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Magda Inês Oliveira Jordão

DO SPONTANEOUS THOUGHTS CHANGE WITH AGING?

FREQUENCY AND EPISODIC SPECIFICITY ANALYSES

Tese no âmbito do Doutoramento em Psicologia, especialidade de Neuropsicologia orientada pela Professora Doutora Maria Salomé Ferreira Estima de Pinho e pela Professora Doutora Peggy L. St. Jacques e apresentada à Faculdade de Psicologia e Ciências de Educação da Universidade de Coimbra.

Janeiro de 2020

Faculdade de Psicologia e Ciências da Educação
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Resumo

As alterações cognitivas associadas à idade são menores na ausência de processos cognitivos auto-iniciados. No entanto, permanece por esclarecer se tal se aplica aos pensamentos espontâneos, que emergem com esforço, intenção e controlo reduzidos. Estes pensamentos são frequentes na vida diária e contribuem para funções importantes, como o planeamento e a consolidação mnésica. Assim, torna-se relevante analisar até que ponto os pensamentos espontâneos se modificam com a idade. Nesta tese de doutoramento, analisámos as diferenças etárias nos pensamentos espontâneos, no que respeita à frequência e a características qualitativas. Nesta análise, controlámos fatores metodológicos geradores de confundimento (*confound*) e destacámos mecanismos de pensamento espontâneo específicos.

Começámos por fazer uma meta-análise de estudos prévios focados na frequência de pensamentos espontâneos e encontrámos uma diminuição consistente nesta frequência, associada à idade. Porém, identificámos pela primeira vez moderadores metodológicos que sugerem que as diferenças etárias na motivação, a dificuldade da tarefa e o enviesamento associado às instruções, têm impacto nos resultados prévios. Assim, sugere-se que a redução na frequência de pensamentos espontâneos associada à idade se possa dever aos métodos que têm sido mais frequentemente utilizados. Concluímos, que são necessários novos estudos com métodos alternativos para compreender as diferenças etárias nesta área. Em particular, enfatizámos a utilidade de métodos de resposta aberta para contornar o impacto de diferenças etárias em enviesamentos associados às instruções e às opções de resposta, e usámos esta abordagem nos estudos seguintes.

No segundo estudo, adaptámos uma tarefa laboratorial para eliciar pensamentos espontâneos evitando as fontes de confundimento identificadas na meta-análise. Mais precisamente, diminuímos a dificuldade da tarefa e solicitámos aos participantes que descrevessem livremente os seus pensamentos em interrupções aleatórias durante a tarefa, evitando assim o recurso à retrospeção e à meta-consciência sustentada. Nesta tarefa, participantes jovens e idosos viam palavras com cor amarela ou vermelha, devendo dizer "sim" apenas quando a palavra estava escrita a amarelo. A tarefa foi dividida em duas partes equivalentes e, entre elas, os participantes realizaram uma tarefa de *priming* destinada a ativar objetivos pessoais orientados para o futuro, que consistia em ordenar diferentes objetivos e parceiros de interação. Não encontrámos diferenças etárias na frequência dos pensamentos espontâneos. Depois da tarefa de *priming*, verificou-se um aumento no número de pensamentos espontâneos acerca do futuro, em jovens e idosos. Este resultado mostra pela primeira vez a preservação da ligação entre a ativação de

objetivos pessoais e pensamentos espontâneos acerca do futuro no envelhecimento saudável. O efeito de *priming* foi confirmado com a análise de um grupo de controlo jovem, no qual não se registaram diferenças. Estes resultados suportam a ideia de que as diferenças etárias são maioritariamente devidas a processos auto-iniciados.

No terceiro estudo, analisámos as diferenças etárias nos pensamentos espontâneos em termos de especificidade episódica. Esta especificidade refere-se à quantidade de detalhes acerca do espaço, tempo ou outros, que constituem um evento único pessoal. Relativamente à recuperação deliberada, conhece-se que a especificidade episódica diminui com a idade, associada a diferenças etárias em processos estratégicos. Com base no envolvimento limitado de processos estratégicos no pensamento espontâneo, não esperávamos que este tipo de pensamento evidenciasse diferenças etárias quanto à especificidade episódica. Para explorar os mecanismos da especificidade episódica no pensamento espontâneo, usámos uma indução de especificidade episódica que tem como alvo os processos de construção episódicos. Pontos de vista teóricos diferentes predizem o envolvimento de processos construtivos na recuperação espontânea ou, pelo contrário, que esta acede a representações de eventos independentes de construção. O uso da indução de especificidade episódica nos pensamentos espontâneos permite testar estas perspetivas teóricas. Os participantes realizaram duas sessões contrabalançadas que incluíram um vídeo, a indução de especificidade episódica ou de controlo, e uma tarefa de vigilância. Na indução de especificidade episódica, os participantes recordavam os detalhes do vídeo visualizado, enquanto na condição controlo resolviam exercícios matemáticos. O impacto desta manipulação foi avaliado na tarefa de vigilância subsequente, que consistiu numa versão melhorada da tarefa do estudo 2. Pela primeira vez, as diferenças etárias na especificidade episódica dos pensamentos espontâneos foram avaliadas objetivamente com base nas descrições livres dos participantes. Como esperado, não observámos diferenças etárias na especificidade episódica. Também não se registaram efeitos da indução, o que indica que a recuperação neste caso acede a eventos pré-armazenados.

Globalmente, não obtivemos resultados empíricos de efeitos associados à idade nos pensamentos espontâneos, o que corrobora a ideia de que as diferenças cognitivas relacionadas com a idade são maioritariamente devidas ao processamento auto-iniciado. Sugerimos, subsequentemente, que a recuperação mnésica espontânea é uma estratégia promissora para promover a especificidade episódica e os benefícios a ela associados. Os resultados obtidos foram ainda explorados no âmbito da neuropsicologia. Discutimos ainda a ideia de estudos futuros devem ser acompanhados de clarificação conceptual e de contextos naturalistas.

Abstract

Cognitive changes in aging have been shown to be diminished when self-initiated processes are not required. However, it is still uncertain if this is also the case for spontaneous thoughts that come to mind with reduced effort, intention and control. Spontaneous thoughts are frequent in daily life and contribute to important functions such as planning and memory consolidation, and thus it is very important to analyze to what extent this type of thought is changed by aging. In the present dissertation we analyzed age-related differences in spontaneous thoughts in terms of frequency and qualitative characteristics, while controlling for methodological confounds and targeting particular spontaneous thought mechanisms.

We started by meta-analyzing previous literature on the frequency of spontaneous thought and related concepts, and found a consistent age-related decrease. Additionally, we found significant methodological moderators of this effect that indicated an impact of age-related differences in motivation, task demand and instruction bias in previous results. These results suggested that the age-related decrease identified may be due to the methods that have been preferred to study spontaneous thought. We concluded that new experimental studies with different methodological approaches are necessary to better understand age-related differences in this area. In particular, we emphasize the usefulness of open-ended response methods to avoid age-related differences in instruction and response option bias, and use this type of approach in our following studies.

In the second study, we adapted a lab task to elicit spontaneous thought while avoiding the sources of confound identified in the meta-analysis. Namely, we diminished task demands and avoided the need for retrospection and sustained meta-awareness by asking participants to freely describe their thoughts at random points of the task. In this task, younger and older participants saw words appearing on the screen written in red and yellow and were asked to say yes out loud only when the yellow words appeared. The task was divided in two parts, and between them participants performed a priming task which activated personal future-oriented goals, or a control task. We found no age-related differences in the frequency of spontaneous task-unrelated thoughts. After the priming task there was an increase in the number of spontaneous task-unrelated thoughts about the future in both younger and older adults. This result supports the link between personal goal activation and spontaneous future thought and its preservation in healthy aging. Confirming the priming effect, we found no differences in future spontaneous task-unrelated thoughts in a younger control group. Our results support the view that age-related differences are mainly due to self-initiated processes, and thus are less prominent

in spontaneous retrieval. We also showed that spontaneous thought mechanisms are based on an interaction between external triggers, that were present in the great majority of the cases, and internal contents such as personal goals, activated by the present successful priming.

In the third study, we extended our analysis of age-related differences in spontaneous thought from frequency to a qualitative variable, namely, episodic specificity. Episodic specificity refers to the amount of place, time and other details that define a unique personal event. In deliberate retrieval there is consistent evidence for an age-related decrease in the episodic specificity of past and future thought that has been associated with age-related differences in strategic processes. Based on the reduced involvement of strategic processes in spontaneous thought, we expected no age-related differences in episodic specificity. To further explore the mechanisms of episodic specificity in spontaneous thought we used an episodic specificity induction that targets episodic construction processes. Different theoretical positions would predict the involvement of construction processes in spontaneous retrieval or, on the contrary, the access to pre-stored event representations that are independent of event construction. Therefore, testing the episodic specificity induction in spontaneous thought provided a way to test these alternative theoretical views. Participants performed two counterbalanced sessions including a video, the episodic specificity or control induction, and a vigilance task. In the episodic specificity induction, participants recalled the details of the video whilst in the control they solved math exercises. The impact of this manipulation on the episodic specificity of spontaneous thoughts was assessed in the subsequent vigilance task, an improved version of the task used in study 2. We found no differences between age groups in the episodic specificity of spontaneous thoughts, supporting the prediction that spontaneous retrieval attenuates the episodic specificity decrease in aging. We also found no effect of the induction, indicating that spontaneous retrieval bypasses event construction and accesses pre-stored events.

Overall, we found no evidence of age-related effects in spontaneous thought, supporting the view that age-related differences are mainly attributable to self-initiated processing. Furthermore, we suggest that triggering spontaneous retrieval of past and future thoughts is a promising strategy in aging to promote episodic specificity and the benefits associated with it. From a wider perspective, we discuss how future developments in this area should be accompanied by conceptual clarification and a greater focus on naturalistic studies and interventions.

