Smallwood, 2010) or results from a *failure* to recruit cognitive resources (McVay & Kane, 2010), both perspectives emphasise the contribution of executive functioning to mind-wandering.

Despite its shifting focus away from an immediate task and therefore decreasing cognitive performance, mind-wandering does seem to function as a goal-oriented process (Smallwood & Schooler, 2006); a common monitoring system seems to contribute to the awareness of goals as well as mind-wandering (Seli, Smilek, Ralph, & Schacter, 2018). Mind-wandering assists in performing self-focused, socio-cognitive tasks such as future-oriented autobiographical planning (Baird, Smallwood, & Schooler, 2011). Although mind-wandering can occur independently of explicit awareness (Smallwood & Schooler, 2006), a period of self-focus can improve meta-awareness of mind-wandering (Sanders, Wang, Schooler, & Smallwood, 2017). These findings indicate ways in which self-focus and mind-wandering may influence each other, potentially as intrinsically connected.

The potential intersection of mind-wandering and self-referencing is interesting for multiple reasons. For one, the overlap in brain regions could indicate interrelated processes. However, the opposing direction of effects on memory, with self-referencing improving memory performance, and mind-wandering impairing memory performance, suggests the processes may be inversely related. To better understand the interrelatedness of these processes, it is necessary to investigate them jointly during a single task. There has been some consideration of effects at rest compared to those observed during tasks (e.g. Whitfield-Gabrieli et al., 2011). The prior task-based work has found that thinking about the self can induce more future thinking than past thinking and that future autobiographical thinking can induce a stronger self-reference effect in memory (Smallwood et al., 2011), providing further evidence for the potential convergence between self-reference on memory and mind-wandering. These studies, however, focus on the *qualities* of mind-wandering that affect cognition (e.g. prospective versus retrospective focus) rather than reflecting coordinated efforts to investigate the effects of self-referencing on memory and mind-wandering jointly during a task. In the present study, we manipulated the self-focus during encoding and compared it with other encoding conditions. While participants made judgments about self, another person, or a control condition, they periodically responded to prompts to assess whether they were attending to the task or mind-wandering. We aimed to investigate how mind-wandering interacts with self-referential memory. We hypothesise that there is a relationship between the two cognitive processes, such that self-focused encoding may increase memory performance as well as mind-wandering compared to other conditions.

Whereas self-referential memory is maintained with aging, mind-wandering may be affected by aging. Although some studies demonstrated similar rates of mind-wandering across age groups (Maillet & Rajah, 2016) or even higher rates of task-related interference among older versus younger adults (McVay, Meier, Touron, & Kane, 2013), the majority of experiments have revealed that older adults tend to mind-wander less than younger adults (Jackson & Balota, 2012; Jackson, Weinstein, & Balota, 2013). The literature presents conflicting evidence for why this might be, suggesting it is due to a failure of executive control (McVay & Kane, 2010) or the over-demand of executive functioning resources (Smallwood et al., 2011). The literature is also murky about whether frequent mind-wanderers tend to have higher working memory ability (Baird et al., 2011) or whether individuals with higher working memory tend to mind-wander less than individuals with lower working memory (Kane & McVay, 2012). Interestingly, the greater reduction in mind-wandering reports as a function of age (i.e. middle age to older adulthood) and dementia (i.e. healthy older adults to early stage Alzheimer's disease) indicates that mind-wandering ultimately depends on cognitive resources, which are reduced for these groups of older adults (Gyurkovics, Balota, & Jackson, 2018). Other factors that may impact mind-wandering frequency and age include the content of the task at hand, particularly emotional or self-relevant information (Krawietz, Tamplin, & Radvansky, 2012; Maillet et al., 2018). It is possible that younger adults self-refer more frequently and consistently across conditions than older adults (Gutchess et al., 2015), which could contribute to young adults' higher mind-wandering frequency in addition to their greater cognitive resources. Despite emerging evidence supporting a neural link between self-referencing and mind-wandering, the nature of this relationship remains fairly unclear, particularly in terms of effects on memory.