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List of Abbreviations

- AI: Autobiographical interview
- AM: Autobiographical memory
- BDI-II: Beck Depression Inventory II
- DMN: Default mode network
- EEG: Electroencephalography
- ERP: Event-related potential
- ESI: Episodic specificity induction
- fMRI: Functional magnetic resonance imaging
- GDS-30: Geriatric Depression Scale 30
- IAM: Involuntary autobiographical memory
- ISI: Inter-stimuli interval
- MoCA: Montreal Cognitive Assessment
- MW: Mind wandering
- OA: Older adults
- OG: Older group
- PFC: Pre-frontal cortex
- SDT: Stimulus-dependent thought
- SFT: Spontaneous future thought
- SIT: Stimulus-independent thought
- sTUT: Spontaneous task-unrelated thought
- TEMPau: *Test Episodique de la Mémoire du Passé lointain autobiographique*
- TRI: Task-related interference
- TRT: Task-related thought
- TUT: Task-unrelated thought
- vmPFC: ventromedial prefrontal cortex
- YA: Younger adults
- YG: Younger group

Introduction

How do cognitive abilities change as we get older? To answer this question is the main aim of cognitive aging research (Schaie & Willis, 2017). The present work contributes to this aim and, in line with a main trend in cognitive aging research, acknowledges that cognition does not change uniformly with aging but is better understood by exploring distinct age-related patterns for specific cognitive components (Anderson & Craik, 2016). Here, the focus is spontaneous thoughts, that is, the mental contents that come to our mind with reduced effort, intention and control and are a frequent daily occurrence (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Cole & Kvavilashvili, 2019). Spontaneous thoughts are an important element in the discussion about cognitive aging because, by definition, they are minimally dependent on effortful processes and the frontal lobes, which have consistently been identified as key contributors to age-related differences (for a review, see Anderson & Craik, 2016). Yet, research on aging and spontaneous thought is sparse and follows from different research traditions that seldom articulate concepts, methods and findings, causing both theoretical and methodological confusion (Maillet & Schacter, 2016). Considering that spontaneous thought is associated with numerous adaptive functions such as goal setting, planning, creative problem-solving and memory consolidation (Klinger, Koster, & Marchetti, 2018), it is also unclear to what extent older adults may be helped or hindered by spontaneous thoughts in their daily life. In this dissertation, we aimed to clarify this area by analyzing age-related differences in the quantity and the qualitative characteristics of spontaneous thoughts, while carefully considering sources of methodological confound identified, for the first time, in a meta-analysis. More generally, we clarify whether spontaneous thought is affected by age-related changes in strategic functions, associated with the frontal lobes, or constitutes a preserved cognitive component.

The following sections present the theoretical frameworks that guided our work. The first section focuses on the concept of retrieval, explaining the difference between spontaneous and deliberate retrieval and the relevance of these concepts in cognitive aging. The second section focuses on the role of cognitive resources on spontaneous thought frequency, and how age-related decrease in cognitive resources may impact the quantity of spontaneous thought reported by older adults. The third section presents the distinction between semantic and episodic memory and reviews the literature on age-related decreases in episodic specificity. To finish this introduction, we summarize the structure of the present dissertation.

Spontaneous and deliberate retrieval in aging

Retrieval refers to the processes by which previously learned information comes to mind (Tulving, 1983). In 1966, Tulving and Pearlstone provided a seminal demonstration of the relevance of retrieval by showing that word-recall performance varied according to whether participants were provided with categories of the words they ought to recall at the time of retrieval (retrieval cues) or not. In this study, the information was learned in the same circumstances but could only be accessed in some retrieval conditions (Tulving & Pearlstone, 1966). This demonstration introduced the idea that the inability to recall may be due to the characteristics of the retrieval process instead of a failure to learn or subsequent forgetting (Frankland, Josselyn, & Köhler, 2019). Thus, a memory could be available (it was learned and it was not subsequently forgotten), but would be accessible only in the presence of an effective retrieval cue.

The distinction between availability and accessibility is key to understand cognitive aging. In fact, it has been shown that age-related decreases in memory performance are minimized when there is additional support at retrieval (i.e., informative cues) (for a review, see Lindenberger & Mayr, 2014). Thus, older adults do not necessarily "lose" information (i.e., lack available information), but instead have more difficulty accessing memory. These findings underpin the view that cognitive aging impairs self-initiated processing due to deficits in cognitive resources and executive control, while sparing more automatic processes (for a review, see Craik, 2020). From a neuropsychological perspective, these age-related deficits in self-initiated processing are associated with the deterioration of frontal lobe structure and function, based on evidence that links age-related deficits in executive control to the pre-frontal cortex (PFC) (for a review see, Cabeza & Dennis, 2013). Consequently, it is important to analyze aging effects on retrieval as a function of the level of self-initiated processing involved. This analysis is given by the distinction between spontaneous/involuntary and deliberate/voluntary retrieval.

Deliberate and spontaneous retrieval were first distinguished by Ebbinghaus in 1885. Memories deliberately retrieved were defined as situations in which one "call[s] back into consciousness by an exertion of the will directed to this purpose the seemingly lost states" (Ebbinghaus, 2013, p. 1). Alternatively, memories could emerge by spontaneous retrieval, that is, "with apparent spontaneity and without any act of the will" (Ebbinghaus, 2013, p. 1). Subsequent research has corroborated this separation, emphasizing not only the differences in intentionality, but also that deliberate retrieval is more reliant on strategic and effortful cognitive processes than spontaneous retrieval (for a review, see Mace, 2007). The less effortful nature of spontaneous retrieval is demonstrated, for example, by studies showing that (1) children as young as 3.5 years-old whose strategic cognitive ability is not yet developed, report spontaneous memories (Krøjgaard, Kingo, Dahl, & Berntsen, 2014), and (2) older adults with dementia and significant executive function decline, are able to retrieve detailed spontaneous memories (Miles, Fischer-Mogensen, Nielsen, Hermansen, & Berntsen, 2013). Additionally, the neural correlates of involuntary and voluntary memories are similar with the exception of reduced activity in frontal regions for involuntary memories (Hall, Gjedde, & Kupers, 2008; Hall et al., 2014; Kompus, Eichele, Hugdahl, & Nyberg, 2010), which is thought to reflect the reduced requirement of self-initiated processes during involuntary memory retrieval. More recently, the analysis of the characteristics of spontaneous and deliberate retrieval has been extended from memories of the past to future episodic thoughts, with evidence showing that it is possible to experience future thoughts without trying to bring them to mind (e.g., Berntsen & Jacobsen, 2008; Cole, Staugaard, & Berntsen, 2016).

If spontaneous retrieval is less effortful and aging effects are mainly due to effortful self-initiated processes, we should find minimal or nonexistent age-related differences in spontaneous thought. However, evidence regarding the frequency of spontaneous thoughts in younger and older adults reveals mixed findings with regard to the role of cognitive resources in spontaneous retrieval. We address this point next.

Frequency of spontaneous thoughts and aging

Spontaneous thought frequency has been studied in various research areas, including involuntary memory, mentioned above, and mind wandering (for a review, see Maillet & Schacter, 2016). Mind wandering is defined as an attentional shift from a task to an internal content (Smallwood & Schooler, 2015) and is often characterized as spontaneous thought (Christoff et al., 2016). Thus, along with evidence from spontaneous memories and future thoughts, mentioned previously, investigations of mind wandering can inform us about the effects of age on spontaneous retrieval.

Overall, spontaneous thought frequency decreases with age (Maillet & Schacter, 2016). This finding is inconsistent with the view that spontaneous thoughts are less dependent on effortful processing, and thus less affected by age-related decrements in executive control (Braver & West, 2008). It has alternatively been suggested that spontaneous thoughts frequently need to be inhibited and such inhibition requires cognitive resources (McVay & Kane, 2010). However, if this explanation were true, then older adults would have more, not less, spontaneous thoughts compared to younger adults, given age-related difficulties in inhibiting irrelevant information (Hasher & Zacks, 1979).

A plausible explanation for the age-related decrease in spontaneous thought is that it relates to methodological confounds to which MW paradigms are prone. More precisely, it has been suggested that age-related differences in MW frequency may be due to motivation, meta-awareness, social desirability and the type of stimulus presented to participants in lab tasks (for a review see Maillet & Schacter, 2016). Supporting this idea, involuntary autobiographical memory studies that target spontaneous retrieval in daily experience, do not typically find age-related differences (Berntsen, Rubin, & Salgado, 2015; Schlagman, Kliegel, Schulz, & Kvavilashvili, 2009). Thus, lab-based investigations of mind wandering may be particularly prone to confounds associated with methodological characteristics that contribute to age-related differences.

We develop in detail the theoretical and methodological issues of the age-related decrease in spontaneous thought frequency by meta-analyzing the existing evidence, in Study 1. Additionally, and given the crucial importance of the methodology used to elicit spontaneous thoughts, we address possible methodological confounds experimentally, by adapting and testing a lab task to measure spontaneous thought with younger and older adults, in Study 2. The adaptations to the task are further tested by another experiment in Study 3. Importantly, if controlling methodological confounds results in minimal or no age-related effects, the view that aging mainly affects strategic processes, but not spontaneous retrieval, would be supported. In addition, because age-related differences may impact not only the quantity of spontaneous thoughts, but also its qualitative characteristics (for a dissociation between quantity and quality see McCormick, Ciaramelli, De Luca, & Maguire, 2018), we analyze the level of episodic specificity in spontaneous thought. The relevance of this concept for aging is introduced in the next section.

Episodic specificity in spontaneous thoughts and aging

Our daily experience shows that we recall information in a variety of forms. On some occasions we are able to remember specific events and re-experience a particular situation, while in others we know a fact about the world without recalling the specific context in which we learned about it. In the first case, we are engaging our episodic memory system, and in the latter, the semantic system (Tulving, 1983; Tulving, 2002). The distinction between the episodic and semantic memory system is supported by evidence from behavioral, neuropsychological, and neural studies (for a review, see Tulving, 2002)[1]. Additionally, it has been suggested that future events similarly rely on semantic and episodic memory (e.g., Atance & O'Neill, 2001). A considerable amount of empirical research on the similarities and differences between past and future thoughts has shown that these representations share important mechanisms based on the semantic and episodic memory systems (for a review, see Schacter et al., 2012). Does this apply to spontaneous retrieval? Research on spontaneous past and future thoughts is less abundant (for a review, see Cole & Kvavilashvili, 2019), but has also shown similarities between the past and future (Berntsen & Jacobsen, 2008; Cole et al., 2016).

The interplay between semantic and episodic memory is a key issue in cognitive aging. Notably, it has been shown that episodic but not semantic memory declines with aging (e.g., Nyberg et al., 2003). One aspect of episodic memory that has shown an age-related decrease is the degree to which a content includes specific event information ("what", "when" and "where") and experiential detail (Tulving, 2002), that is, episodic specificity. An age-related reduction of episodic specificity, or the degree of episodic to semantic details, in memories and future thoughts is a consistent finding in the literature (for a recent review see Devitt, Addis, & Schacter, 2017). Age-related reductions in episodic specificity are largely attributed to effortful cognitive processes (e.g., Piolino, Desgranges, & Eustache, 2009; Zavagnin, De Beni, Borella, & Carretti, 2016) involving the PFC (e.g., St. Jacques, Rubin, & Cabeza, 2012). Thus, the age-related decrease in episodic specificity may be bypassed when less effortful mechanisms are involved and the PFC is less engaged, as in spontaneous retrieval. However, only two studies have

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[1]This does not mean that the two systems do not interact. Since the creation of these concepts, it has been recognized that "[episodic memory] operations require, but go beyond, the semantic memory system" (Tulving, 2002, p. 5). The interaction between semantic and episodic memory has been further developed in new theoretical proposals such as the semantic scaffolding hypothesis (Irish, Addis, Hodges, & Piguet, 2012) and the concept of personal semantics (Renoult, Davidson, Palombo, Moscovitch, & Levine, 2012).

directly tested this idea and both focused on past-oriented thoughts (Schlagman et al., 2009; Schlagman, Kvavilashvili, & Schulz, 2007). We pursue this research in Study 3, by comparing the episodic specificity of spontaneous thoughts in younger and older adults, while exploring the mechanisms responsible for episodic specificity in spontaneous thought.

In theory, minimal or absent age-related differences in episodic specificity would be in line with the main role of self-initiated processing in age-related decreases (Craik, 2020) and the role of age-related deterioration in frontal lobe function (Craik, 2011). It will also support the view that self-initiated processes are the main source of age-related differences in the deliberate generation of episodic details (e.g., De Beni et al., 2013). Practically, fewer age-related differences in the episodic specificity of spontaneous thought would indicate that spontaneous retrieval is a useful pathway to access detail in old age. This is particularly important in light of the relationship between episodic detail and important daily functions such as problem solving (e.g., Beaman, Pushkar, Etezadi, Bye, & Conway, 2007). The present dissertation contributes to determine which conditions favor the elicitation of specific spontaneous thoughts in older adults. In the long run, this knowledge should help to create environments built to trigger important cognitive processes which older adults struggle to self-initiate, that is, “environments for successful aging” (Lindenberger & Mayr, 2014, p. 13) that provide support based on preserved cognitive functions.

Structure of the dissertation

The structure of the present dissertation follows from the issues presented above, addressing them in three studies. First, we focus on the frequency of spontaneous thought, in a meta-analysis that identified key methodological confounds on age-related differences in the frequency of spontaneous thoughts. In the second study, these methodological confounds were controlled for in a newly adapted lab task. We tested age-related differences in the frequency of spontaneous thought in this task and, for the first time, explored priming mechanisms of spontaneous thought in both younger and older adults. Then, in the third study, we analyzed episodic specificity in spontaneous thought by comparing the descriptions of younger and older participants and explored the processes underlying episodic specificity in spontaneous thought. In a final chapter we discuss the results as a whole by highlighting the main findings, their relevance for cognitive aging theory and practice, and future avenues of research.

References

Anderson, N. D., & Craik, F. I. M. (2016). 50 years of cognitive aging theory. *The Journals of Gerontology: Series B*, *72*(1), 1–6. doi:10.1093/geronb/gbw108

Atance, C. M., & O’Neill, D. K. (2001). Episodic future thinking. *Trends in Cognitive Sciences*, *5*(12), 533–539. doi:10.1016/S1364-6613(00)01804-0

Beaman, A., Pushkar, D., Etezadi, S., Bye, D., & Conway, M. (2007). Autobiographical memory specificity predicts social problem-solving ability in old and young adults. *The Quarterly Journal of Experimental Psychology*, *60*(9), 1275–1288. doi:10.1080/17470210600943450

Berntsen, D., & Jacobsen, A. S. (2008). Involuntary (spontaneous) mental time travel into the past and future. *Consciousness and Cognition*, *17*(4), 1093–1104. doi:10.1016/j.concog.2008.03.001

Berntsen, D., Rubin, D. C., & Salgado, S. (2015). The frequency of involuntary autobiographical memories and future thoughts in relation to daydreaming, emotional distress, and age. *Consciousness and Cognition*, *36*, 352–372. doi:10.1016/j.concog.2015.07.007

Braver, T. S., & West, R. (2008). Working memory, executive control, and aging. In F. I. M. Craik & T. A. Salthouse (Eds.), *The Handbook of aging and cognition* (3rd ed., Vol. 3, pp. 311–372). Psychology Press.

Cabeza, R., & Dennis, N. A. (2013). Frontal lobes and aging deterioration and compensation. In D. T. Stuss & R. T. Knight (Eds.), *Principles of frontal lobe function*. Retrieved from https://oxfordmedicine.com/view/10.1093/med/9780199837755.001.0001/med-9780199837755-chapter-44

Christoff, K., Irving, Z. C., Fox, K. C. R., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: A dynamic framework. *Nature Reviews Neuroscience*, *17*(11), 718–731. doi:10.1038/nrn.2016.113

Cole, S. N., & Kvavilashvili, L. (2019). Spontaneous future cognition: The past, present and future of an emerging topic. *Psychological Research*, *83*(4), 631–650. doi:10.1007/s00426-019-01193-3

Cole, S. N., Staugaard, S. R., & Berntsen, D. (2016). Inducing involuntary and voluntary mental time travel using a laboratory paradigm. *Memory and Cognition*, *44*(3), 376–389. doi:10.3758/s13421-015-0564-9

Craik, F. I. M. (2011). Effects of aging on memory and attention: A frontal lobe problem? In B. Levine & F. I. M. Craik (Eds.), *Mind and the frontal lobes: Cognition, behavior, and brain imaging* (pp. 183-197). New York: Oxford University Press.

Craik, F. I. M. (2020). Remembering: An activity of mind and brain. *Annual Review of Psychology*, *71*, 1-24. doi:10.1146/annurev-psych-010419-051027

De Beni, R., Borella, E., Carretti, B., Zavagnin, M., Lazzarini, L., & Milojevi, G. (2013). Remembering the past and imagining the future: Age-related differences between young, young-old and old-old. *Aging Clinical and Experimental Research*, *25*(1), 89–97. doi:10.1007/s40520-013-0003-3

Devitt, A. L., Addis, D. R., & Schacter, D. L. (2017). Episodic and semantic content of memory and imagination: A multilevel analysis. *Memory and Cognition*, *45*(7), 1078–1094. doi:10.3758/s13421-017-0716-1

Ebbinghaus, H. (2013). Memory: A contribution to experimental psychology. *Annals of Neurosciences*, *20*(4), 155–156. doi:10.5214/ans.0972.7531.200408

Frankland, P. W., Josselyn, S. A., & Köhler, S. (2019). The neurobiological foundation of memory retrieval. *Nature Neuroscience*, *22*(10), 1576–1585. doi:10.1038/s41593-019-0493-1

Hall, N. M., Gjedde, A., & Kupers, R. (2008). Neural mechanisms of voluntary and involuntary recall: A PET study. *Behavioural Brain Research*, *186*(2), 261–272. doi:10.1016/j.bbr.2007.08.026

Hall, S. A., Rubin, D. C., Miles, A., Davis, S. W., Wing, E. A., Cabeza, R., & Berntsen, D. (2014). The neural basis of involuntary episodic memories. *Journal of Cognitive Neuroscience*, *26*(10), 2385–2399. doi:10.1162/jocn_a_00633

Hasher, L., & Zacks, R. T. (1979). Automatic and effortful processes in memory. *Journal of Experimental Psychology: General*, *108*(3), 356–388. doi:10.1037/0096-3445.108.3.356

Irish, M., Addis, D. R., Hodges, J. R., & Piguet, O. (2012). Exploring the content and quality of episodic future simulations in semantic dementia. *Neuropsychologia*, *50*(14), 3488–3495. doi:10.1016/j.neuropsychologia.2012.09.012

Klinger, E., Koster, E. H. W., & Marchetti, I. (2018). Spontaneous thought and goal pursuit from functions such as planning to dysfunctions such as rumination. In K. Christoff & K. C. R. Fox (Eds.), *The Oxford handbook of spontaneous thought: Mind-wandering, creativity, and dreaming*. Retrieved from https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780190464745.001.0001/oxfordhb-9780190464745-e-24

Kompus, K., Eichele, T., Hugdahl, K., & Nyberg, L. (2010). Multimodal imaging of incidental retrieval: The low route to memory. *Journal of Cognitive Neuroscience*, *23*(4), 947–960. doi:10.1162/jocn.2010.21494

Krøjgaard, P., Kingo, O. S., Dahl, J. J., & Berntsen, D. (2014). “That one makes things small”: Experimentally induced spontaneous memories in 3.5-year-olds. *Consciousness and Cognition*, *30*, 24–35. doi:10.1016/j.concog.2014.07.017

Lindenberger, U., & Mayr, U. (2014). Cognitive aging: Is there a dark side to environmental support? *Trends in Cognitive Sciences*, *18*(1), 7–15. doi:10.1016/j.tics.2013.10.006

Mace, J. H. (2007). Involuntary memory: Concept and theory. In J. H. Mace (Ed.), *Involuntary Memory*. Retrieved from https://doi.org/10.1002/9780470774069.ch1

Maillet, D., & D. L. Schacter. (2016). From mind wandering to involuntary retrieval: Age-related differences in spontaneous cognitive processes. *Neuropsychologia*, *80*, 142–156. doi:10.1016/j.neuropsychologia.2015.11.017

McCormick, C., Ciaramelli, E., De Luca, F., & Maguire, E. A. (2018). Comparing and contrasting the cognitive effects of hippocampal and ventromedial prefrontal cortex damage: A review of human lesion studies. *Neuroscience*, *374*, 295–318. doi:10.1016/j.neuroscience.2017.07.066

doi:McVay, J. C., & Kane, M. J. (2010). Does mind wandering reflect executive function or executive failure? Comment on Smallwood and Schooler (2006) and Watkins (2008). *Psychological Bulletin*, *136*(2), 188–207. doi:10.1037/a0018298

Miles, A. N., Fischer-Mogensen, L., Nielsen, N. H., Hermansen, S., & Berntsen, D. (2013). Turning back the hands of time: Autobiographical memories in dementia cued by a museum setting. *Consciousness and Cognition*, *22*(3), 1074–1081. doi:10.1016/j.concog.2013.07.008

Nyberg, L., Maitland, S. B., Rönnlund, M., Bäckman, L., Dixon, R. A., Wahlin, Å., & Nilsson, L.-G. (2003). Selective adult age differences in an age-invariant multifactor model of declarative memory. *Psychology and Aging*, *18*(1), 149–160. doi:10.1037/0882-7974.18.1.149

Piolino, P., Desgranges, B., & Eustache, F. (2009). Episodic autobiographical memories over the course of time: Cognitive, neuropsychological and neuroimaging findings. *Episodic Memory and the Brain*, *47*(11), 2314–2329. doi:10.1016/j.neuropsychologia.2009.01.020

Renoult, L., Davidson, P. S. R., Palombo, D. J., Moscovitch, M., & Levine, B. (2012). Personal semantics: At the crossroads of semantic and episodic memory. *Trends in Cognitive Sciences*, *16*(11), 550–558. doi:10.1016/j.tics.2012.09.003

Schacter, D. L., Addis, D. R., Hassabis, D., Martin, V. C., Spreng, R. N., & Szpunar, K. K. (2012). The future of memory: Remembering, imagining, and the brain. *Neuron*, *76*(4), 677–694. doi:10.1016/j.neuron.2012.11.001

Schaie, K. W., & Willis, S. L. (2017). History of cognitive aging research. In N. A. Pachana (Ed.), *Encyclopedia of geropsychology*. Retrieved from https://doi.org/10.1007/978-981-287-082-7_99

Schlagman, S., Kliegel, M., Schulz, J., & Kvavilashvili, L. (2009). Differential effects of age on involuntary and voluntary autobiographical memory. *Psychology and Aging*, *24*(2), 397–411. doi:10.1037/a0015785

Schlagman, S., Kvavilashvili, L., & Schulz, J. (2007). Effects of age on involuntary autobiographical memories. In J. H. Mace (Ed.), *Involuntary Memory* (pp. 87–112). New York: Blackwell.