In the present study, we aim to investigate how mind-wandering interacts with self-referential memory and if this relationship changes in healthy aging. We predict that the relationship may decouple, or be weakened, in healthy aging. Cognitive resource limitations with age may disproportionately affect the frequency of mind-wandering reports, across-the-board, whereas a self-referencing strategy would continue to enhance memory in older adults.

Method

Participants

88 younger adults aged 17–23 and 61 older adults aged 59–97 were recruited and run in this study. Younger adult participants were recruited from a pool of undergraduate students at Brandeis University given credit towards course requirements. Older adults were recruited from the community and compensated monetarily for their time. All older adults scored at least a 25 on the Mini-Mental Status Exam (Folstein, Folstein, & McHugh 1975), assessing cognitive orientation. The study protocol was approved by the Brandeis IRB committee, and participants provided written informed consents. Additionally, parental consents were obtained for participants under the age of 18.

Due to potential effects of testing in a non-native language on encoding condition and mind-wandering, we only included participants whose first language was English, excluding 15 younger adults and 1 older adult. Additionally, 1 younger adult's data from this final version of the task was used for piloting purposes, and another younger adult's data was excluded due to technical difficulties during testing. In summary, data from 71 younger adults and 59 older adults were analysed.

Procedure

Participants first completed a demographics questionnaire, followed by the primary task. The task was programmed with E-Prime software; the text was presented in the centre of a black background with white, sans-serif font. Instructions appeared on screen and were simultaneously read aloud to participants, explaining that they would use the keyboard to respond to adjectives based on how well the adjective described one of three target judgments: themselves (self), Albert Einstein (Einstein), who was selected as a comparison condition of a person with whom younger and older adults were familiar, or the extent to which the word was commonly encountered (common). Participants were assigned to only one condition of encoding judgments in a between-participants design. Participants had 7 seconds to rate each of 108 valence-balanced adjectives, which were drawn from Anderson (1968). Participants determined how well the word described the given condition using a scale of 1, meaning that the word did not describe the target (self, Einstein, or common) of their encoding condition well, to 6, meaning that the word described the target of their encoding condition well. They responded 0 when they did not know the meaning of the word; this response was rarely used (proportion of trials: .015 for younger adults and .004 older adults). Immediately following completion of the main rating task, participants completed a surprise free recall task in which they were asked to type as many adjectives as they could remember; older adults were allowed to write responses if they were not comfortable typing. The number of words recalled were recorded and analysed according to participants' encoding conditions.

Participants were instructed that a mind-wandering probe would randomly appear and interrupt the rating task, and that they had an unlimited amount of time to respond. This prompt asked participants to select from four responses describing their experience with the task up until the mind-wandering probe to assess attention to the task or different types of mind-wandering. One response described task-related thought, "I was only thinking about the rating task," and three described different types of mind-wandering: "My mind was totally blank," "My mind drifted to things other than the task, but I wasn't aware of it until just now," or "While doing the task, I was aware that thoughts about other things popped into my head" (based on Jackson & Balota 2012). Participants completed 7 different, randomly appearing mind-wandering probes. The low number of probes reflects the fact that our methods were largely informed by the protocols used by Jackson & Balota (2012) and Smallwood et al. (2004), which utilised infrequent and unpredictable thought probes (~5% of trials). A mind-wandering proportion variable was computed by making a ratio of self-reported instances of mind-wandering in response to the prompt to the number of opportunities to report mind-wandering. Each participant's mind-wandering proportion, as well as responses to each of the 7 prompts, were collected and recorded as a function of encoding condition. Proportions are presented in Table 1.

Table 1. Proportion of responses for different mind-wandering prompts.

	Younger			Older		
	Self	**Einstein**	**Common**	**Self**	**Einstein**	**Common**
"My mind was totally blank"	.07 *(.12)*	.07 *(.13)*	.05 *(.11)*	.02 *(.05)*	.06 *(.18)*	.02 *(.07)*
"My mind drifted to things other than the task, but I wasn't aware of it until just now"	.08 *(.20)*	.11 *(.22)*	.10 *(.15)*	.07 *(.15)*	.02 *(.05)*	.00 *(.00)*
"I was only thinking about the rating task"	.39 *(.26)*	.23 *(.21)*	.32 *(.27)*	.82 *(.28)*	.71 *(.31)*	.90 *(.15)*
"While doing the task, I was aware that thoughts about other things popped into my head"	.46 (.26)	.59 (.27)	.52 *(.28)*	.10 *(.22)*	.21 *(.29)*	.09 *(.13)*

After completing these tasks, participants were asked to complete a series of neuropsychological tasks in order to characterise the samples: Digit Comparison (Hedden et al., 2002), Shipley (Shipley, 1986), and Letter-Number Sequencing (Wechsler, 2009). At this time, older adults were then assessed using the Mini-Mental Status Exam (Folstein, Folstein, & McHugh, 1975). Results from neuropsychological tests and the demographics questionnaire are summarised in Table 2. At the end of the study, participants were debriefed and compensated.

Table 2. Participant demographics

Measure	Self		Common		Einstein	
	Younger	Older	Younger	Older	Younger	Older
***N* (female)**	24 (15)	19 (13)	26 (15)	19 (8)	21 (13)	21 (17)
Age[a]	18.75	78.16	18.73	79.32	18.81	77.76
Years of Education[a]	13.46	16.84	13.38	17.26	13.48	15.57
LNS Correct[a]	12.50	6.89	11.94	6.53	10.92	7.29
LNS Max[a]	6.93	8.63	6.76	7.32	6.50	8.86
Digit Comparison[a]	83.64	56.21	80.41	54.89	81.58	61.29
Shipley[a]	31.14	36.00	31.71	35.05	32.00	36.71
MMSE		29.21		29.00		29.33

[a] = differences between age groups, $p < .05$

Note: Not all younger adults completed Letter Number Sequencing (LNS), Digit Comparison, and Shipley, as these were added to the protocol after data collection had begun. Stated values reflect 43 of 71 younger adults (14 in the self condition, 17 in the common condition, and 12 in the Einstein condition).

Results

This study has two dependent variables: the number of words freely recalled and the proportion of times participants reported mind-wandering. We examined how three different encoding conditions – self, common, or Einstein – impacted these dependent variables, using a 2 (Younger / Older Adult) x 3 (Self / Common / Einstein) between-participants multivariate analysis of covariance (MANCOVA), in order to initially test the effects of these factors across both dependent variables. Because the distribution of males and females and years of education differed across the groups and conditions (see Table 1), we included sex and years of education as covariates in the model to control for any contribution from these variables[1]. Multivariate results are presented using Wilks' and an alpha of .05 was set as the significance level.

The results from this MANCOVA did not support a significant age x condition interaction, $\lambda = .96$, $F(4, 242) = 1.39$, $p = .24$, $\eta^2_p = .02$. However, the results revealed a significant effect of encoding condition on mind-wandering and recall, $\lambda = .86$, $F(4, 242) = 4.84$, $p = .001$, $\eta^2_p = .07$. Univariate tests demonstrated a significant effect of encoding condition for both recall performance, $F(2, 122) = 5.92$, $p = .004$, $\eta^2_p = .09$, and reported mind-wandering proportion, $F(2, 122) = 3.90$, $p = .02$, $\eta^2_p = .06$. Follow-up independent samples t-tests showed that the self encoding condition resulted in higher levels of recall ($M = 14.67$) compared to the Einstein ($M = 9.86$, $p = .006$) or common ($M = 9.60$, $p = .005$) encoding conditions whereas recall in the Einstein and common encoding conditions did not significantly differ from each other ($p = .86$). See Figure 1.