Smallwood, J., & Schooler, J. W. (2015). The science of mind wandering: Empirically navigating the stream of consciousness. *Annual Review of Psychology*, *66*(1), 487–518. doi:10.1146/annurev-psych-010814-015331

St. Jacques, P. L., Rubin, D. C., & Cabeza, R. (2012). Age-related effects on the neural correlates of autobiographical memory retrieval. *Neurobiology of Aging*, *33*(7), 1298–1310. doi:10.1016/j.neurobiolaging.2010.11.007

Tulving, E. (1983). *Elements of episodic memory*. Retrieved from https://books.google.co.uk/books?id=2699AAAAMAAJ

Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology*, *53*(1), 1–25. doi:10.1146/annurev.psych.53.100901.135114

Tulving, E., & Pearlstone, Z. (1966). Availability versus accessibility of information in memory for words. *Journal of Verbal Learning and Verbal Behavior*, *5*(4), 381–391. doi:10.1016/S0022-5371(66)80048-8

Zavagnin, M., De Beni, R., Borella, E., & Carretti, B. (2016). Episodic future thinking: The role of working memory and inhibition on age-related differences. *Aging Clinical and Experimental Research*, *28*(1), 109–119. doi:10.1007/s40520-015-0368-6

Study 1. Meta-Analysis of Aging Effects in Mind Wandering: Methodological and Sociodemographic Factors

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In our daily life, we frequently experience thoughts unrelated to the tasks in which we are involved (Killingsworth & Gilbert, 2010), such as suddenly remembering a past vacation or imagining the restaurant where we will meet a friend. These experiences, in which an attentional shift directs us away from an ongoing task or activity and towards internal information, have been defined as mind wandering (MW, Smallwood & Schooler, 2006). In the last decade or so, theory and research about MW has steadily developed (for reviews see Callard, Smallwood, Golchert, & Margulies, 2013; Smallwood & Schooler, 2015), encompassing critical analyses of the concept and suggestions for its refinement (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Seli et al., 2018b). Moreover, MW research has extended to a wide variety of populations, including healthy older adults. Studying age-differences in MW is particularly important in light of the costs and benefits that accompany fluctuations in MW (for a review, see Mooneyham & Schooler, 2013). A recent review of age-related differences in spontaneous thought found a decrease in MW frequency in older adults (Maillet & Schacter, 2016a), which may have important consequences for older adults' well-being and decision making, considering that the capacity to mind wander is related to creativity (Baird et al., 2012), and the ability to plan the future (Smallwood, Nind, & O'Connor, 2009). However, it is currently unclear what methodological factors related to the way MW has been measured (especially in laboratory tasks) and sample characteristics may explain age-related differences in MW. Thus, we conducted a meta-analysis on age-related differences in MW to pursue two main aims. First, to measure the consistency and size of age-related differences, controlling for publication bias and dependent results. Second, to analyze the influence of methodological and socio-demographic moderators and to shed light on the specific conditions in which the MW decrease in older adults is more pronounced. We also discuss theoretical and practical implications that inform the design of future experiments.

This study aims to assess the extent to which MW frequency differs in younger and older adults, and how such age-related difference may be moderated by factors of interest. The present approach is developed below where we (1) present the main theories proposed to explain MW and its relation with the cognitive aging literature, (2) review previous evidence on age-differences in MW frequency, and (3) describe factors that have been proposed to modulate those differences and are included as possible moderators in the present meta-analysis.

Theoretical Approaches to MW

Smallwood and Schooler (2006) defined MW as “a shift of attention away from a primary task toward internal information” (p. 946). Although MW was not a recent term (Antrobus, Singer, Goldstein, & Fortgang, 1970), the broad conceptualization proposed by Smallwood and Schooler (2006) brought together similar concepts previously explored in the literature, and has proven useful in stimulating the development of the field and in contributing to a more complete view of the phenomenon (Callard et al., 2013; Seli et al., 2018b). Two main theoretical approaches have been proposed to explain MW that both emphasize the role of executive control: the executive control hypothesis (Smallwood & Schooler, 2006) and the control failure × concerns approach (McVay & Kane, 2010). The executive control hypothesis (Smallwood & Schooler, 2006) suggests that MW is a controlled shift towards a personal goal, such that executive resources support MW. In contrast, the control failure × concerns approach (McVay & Kane, 2010) proposes that MW is a result of automatic elicitation of thoughts triggered by cues related to current concerns (or active personal goals; Klinger, 1975) that failed to be inhibited. More recently, it has been suggested that these theories complement each other, by focusing on different aspects of MW (Smallwood, 2013; Thomson, Besner, & Smilek, 2015). Specifically, the executive control hypothesis explains MW continuity, while the control failure × concerns approach explains its initiation, so that executive resources assume distinct roles along the MW process (i.e., support continuity but prevent MW occurrence). The contribution of executive resources to MW is important when considering age-related differences in MW because older adults show lower executive control (Braver & West, 2008). Within the present theoretical framework, this would lead to more frequent MW initiation but to a greater difficulty in supporting its continuity. Although this distinction between MW occurrence and maintenance has rarely been explored in aging, it is relevant to consider when analyzing some of the particular factors included in the next section.

Aging and MW

Current evidence overwhelmingly points to a decrease in MW frequency in older compared to younger adults (for a review, see Maillet & Schacter, 2016a). However, several factors, both methodological and socio-demographic, have been suggested to influence the age-related decrease in MW.

Methodological Factors

Current concerns cues. The first factor is the impact of current concerns cues on MW initiation. McVay and Kane (2010) and McVay, Meier, Touron, and Kane (2013) suggested that age-related differences in current concerns and their interaction with executive control leads to a decrease in MW frequency in older adults. More specifically, older adults may have current concerns unrelated with the lab-context, which would decrease the automatic initiation of MW. Consequently, despite being more prone to inhibition failure (e.g., Lustig, Hasher, & Zacks, 2007), older adults would have less MW occurrences to inhibit. Age-related differences in the content of current concerns and their relationship with MW leads to two main hypotheses. First, in experimental settings, including meaningful stimuli should facilitate the activation of current concerns in both age groups and contribute to equate current concern cues. However, several studies using meaningful information during text comprehension tasks still find an age-related decrease in MW (e.g., Krawietz, Tamplin, & Radvansky, 2012). In the present study, we further consider this possibility by analyzing the impact of meaningful stimulus on the size of the age-related decrease (question 3). Second, in naturalistic settings age-related differences in current concerns cues should have less influence on MW frequency. However, age-related differences in MW are still found when participants used an internet-based task performed in their environment (Jackson, Weinstein, & Balota, 2013), and in daily-life (Maillet et al., 2018). These findings may be due to age-related decreases in the quantity of current concerns (as shown by Parks, Klinger, & Perlmutter, 1989), which would lead to an overall decrease in MW initiation. However, this assumes that current concerns are linearly related to MW (i.e., more current concerns would lead to more MW, irrespective of their content). Given that this linear relationship has not yet been established, it is still uncertain how the number of current concerns contributes to the age-related decrease in MW frequency. Thus, the impact of current concerns on age-differences in MW frequency still warrants further research.

Meta-awareness. Meta-awareness is defined as the "explicit awareness of the current contents of our own experiences" (Smallwood & Schooler, 2006, p. 946). The method by which participants report MW may require more or less meta-awareness (Smallwood & Schooler, 2015). In self-caught reporting participants keep track of their thoughts and stop the task when aware of MW experiences, requiring a higher level of meta-awareness. In contrast, in probe-caught reporting participants are interrupted periodically and asked to describe their present experience, restricting the need for meta-awareness. It has been suggested that lower meta-awareness in older adults may be one possible reason for the age-related decrease in MW (Maillet & Schacter, 2016a). As a result, age differences in MW should be more pronounced in self than probe-caught reporting that is more reliant on meta-awareness. However, the present evidence demonstrates age-related decreases in MW in both self (e.g., Giambra & Grodsky, 1992) and probe-caught (e.g., Frank, Nara, Zavagnin, Touron, & Kane, 2015) based studies, suggesting either that meta-awareness does not fully account for the age-related decrease in MW or that probe-caught methods may rely more on meta-awareness than has been previously assumed. In the present study, a measure of the contribution of meta-awareness is given by comparing the size of age differences in self and probe-caught studies (question 1).

Task demand. Task demand represents another key factor in understanding the occurrence of MW by modulating the involvement of executive control and thus the resources available to support and inhibit MW. Evidence shows higher working memory capacity is related to more MW in non-demanding contexts (e.g., Levinson, Smallwood, & Davidson, 2012, but see Meier, 2019), and with less MW in demanding contexts (e.g., Unsworth & McMillan, 2013). To account for these findings, the context regulation hypothesis proposes that task demand determines the relationship between executive control and MW (Smallwood & Schooler, 2015). In particular, under lower task demands MW is positively associated with executive control abilities, whereas under higher task demands MW is negatively associated with executive control abilities. In light of the interaction between task demand and executive control, it is reasonable to expect different age-related patterns in MW according to task demands. Specifically, because older adults show a decline in executive control (Braver & West, 2008), the MW age-related decrease should be more apparent when task demands are lower. Current evidence shows the MW age-related decrease across more or less demanding conditions (Jackson & Balota, 2012), but how this effect size differs according to methodological factors related with demand, such as stimulus presentation time, inter-stimuli interval (ISI), pace, target proportion and probe rate, is unknown. In this study, we pursue this analysis by including task characteristics related with demand as moderator variables (question 2).

Reporting bias. A number of conceptual issues surround the definition of MW (e.g., Christoff et al., 2016; Seli et al., 2018b), which may influence age-related differences. One important aspect is whether thoughts related to task performance or assessment (i.e., task-related interference, TRI) are considered, by presenting a TRI option for participants to select when describing their experience. In the absence of a TRI option participants may misclassify TRI as on-task thought, given that the content of these thoughts is related with the task. Considering that TRI increases with age (McVay et al., 2013), this would impact older participants in particular and increase the differences in MW frequency between age groups. However, the age-related decrease in MW is still observed when the TRI option is included (for a review, see Maillet & Schacter, 2016a), indicating that a misclassification of TRI as on-task thought does not explain the decrease. Accordingly, recent evidence with younger adults comparing MW with and without a TRI option, shows that TRI is also misclassified as MW (in one third of the occasions, Robison, Miller, & Unsworth, 2019). Thus, the absence of a TRI option does not seem to explain the age-related decrease in MW. However, it is still a possible moderator of age-differences, given that TRI increases in older adults and evidence for confound between TRIs and other types of MW. Another important conceptual issue when determining age-related differences in MW refers to its relation to external stimuli. Older adults tend to rely more on environmental support (e.g., Lindenberger & Mayr, 2014) which could lead to different patterns of age-related differences in MW depending upon how they are triggered by external stimulus. In line with this idea, it has been shown that the number of overall thoughts and stimulus-independent thoughts are more frequent in younger participants, but stimulus-dependent thoughts are more frequent in the older (Maillet & Schacter, 2016b). Currently, it is not possible to directly meta-analyze different age patterns related with stimulus-dependency, given that this distinction is relatively recent in the MW literature. Nonetheless, we provide an indirect analysis by comparing age-related differences in tasks including non-meaningful versus meaningful stimuli (question 3). Meaningful stimuli are more likely to trigger stimulus-dependent thought (Maillet & Schacter, 2016b) and should increase MW frequency in older adults, which would lead to an overall decrease in age-related differences in MW.

Methodological issues may also contribute to response bias. In particular, probe framing may reduce MW when it is presented as less desirable (Weinstein, 2018), and the probe refers to being on-task *vs* MW (i.e., "were you on-task?" Weinstein, De Lima, & van der Zee, 2018). Given the increased social desirability (Soubelet & Salthouse, 2011), and greater acquiescence of older adults (e.g., tendency to agree with what is stated in the instructions, Vigil-Colet, Morales-Vives, & Lorenzo-Seva, 2013), these conditions could induce an age-related decrease in MW. However, the age-related decrease is found when the term "mind wandering" is not mentioned (Jackson & Balota, 2012), and in MW focused probes (Krawietz et al., 2012), suggesting these variations in probe framing are not sufficient to explain the age-related decrease in MW. Finally, MW reporting can be done retrospectively or online. Retrospective reporting may be influenced by episodic memory decline in older adults (Salthouse, 2010), leading to fewer MW reports than actually experienced. However, the age-related decrease in MW frequency is still observed when reported online (e.g., Frank et al., 2015; Jackson & Balota, 2012). Nonetheless, it is important to analyze whether retrospective reports impact the size of age-related differences in MW, especially considering that such are widely used to measure MW and related phenomena (e.g., Daydreaming Frequency Scale, Giambra, 1993). We pursue this analysis in the present study by comparing retrospective and on-line reporting (question 4).

Task interest. In reading comprehension tasks, younger participants who report more interest are also more motivated to complete the task, which is associated with lower levels of MW (Unsworth & McMillan, 2013). In general, older adults report more interest and/or motivation than younger adults both in reading comprehension tasks (Shake, Shulley, & Soto-Freita, 2016) and other lab tasks (Jackson et al., 2013), and differences in motivation have been shown to mediate age-differences in MW (Frank et al., 2015). However, these studies collected ratings on interest and/or motivation after the task was completed and may be influenced by task performance (Frank et al., 2015) Thus, additional research is required to understand the mechanisms by which age-differences in interest/motivation impact on the frequency of MW.

Sociodemographic Factors

Three main socio-demographic factors may contribute to age-differences in MW frequency: the mean age and education of the older group, and gender. First, because old-old (75 to 85 year-olds) show a more accentuated cognitive decline than young-old (65 to 74 year-olds) (e.g., Borella, Carretti, & De Beni, 2008), not distinguishing these groups may obscure different age patterns related with the role of executive resources in MW (Zavagnin, Borella, & De Beni, 2014). Second, educational level influences the cognitive decline associated with age, such that older adults with higher levels of education generally show a smaller decline (van Hooren et al., 2007). Thus, the impact of executive resources in age-related differences in MW should be reduced as the level of education of older participants' increases. Finally, Giambra (2000a) found that across the lifespan women experience daydreaming more frequently. Thus, the age-related decrease in MW may be more pronounced when younger groups include proportionally more women. To analyze the impact of these socio-demographic factors, we include the mean age and education of the older group, as well as differences in gender proportion as moderator variables in our study (questions 5, 6 and 7, respectively).

The Present Study

In sum, previous studies have reported a decrease in MW frequency with age, but the processes supporting it are not clear. In the present study, we sought to better understand the age-related difference in the frequency of MW, hereafter termed *MW age-related effect*, using a meta-analytical approach. First, we assessed the strength and consistency of the effect of aging on MW. Second, we analyzed methodological and socio-demographic factors that could interact with the MW age-related effect. Considering the research reviewed above, we focused on answering the following questions:

1. Does the probe-caught reporting procedure reduce the MW age-related effect, given that probe-caught reports are less dependent on meta-awareness?
2. Does increased demand (by stimulus time, ISI time, pace, target proportion, and probe rate) attenuate the MW age-related effect, according with the context regulation hypothesis?

3. Do tasks including meaningful material reduce the MW age-related effect, given they are more likely to cue current concerns and stimulus-dependent thoughts?
4. Does on-line reporting reduce the MW age-related effect, given the age-related decline in episodic memory?
5. Does the mean age of the older group influence the MW age-related effect, given the role of executive resources in MW?
6. Does higher mean education in the older group reduce the MW age-related effect, given that education can protect age-related changes in cognition?
7. Does an increased proportion of women in the older group reduce the MW age-related effect, given that women experience MW more frequently?

Answering these questions will contribute to both theory and practice of MW research. Theoretically, it will provide evidence for the contribution of different factors in the decrease of MW frequency with aging. In practice, it will help to create better experimental designs, by identifying variables that influence age-related differences in MW frequency.

Method

Inclusion and Exclusion Criteria

We searched for peer-reviewed empirical research unconstrained by time and cultural framing. To be included in the meta-analysis, studies had to provide a score of MW frequency (the dependent variable) for a younger and an older adults group. Since we were interested in analyzing normal aging, studies using clinical samples were excluded.

Search Strategy

The search was performed in the databases made available through B-On (http://www.b-on.pt/), EBSCO (http://www.ebsco.com/), ProQuest (http://www.proquest.com/), OVID (http://www.ovid.com/site/index.jsp) and WOS (http://www.webofknowledge.com/), using the following expression: AB("involuntary thought" OR "involuntary memor*" OR "involuntary autobiographical memor*" OR "spontaneous thought" OR "mind wander*" OR "daydream*" OR "task unrelated thought" OR "mind pop*" OR "self generated thought" OR "perceptual decoupling")

AND AB("older adult" OR "older people" OR aging OR ageing OR elderly OR retired OR elder)). For WOS, there were many off topic results related with childhood age differences, thus we added the term NOT TS=(child*). The search in the databases was concluded by October 6th 2015. Other sources were also searched, namely, the list of references of papers identified as eligible, the proceedings of recent international conferences that include memory research (e.g., International Conference on Memory, ICOM) and authors were contacted for additional information when needed. Additional new published literature was signaled using publishing alerts until April 2018.

Coding Procedures

The coding of most variables was based on the direct transcript of the information provided in the studies (e.g., MW mean frequency, mean age of the groups). Two additional types of coding were performed. The first consisted of computations for pace, target proportion, probe rate, and gender proportion differences, based on the information provided. The second type of coding concerned stimulus meaningfulness, following a strictly defined strategy. Namely, stimuli were coded as not meaningful when consisting of abstract stimuli, like geometrical forms (e.g., Giambra, 1989) and numbers (e.g., Jackson et al., 2013). Words and related figurative images and sentences, requiring judgments of category or comprehension, and text were considered meaningful. As all coding was based on information directly provided in the studies, it was performed by one coder (MJ).

Effect Size Calculations

The effect sizes were calculated based on the standardized mean difference between the frequency of MW in older adults and younger adults (Cohen's *d*). This value was corrected for small sample size using Hedges' *g* (Lipsey & Wilson, 2001). Since our effect size was based on subtracting younger from older adults' scores, negative values mean less MW frequency for older adults. In some cases (Maillet & Schacter, 2016b; Parks et al., 1989), *F* values were used to calculate effect sizes using Cochrane Systematic Reviews guidelines (Higgins & Green, 2011). Those guidelines were also used to combine groups (e.g., males and females scores in Giambra & Grodsky, 1992). The average effect size is based on a random effects-model. This and all subsequent analyses were performed using the metafor package for R (Viechtbauer, 2010).

Many studies included more than one MW score for the same group comparison. This happens when authors used a more fine-grained conceptualization of MW including tune outs and zone outs (MW with and without awareness; Jackson & Balota, 2012), and when there were different experimental conditions (e.g., semantic or perceptual task, Zavagnin et al., 2014). This resulted in having more effect sizes for the relationship of interest than independent studies. Here, we chose among multiple effect sizes by selecting ones that were the most consistent across studies. Thus, the overall MW score was preferred to other types of MW measures. When MW scores were distinguished by experimental conditions they were included separately if the experimental condition could be described by a moderator variable of interest (e.g., type of stimuli). When the difference between the experimental conditions was unique to that study, MW scores were averaged. Additionally, some studies included more than one younger and/or older group (e.g., young, young-old, and old-old group; Zavagnin et al., 2014) and it was possible to draw more than one comparison between young and older groups (comparing young to young-old, and young to old-old groups).

In summary, several studies provided more than one effect size for the age-differences in MW. If these different effect sizes from a single study were obtained from different samples (e.g., Giambra, 1989), they were entered into the meta-analysis as independent observations. However, in some cases, the same sample of participants provided more than one effect size (e.g., a study that used two dependent variables for MW with the same groups) leading to dependent comparisons. To correct for the inflation of the precision of effect sizes calculated from the same sample, the weight attributed to each of these dependent effect sizes was divided by the total number of effect sizes being contributed by that sample (Ferreira-Santos, 2018; Hedges, Tipton, & Johnson, 2010). For the example with two dependent variables for MW, each of these two effect sizes would receive a weight of 0.5 times the precision of the study, effectively bounding the contribution of this sample to the meta-analysis.