For mind-wandering, follow-up t-tests revealed that participants in the Einstein encoding condition reported numerically more mind-wandering ($M = .53$) than those in the self ($M = .42$) or the common conditions ($M = .43$), but none of the differences approached significance (*p*s > .15). See Figure 2.

1 Results of the MANCOVA are consistent with those reported here when sex is not included as a covariate.

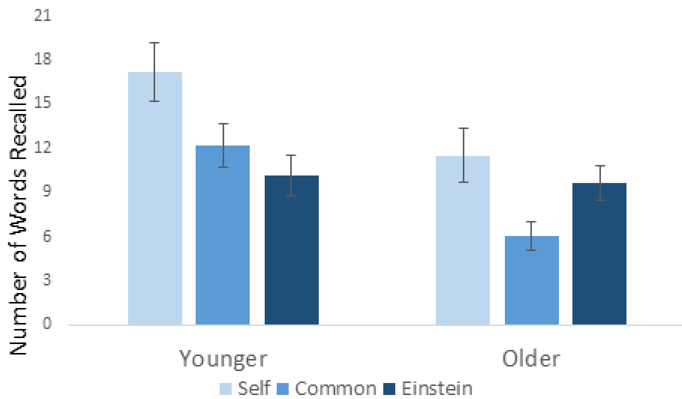

Figure 1. Number of words recalled by encoding condition in younger versus older adults. Across age groups, participants in the self encoding condition had higher levels of recall compared to the Einstein or common conditions. Older adults recalled fewer words than younger adults.

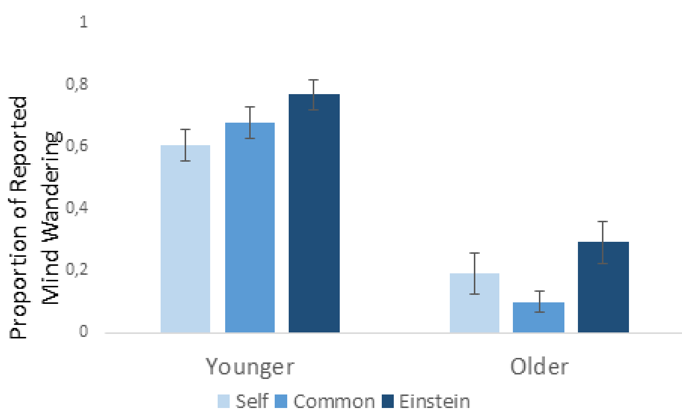

Figure 2. Proportion of reported mind-wandering by encoding condition in younger versus older adults. Across age groups, participants reported the most mind-wandering for the Einstein condition compared to self or common conditions. Older adults reported less mind-wandering than younger adults.

There was also a multivariate main effect of age, $\lambda = .60$, $F(2, 121) = 40.27$, $p < .001$, $\eta^2_p = .40$. Univariate tests revealed significant effects of age on reported mind-wandering, $F(1, 122) = 71.67$, $p < .001$, $\eta^2_p = .37$, and recall, $F(1, 122) = 9.78$, $p = .002$, $\eta^2_p = .07$. This analysis revealed that older adults recalled fewer words ($M = 9.07$) than younger adults ($M = 13.27$) and reported less mind-wandering ($M = .20$) than younger adults ($M = .68$).