Outliers Analyses

To identify possible outliers we determined if any individual effect size was more than 3 SDs away from the average effect size (Lipsey & Wilson, 2001). Additionally, we performed an influence analysis based on leave-one-out estimates (Viechtbauer, 2010), which consists of repeatedly calculating the combined meta-analytic effect size but leaving out one individual effect size at a time, allowing for the identification of cases that change the overall pattern of results.

Publication Bias Analyses

Publication bias was assessed using several methods, including: the funnel plot, Egger's regression test, Kendall's tau, Rosenthal’s fail-safe N, and the trim-and-fill analysis, as implemented in the metafor package (Viechtbauer, 2010).

Heterogeneity Analysis

To analyze variability between studies, we used the Q test (Cochran, 1954), testing for significant non-random variability, and I^2, as a measure of non-random variability (Higgins, Thompson, Deeks, & Altman, 2003).

Moderator Analyses

We performed planned moderator analyses, following the hypotheses described in the previous section. These analyses consisted of computing separate mixed effect models for each categorical and continuous moderator based on restricted maximum likelihood (REML) estimation as implemented in the metafor package (Viechtbauer, 2010). Whenever a study lacked information about a moderator variable, it was excluded from that particular analysis.

Exploratory Analyses

We conducted two types of exploratory analyses. The first for variables for which we had no specific predictions, namely, TRI status (not mentioned *vs* measured separately), and ISI type (visual mask *vs* no mask). The analysis of TRI status was included to determine if the analysis of MW conceptualized in a more specific form (i.e., as task-unrelated thought experimentally distinguished from TRI) moderates age differences and if so, in what way (following recent conceptual discussions, e.g., Seli et al., 2018b). To ensure that different types of MW were not conflated in this analysis (namely task free MW), we restricted it to the studies that explicitly assigned an experimental task (i.e., rest, inventories about daily life and experience sampling are not included). The analysis of ISI type arouses from the observation that, although there were no specific MW literature and predictions associated with it, this factor varied considerably. Given the close relation between visual masking and attention (Enns & Di

Lollo, 2000) and the idea that attention fluctuation is key to MW (Smallwood, 2013), it seemed reasonable to anticipate an impact of this factor on MW. The second type of exploratory analysis aimed to clarify the results of the planned analysis by testing possible confounds.

Results

Study Selection

The search and selection process is summarized in Figure 1.1. First, abstracts were screened and excluded when repeated or clearly off-topic (e.g., age differences referred to childhood). A broad approach of the MW concept was taken in this stage, and references analyzing terms related to MW (e.g., daydreams, involuntary memory, earworms, etc.) were kept to be analyzed in a second stage of analysis based on the full text. Then, references were assessed by two independent coders with a master level education in Psychology and research experience, and excluded based on the reasons detailed in Figure 1.1. In this stage we took a more refined approach to the concepts included in the meta-analysis, by excluding references dealing with very specific concepts like sexual daydreaming (Purifoy, Grodsky, & Giambra, 1992). Six studies about involuntary memories (IMs) were also not included, considering relevant differences with MW (Berntsen, 2009; Berntsen, Rubin, & Salgado, 2015). In sum, the majority of studies (see Supplemental Material for description) used as dependent measure task-unrelated thoughts (TUTs), daydreaming or MW, all representative of the MW experience as defined by Smallwood & Schooler (2006)[2]. The inter-coder agreement was very good (Cohen's *kappa* = .91, *SE* = .05). Disagreements were resolved by discussion between the two coders, with the input of a senior researcher, when needed.

[2]Although not mentioned by Smallwood and Schooler (2006), daydreaming is by definition also very similar to MW (Giambra, 2000a, p. 147) and has been considered akin to it (e.g., Krawietz et al., 2012).

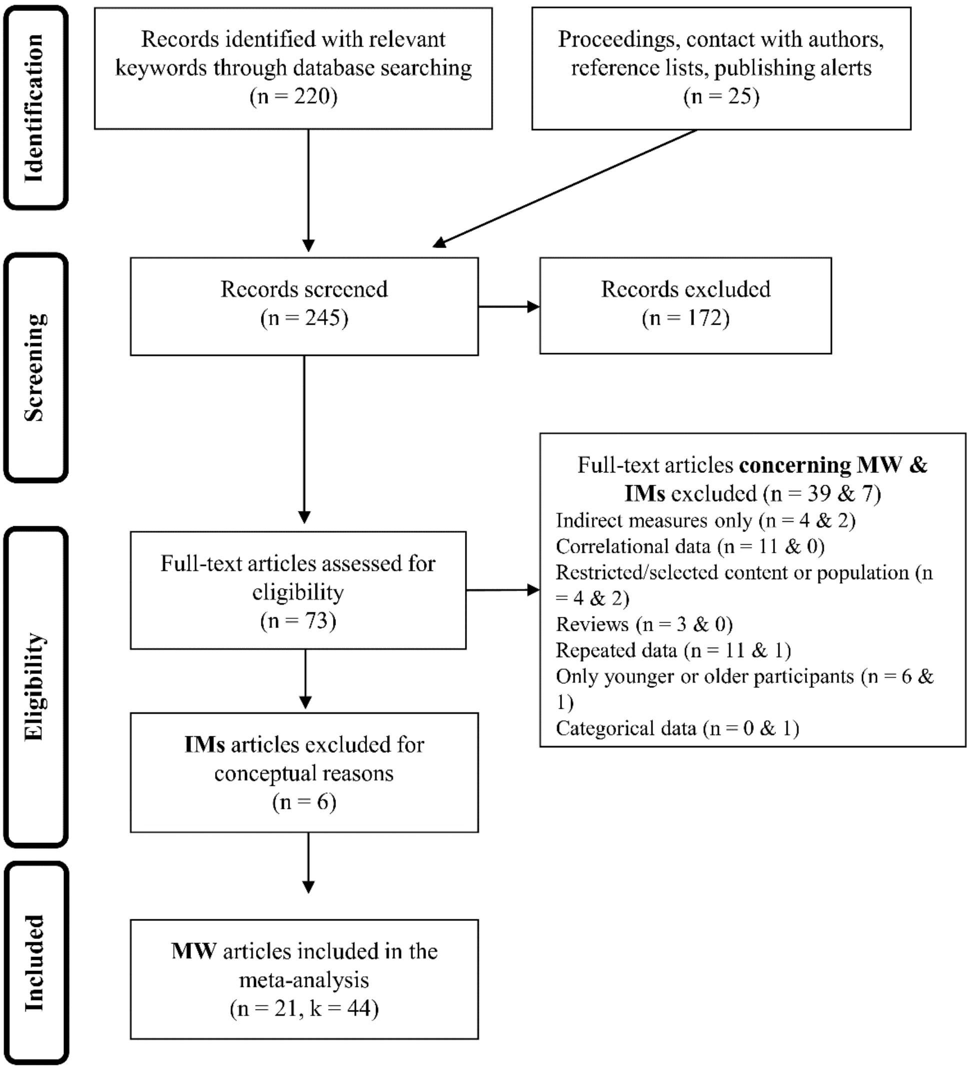

Figure 1.1. Flow chart for study inclusion.

Age-related Differences in MW Frequency

As can be seen in Figure 1.2, the average effect size analysis revealed a significant age-related decrease in MW frequency (k = 44, g = -0.89, 95% CI [-1.03, -0.75], Z = -12.32, p < .0001), considered to be a large effect (Cohen, 1988)[3].

[3]In Zavagnin et al. (2014) we did not include the Mind Wandering questionnaire because as described by the authors (pp. 57-58), it aimed at assessing "control failures” and "intrusive thoughts" (e.g., “how often do you put things in the wrong place?”; “sleep poorly at night because you keep thinking about something that is worrying you?”). We considered that the emphasis on failure and the intrusiveness distinguished this from other measures included in the meta-analysis. This decision did not changed the pattern of results, as confirmed by the overall effect size analysis including the questionnaire data, specifically, two additional dependent effect sizes

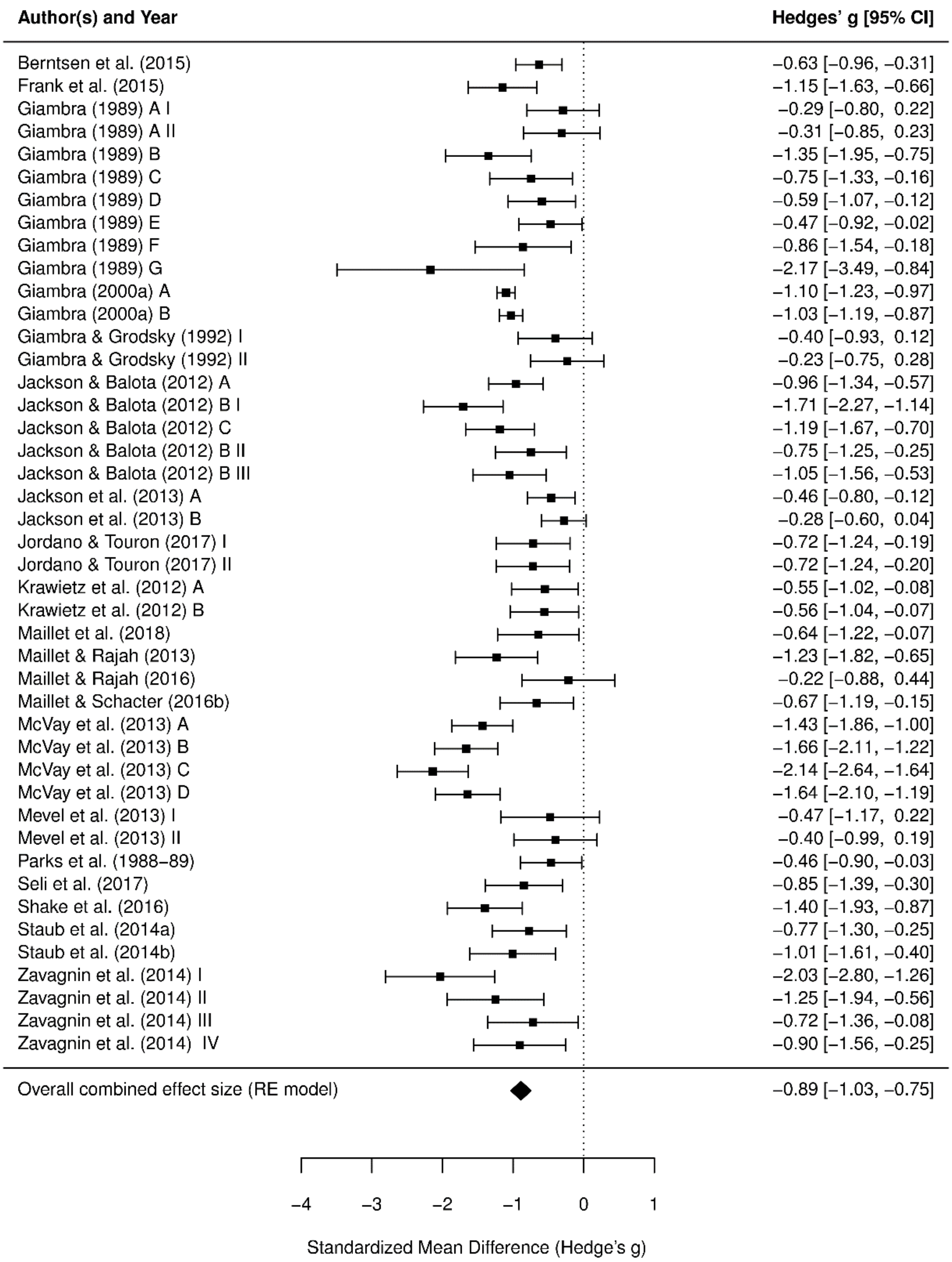

Figure 1.2. Forest plot representing all effect sizes included in the meta-analysis. In the references identification added capital letters and roman numerals represent independent and dependent effect sizes, respectively.