To further assess the robustness of the effects of encoding condition on memory, we created standardised residuals. This approach serves as a test of the independence of the effects of encoding condition and age on mind-wandering and free recall. That is, if a single set of processes contribute to both free recall and mind-wandering, partialling out one should eliminate effects on the other; effects that persist even when the other is controlled for suggested separate mechanisms. We first examined recall by partialling out mind-wandering in order to examine the effects of encoding condition on memory, separate from the effects on mind-wandering. Thus, if age and encoding condition impact free recall separate from any effects on mind-wandering, the effects should emerge even when controlling for individual variation in mind-wandering. Similar to the unadjusted recall measure, there was a significant effect of encoding condition, $F(2, 122) = 6.31$, $p = .002$, $\eta^2_p = .09$. Follow-up t-tests substantiate that participants in the self condition had a higher level of recall than those in Einstein (p = .003) or common (p = .004) conditions. The common and Einstein conditions did not significantly differ from one another in this analysis (p = .99). Standardised residuals for mind-wandering also were computed, partialling out memory performance in order to assess whether the effects of age and encoding condition impact the reports of mind-wandering separate from any effects on memory. It might not initially be intuitive to think that memory, tested at a later point in time, could influence mind-wandering reports. However, if free recall performance is thought to reflect effective encoding processes, focused attention on the task when words are encoded could directly impact mind-wandering. Thus, by partialling out recall performance, we are attempting to control for the effects of focused encoding processes (which result in higher levels of memory when assessed on a later recall test) that could impact mind-wandering. In this analysis, we again found a significant effect of encoding condition, $F(2, 122) = 4.59$, $p = .01$, $\eta^2_p = .07$. Follow-up t-tests showed a marginal trend for participants in the Einstein condition to report higher levels of mind-wandering than those in the self condition (p = .07) but not the common condition (p = .21). The self and common conditions did not significantly differ from one another in this analysis (p = .56). Thus, the results from these analyses indicate that the reported efforts emerge for both free recall and mind-wandering, even when controlling for the contributions from the other task.

Discussion

The present study investigated a potential overlap in the ways in which self-referencing impacts memory and mind-wandering in younger and older adults. We predicted that thinking about the self would increase both levels of memory and mind-wandering, particularly in younger adults, but the two processes do not appear to be related in the predicted manner. Although self-referencing influenced both memory and mind-wandering, they were affected in diverging ways, with self-referencing increasing levels of recall and decreasing mind-wandering frequency in both age groups, compared to other conditions. The potential implications of this work and directions for further exploration are discussed below.

The inverse relationship between self-referential memory encoding and mind-wandering is somewhat surprising given previous work suggesting a positive relationship between the two processes. In prior studies, mind-wandering has been demonstrated to benefit autobiographical planning for future events (Baird et al., 2011) and self-focus may improve the awareness of mind-wandering (Sanders et al., 2017) within the same system that contributes to goal monitoring and mind-wandering (Seli et al., 2018). Our findings are intriguing because they may suggest that self-focus could suppress mind-wandering, perhaps by providing a focus for internal mentation. It is also possible that the interrelatedness of these processes vary across different self-focused processes. A rich body of literature indicates the importance of external focus during memory encoding processes, with the default network deactivated during successful encoding and more active during unsuccessful encoding, perhaps suggesting that the occurrence of mind-wandering can disrupt encoding (Daselaar, Prince, & Cabeza, 2004; Daselaar et al., 2009; Gusnard, Akbudak, Shulman, & Raichle, 2001; Raichle et al., 2001). Thus, it may be the case that successful encoding imposes an inverse relationship between self-focus and mind-wandering whereas tasks such as planning invoke similar functions for mind-wandering and self-focus.

Despite evidence for some connections between self-referencing effects in memory and mind-wandering, they do not seem to rely on a single common mechanism. When considering the other conditions in the present study, the relationships vary: the recall of words judged for self-reference differs from the recall of words judged for commonness, but mind-wandering reports do not differ for the self and common conditions. Thus, the results indicate complex interrelationships amongst self-focus, mind-wandering, and memory. Another unusual result of this study involves the pattern of recall and mind-wandering for the Einstein and common conditions. Surprisingly, recall performance in younger adults was higher in the common condition than in the Einstein condition, which contrasts findings from a number of studies on recognition memory in which making judgments about Albert Einstein leads to higher levels of memory performance than making commonness judgments (Gutchess, Kensinger, Yoon, & Schacter, 2007; Gutchess, Kensinger, & Schacter 2010). This pattern may indicate that prompting for self-reported mind-wandering can change the ways in which the encoding conditions operate. For example, perhaps the interpretation of the commonness condition is contaminated by self-focus when awareness is heightened to the content of one's internal thoughts by prompting participants to report any task-unrelated thought. We speculated about such effects in our prior work suggesting that young adults may be more prone than older adults to spontaneously infuse self-referencing into control conditions (Gutchess, Kensinger, Yoon, & Schacter, 2007). Interestingly, it was the younger adults, but not the older adults, who show the unusual pattern of numerically higher performance in the commonness condition than in the Einstein condition.