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comparing the young and the young-old and the young and the old-old groups (k = 46, g = -0.88, 95% CI [-1.02, -0.75], Z = -12.70, p < .0001).

The outliers analysis revealed that no individual effect size was more than three SDs away from the average effect size and no single case could alter the pattern of results, as assessed by the leave-one-out analysis. Thus, there was no evidence that the average effect size was influenced by extreme values. There was also no evidence of publication bias, as shown by convergent results from several analyses. Specifically, there was no clear asymmetry in the funnel plot (Figure 1.3), which is consistent with a non-significant Egger's Regression Test (z = -1.15, p = .25). Kendall's tau was also non-significant (-.11, p = .31) and the number of studies required to change the average effect size, as given by Rosenthal's fail-safe N test is 7296, again indicating that publication bias is unlikely in the present analysis. Finally, we assessed heterogeneity and found the sample was significantly heterogeneous, Q (df = 43) = 160.72, p < .0001, I^2 = 77.21%, justifying further moderator analysis.

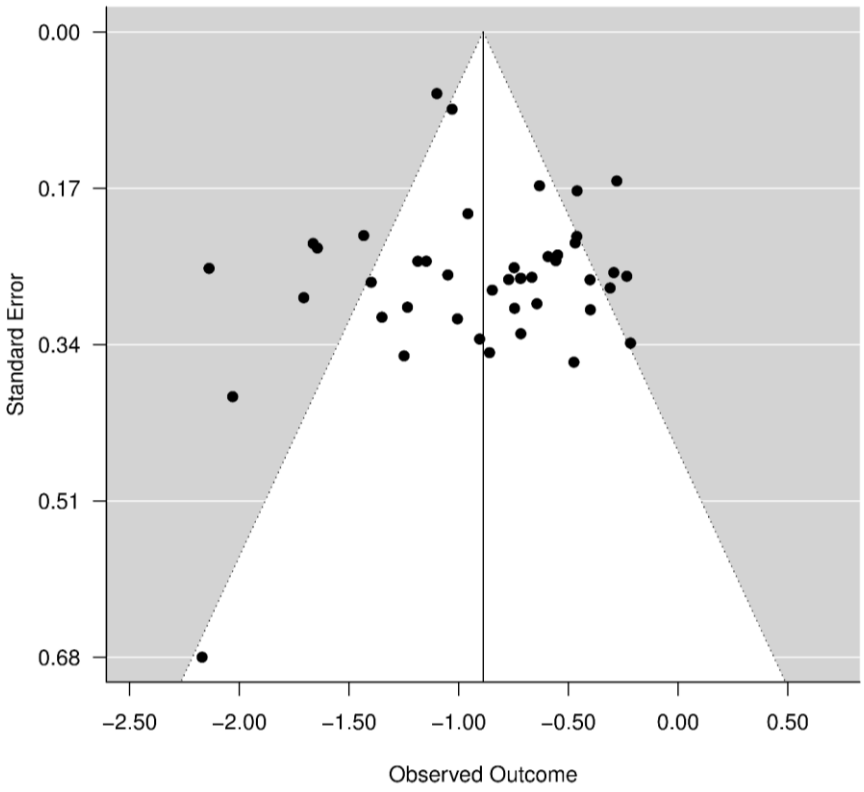

Figure 1.3. Funnel plot representing the dispersion of effect sizes for age-related differences in mind wandering frequency by standard error.

Moderator Analyses

A summary of the moderator analyses can be seen in Table 1.1 for categorical variables, and in Table 1.2 for continuous variables. Below we detail the results for significant moderators.

Methodological moderators. As reported in Table 1.1, we found a significant effect of reporting mode, which revealed that the MW age-related decrease was more pronounced in probe compared to self-caught reporting (g = -1.04 *vs* -0.48). There was also a significant effect of target proportion, as reported in Table 1.2, whereby the MW age-related decrease was more pronounced when there was a greater proportion of targets.

Moderator					Q_B	p_{QB}
	Level	*k*	Hedges' *g*	95% CI		
Reporting mode					6.63	.010
	Probe-caught	26	-1.04	[-1.26, -0.81]		
	Self-caught	8	-0.48	[-0.69, -0.26]		
Stimuli meaningfulness					2.08	.149
	Meaningful	19	-1.02	[-1.27, -0.75]		
	Not meaningful	19	-0.76	[-0.95, -0.58]		
Measure type					0.12	.726
	On-line	34	-0.91	[-1.10, -0.72]		
	Retrospective	10	-0.88	[-1.07, -0.69]		
TRI status					14.10	< .001
	Not mentioned	24	-0.71	[-0.86, -0.56]		
	Measured separately	9	-1.29	[-1.66, -0.91]		
ISI type					17.93	< .001
	With visual mask	6	-1.56	[-1.92, -1.20]		
	No visual mask	21	-0.76	[-0.93, -0.58]		

Table 1. Moderator analysis for categorical variables. TRI = Task-Related Interference; ISI = Inter-Stimuli Interval; k = number of samples; CI = confidence interval; Q_B = Cochran's measure of homogeneity between samples; p_{QB} = significance Q_B.

Sociodemographic moderators. As reported in Table 1.2, we found a significant moderation effect of the mean age of the older group, whereby the MW age-related decrease was more pronounced when the mean age of the older group was higher. Gender proportion differences also had a significant impact on age-related differences, specifically, the MW age-related decrease was less pronounced when the older adult groups included proportionally more women compared to younger groups.

Moderator	*k*	*b*	*z*	*p*
Stimulus time	26	0.0001	1.24	.215
ISI time	18	-0.0001	-.72	.469
Pace	23	-0.0014	-.20	.838
Target proportion	18	-4.24	-3.27	.001
Probe rate	8	-0.0019	-1.57	.117
Mean age of the older group	26	-0.0262	-3.26	.001
Mean education of the older group	26	0.0580	.65	.517
Gender proportion differences	29	0.9724	2.51	.012

Table 1.2. Moderator analysis for continuous variables. *k* = number of samples. Pace was defined as the number of stimuli presented per minute, calculated by dividing the total number of stimuli presented by the duration of the task (in minutes). Target proportion was calculated by dividing the total number of targets by the total number of stimuli. Probe rate consisted of the time between each probe, calculated by dividing the total time of the task (in seconds) by the number of probes. Gender proportion differences were based on subtracting younger from older group gender proportions, which were calculated by dividing the number of women by the total number of participants in each group.

Exploratory Analyses

As can be seen in Table 1.1, the MW age-related decrease was more pronounced when TRIs were measured separately compared to when they were not mentioned (*g* = -1.29 *vs* -0.71). We also found that presenting a visual mask in the ISI resulted in a more pronounced MW age-related decrease than not presenting a visual mask (*g* = -1.56 *vs* -0.76).

Given that several significant moderators were identified, we tested for possible confounds related to the interdependence between them. For categorical variables, we examined violations of independence by computing Fisher’s exact test and found a significant interaction between TRI status and ISI type (*p* = .021). This result refers to a subset of 23 effect sizes for which coding on both variables was applicable, and reflects the proportional tendency for studies in which TRI was measured separately to be also the studies in which a visual mask was included (4 in 6 cases). Conversely, studies in which TRI is not mentioned more frequently do not include a visual mask (15 in 17 cases). For continuous variables, we examined pair-wise non-parametric correlations and found no significant effects (all *p*s > .078). Finally, to test for confounds between categorical and continuous variables, we examined differences between the categories on each one of the continuous variables. However, the small number of studies precluded an adequate analysis in some cases. Namely, the analysis of target proportion and mean age of the older group by reporting mode included only 2 effect sizes for self-caught studies, the analysis of sex proportion differences by TRI status included only 2 effect sizes for studies measuring TRI separately and, finally, the analysis of mean age of the older group and sex proportion differences included only 2 effect sizes for studies using a visual mask. Thus, these results could not be interpreted. For the remaining combinations of categorical and continuous variables no effects were found (*p* > .156).

Regarding the significant interaction found between TRI status and ISI type, performing a hierarchical moderator analysis to clarify spurious effects in the present case was inadequate (due to the small number of studies, see Hunter & Schmidt, 2004, p. 424). However, a closer analysis of these variables provides additional information. Namely, almost all studies using a visual mask measure TRIs separately (4 in 6 studies), and thus the possibility that the effect on ISI type is driven by TRI status cannot be distinguished based on the present data. On the other hand, the effect of TRI status is found in a larger group of studies (33) in which only approximately half of the studies could be influenced by the ISI effect found (4 in 9 studies measuring TRIs separately include a visual mask, and 15 in 24 studies not mentioning TRIs do not include a visual mask). Thus, it seems unlikely that this effect can be fully atributed to its interdependence with ISI type.

Discussion

The MW literature indicates that there is an age-related decrease in the frequency of MW (Maillet & Schacter, 2016a), but has raised a number of questions regarding the nature of such differences. In this study, we analyzed the consistency and size of the age-related decrease in MW when comparing healthy younger and older adults. Importantly, we also identified key moderators of the age-related decrease in MW in order to improve our understanding of the processes that contribute to it and to inform the design of future experiments. Our findings show a large age-related decrease in MW frequency across a methodologically diverse group of studies. Additionally, a more pronounced age-related decrease was found when using probe compared to self-caught procedures, measuring TRIs separately, presenting visual masks, increasing target proportion, and as older participants and less women were included in older adults' groups. Below we discuss the main findings and their implications for future research.