In terms of effects of aging, these data may suggest a relationship between mind-wandering and memory recall that exists in younger adults and decouples with healthy aging, as younger adults mind-wander most and had the worst recognition performance in the Einstein condition, whereas older adults mind-wander least in the Common condition, in which they also have the poorest memory recognition performance. The lack of significant interactions with age, however, prevent us from speculating too much about age differences other than suggesting this is an interesting question to pursue in future work. In particular, identifying appropriate control comparison conditions and focusing on fewer conditions with more power would be promising avenues to examine ways in which these processes interact with age. It would also be ideal to incorporate a higher frequency of thought probes in order to reduce variability as well as including a wider variety of prompts that could capture other subsets of task-unrelated thoughts. Considering that some evidence suggests that older adults report higher rates of task-related interference than younger adults (McVay et al., 2013), prompts assessing task-related interference may have identified a stronger link between mind-wandering and self-reference, particularly in terms of age differences.

Despite some unexpected patterns of findings, our results do replicate three prior effects shown in the literature. First, this study presents a self-reference effect in memory across younger and older adults (e.g. Glisky & Marquine, 2009; Gutchess, Kensinger, & Schacter, 2007; Gutchess, Kensinger, Yoon, & Schacter, 2007; Mueller et al., 1986; Rogers et al., 1977; Yang et al., 2012). Second, these data demonstrate that older adults report less mind-wandering than younger adults (as in Jackson & Balota, 2012; Jackson et al., 2013). Our results do not show any evidence that different conditions, including self-referencing, mitigate this age difference. Third, we found that self-referencing, in comparison to the Einstein condition, reduces reports of mind-wandering, as found in the previous work manipulating self-focus (Sanders et al., 2017). In future work, it will be useful to further manipulate control conditions to interpret effects across conditions. Thinking about others (Einstein) led to the highest level of mind-wandering but it is difficult to know whether this condition increased mind-wandering, or if self and common conditions *decreased* mind-wandering. Including within-participant assessment of different conditions may help to address these questions, perhaps including multiple blocks comparing self versus control conditions over time.

Examining the impact of attentional training, such as mindfulness meditation, may further inform the relationship between mind-wandering and self-referential memory. Dispositional mindfulness has a negative relationship with activity in self-referential processing (Way, Creswell, Eisenberger, & Lieberman, 2010) and default mode network brain areas (Berkovich-Ohana, Glicksohn, & Goldstein, 2012). Mindfulness meditation practice, particularly practice involving acceptance training, has been found to reduce mind-wandering in younger adults (Rahl, Lindsay, Pacilio, Brown, & Creswell, 2017). Our findings suggest that mindfulness research may also benefit from a more nuanced understanding of the relationship between self-referencing, mind-wandering, and age.

In conclusion, we find evidence that a self-focused strategy affects memory retrieval and mind-wandering. Our results, however, do not support a single common mechanism, even in younger adults. Our findings replicate the previous findings of reduced mind-wandering reports with age and self-focus, though there is much work to be done in this nascent research topic to further explore the connections amongst self, memory, and mind-wandering as well as potential ways in which the relationship amongst these processes differs with age.

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Conflict of Interest: Authors report no conflict of interest.

Ethics statement: The protocol for this study was approved by the Brandeis University Institutional Review Board, which adheres to the Federal Policy for the Protection of Human Subjects (Common Rule). All participants gave written informed consent in accordance with the Declaration of Helsinki.

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