Age-related Differences in Motivation and Reporting Mode

We found smaller age-related differences in MW in self than in probe-caught reporting (question 1), contrary to our predictions based on a possible age-related decline in meta-awareness (Maillet & Schacter, 2016a). How can this result be explained? One possibility is that it was influenced by the inclusion of a limited number of self-caught effect sizes. Alternatively, we suggest that the effect may rely on motivation. In fact, experimentally increasing motivation to accurately report MW in younger participants increases self but not probe-caught reporting (Zedelius, Broadway, & Schooler, 2015). More recently, increasing motivation of participants to perform well has been shown to influence probe-caught reporting in younger adults but in the opposite direction, by decreasing MW (Seli, Schacter, Risko, & Smilek, 2019). Note that in self but not in probe-caught procedures, monitoring one's thoughts is explicitly part of the task. As such, the higher levels of task motivation usually reported by older adults (e.g., Frank et al., 2015; Seli, Maillet, Smilek, Oakman, & Schacter, 2017) may result in contrary effects in self and probe-caught reporting, namely in self-caught experiments older adults may be more motivated to identify MW because reporting is part of the task. In probe-caught experiments the motivation is mainly directed at performing the task, which should increase on-task focus and reduce MW (Seli, Maillet, et al., 2017).

Although two recent studies have shown larger effect sizes in self compared to probe-caught measures (Jackson & Balota, 2012; Jackson et al., 2013), they do not preclude the motivation effect suggested here. First, in Jackson and Balota (2012), self and probe-caught procedures are used simultaneously in the same task, thus the impact of motivation should be similar in both measures. Second, in Jackson et al. (2013), task interest was greater for older adults in probe but not in the self-caught procedure, possibly due to less pronounced age differences related to the mean age of the older participants (around 57 years-old). Therefore, comparing these effects cannot inform us about the contrary effects of motivation on different reporting modes (as age-differences were found only for the probe-caught study).

The mechanisms underlying motivation effects on self and probe-caught MW also seem to differ. In probe-caught reporting the mechanism seems to be the decreased likelihood of MW when a motivated participant increases his/her on-task focus (Seli, Schacter, et al., 2019). This is consistent with evidence showing that probe-caught reporting is a reliable measure of MW (correlated with eye-movement, Frank et al., 2015), which is not the case for self-caught reporting (often unrelated with behavioral measures of MW, Smallwood, McSpadden, & Schooler, 2007, 2008). In fact, the mechanisms suggested to explain the impact of motivation in self-caught MW do not impact MW frequency itself but how it is reported. These include two possible candidates: increased meta-awareness and a bias for a more liberal interpretation of MW (Zedelius et al., 2015). Zedelius et al. found that incentives in self-caught reporting did not increase MW reports compared to incentives for accuracy, suggesting that greater meta-awareness is a more plausible mechanism to explain the impact of motivation than a bias to report more. Additionally, it has been shown that MW reporting is susceptible to participant interpretations of what it means to be on and off-task (Seli, Beaty, Cheyne, Smilek, & Schacter, 2018a). However, these effects have also been identified as affecting probe-caught procedures, which indicates that a bias to report more cannot explain a selective impact of motivation on self-caught reporting. Thus, an increase in meta-awareness based on motivation is a more plausible candidate to explain our results in self-caught procedures, and indicates that probe-caught reporting provides a more accurate measure of age-related differences in MW and should be preferred. Nevertheless, both methods may be influenced by older adults' higher motivation, that should be taken into account (e.g., controlled statistically) in future research. Additionally, the fact that meta-awareness is a more plausible mechanism to explain the impact of motivation in self-caught procedures does not exclude the possibility that biases in the interpretation of instructions influences both probe and self-caught reporting.

Requiring More Executive Resources Increases Age-related Differences

According to the context regulation hypothesis (Smallwood & Schooler, 2015), the age-related decrease in MW should be attenuated when demands are higher (question 2). However, higher demand as reflected by increased target proportion actually led to a more pronounced age-related decrease in MW frequency. This effect may be due to the impact of declining executive resources with aging (Braver & West, 2008) in MW continuity, which would make it particularly difficult to older adults to maintain a MW episode in high demand conditions. Another interpretation for the observed increase in age-differences when more executive resources are required is an impact of motivation. Older adults may feel more motivated in more demanding tasks, which would increase their on-task engagement and reduce MW (Seli, Schacter, et al., 2019)[4]. Although in other areas of cognitive aging older adults are typically less motivated to engage in demanding tasks (Hess, 2014), MW research has shown higher subjective levels of difficulty along with higher levels of task interest (see experiments 2 and 3 in Jackson & Balota, 2012). This possibility reinforces the importance of analyzing the impact of age-differences in motivation on MW frequency. Practically, this result suggest that more demanding tasks may particularly impede catching MW in older groups. Thus, future research aiming to analyze different varieties of MW and its characteristics may benefit from low demand tasks in order to catch a greater variability of MW (e.g., negative, neutral and positive thoughts about the past, present and future) for each participant.

Additionally, in an exploratory analysis, we found that visual masks led to a more pronounced age-related decrease in MW. We suggest that this effect may be due to the greater reliance of older adults on environmental stimuli (Lindenberger & Mayr, 2014). A visual mask can be considered a form of environmental distraction, disruptive to the internal train of thought that constitutes MW and that requires executive resources to be maintained (Smallwood, 2013). Thus, older adults may be particularly vulnerable to MW disruption when external information, such as a visual mask, is presented. However, it cannot yet be dismissed that the impact of visual masks result from the interdependence of this variable with TRI status. As studies including a visual mask more often also measure TRIs separately, it is uncertain to what extent the effect of visual mask is driven by differences in TRI, and the present result should be taken cautiously.

Response Options Bias Age-related Differences

We found that studies including a TRI response option showed a more pronounced age-related decrease than studies in which it was not mentioned, in line with the idea that at least part of the TRIs experienced are classified by participants as MW (Robison et al., 2019). When TRIs are measured in a separate category, the MW age-related decrease is more pronounced because older adults experience more TRIs misclassified as MW. Another interpretation is that including more response options increases task demand

[4] We thank Paul Seli for suggesting this possibility.

particularly for older adults. Following the idea that executive resources support MW continuity (Smallwood, 2013) that would lead to a more pronounced MW age-related decrease. Both of these possibilities highlight that the way participants are instructed to report MW is a key factor contributing to age-related differences. The open-ended reporting method has been suggested to be the most neutral way to measure MW because it requires participants to simply describe what is on their minds when probed (Weinstein, 2018). In fact, we recently found no evidence of age-related differences in MW frequency using an open-ended reporting method (Jordão, Pinho, & St. Jacques, 2019). The advantage of open-ended methods to measure self-generated thoughts has also been acknowledged (O'Callaghan & Irish, 2018) and validated in cases of cognitive decline (Niedźwieńska & Kvavilashvili, 2018; O'Callaghan, Shine, Lewis, Andrews-Hanna, & Irish, 2015). Additionally, recent research (Jordano & Touron, 2018) highlights the need to explore the content of TRI to better understand age-differences in spontaneous monitoring, which is made possible by analyzing participants' descriptions of their MW experiences. However, several disadvantages should also be considered when using open-ended reports, namely: (1) participants may report less because it is harder and/or takes more time to report compared to forced-choice probes, or (2) because they feel embarrassed to share personal thoughts; and (3) these methods may be more difficult to use along with other objective measures and techniques (e.g., neuroimaging). Some strategies may diminish the impact of these disadvantages, such as asking participants to describe their thoughts out loud to an audio recorder instead of writing them, in order to make reporting less effortful (as in Niedźwieńska & Kvavilashvili, 2018; O'Callaghan, et al., 2015). Unfortunatelly, this may increase bias related with social desirability that impact older adults in particular (Soubelet & Salthouse, 2011). This bias may be reduced by asking participants to skip the description when they feel the subject is too personal (following previous research in autobiographical memory, Berntsen & Rubin, 2002, and involuntary autobiographical memory, Schlagman, Kvavilashvili, & Schulz, 2008). Although here the experimenter has no direct access to the content of the thought, this would prevent the misclassification of these cases as on-task thought.

Given the above mentioned disadvantages, why would open-ended methods be a preferable option to investigate MW in aging? This question is particularly relevant considering that combining thought categories with objective measures has been shown to be a valid method with both younger and older adults (e.g., Frank et al., 2015). The problem with this approach is that, when finding age-differences for thought categories in objective measures, it is not possible to determine if they are due to age-differences in the MW process or in thought categorization (as other authors have pointed out, Frank et al., 2015, p. 276). One way to deal with this issue would be to ask participants for open-ended reports and thought categories classifications, simultaneously. Then, independent coders would be able to assess inconsistencies on participants' categorizations. Identifying such issues would provide a way to adapt the task (e.g., include clearer examples of what is usually misclassified by participants) and, once the inconsistencies are solved, possibly drop the open-ended description. In this sense, open-ended reporting methods seem to be a necessary step to better understand MW in aging, by allowing to clarify age-differences in how participants classify their MW experiences.

Age and Gender-Related Differences Confounds

The significant moderation of the mean age the older group (question 5) indicates that having broad age ranges in older groups confounds age comparisons with younger adults in MW. This result may be interpreted in line with the need of executive resources to maintain MW: as age increases, participants are more likely to have depleted executive resources, impairing MW continuity and increasing differences compared to young adults (see Gyurkovics, Balota, and Jackson, 2018, for a similar interpretation). Alternatively, this may also result from motivation, considering that task interest has been shown to increase in old-old compared to young-old participants (Gyurkovics, et al., 2018). If motivation is higher as the age of the older group increases, this would also lead to an increase in on-task engagement and MW reduction (Seli, Schacter, et al., 2019)[5]. It should be noted that although the present effect suggests differences only in degree, further changes in young-old and old-old adults emerge when task demand and, particularly, task performance indices are considered, as MW seems to be less frequent but more detrimental with increased age (Zavagnin et al., 2014). Future experiments should thus be aware of possible quantitative and qualitative differences in the MW processes of young-old and old-old adults.

Additionally, we found that when there are proportionally more women in older groups the age-related decrease in MW frequency is less pronounced (question 7), as expected based on daydreaming research showing greater frequency in women across the lifespan (Giambra, 2000a). A possible reason for these differences is, again, response

[5] We thank Paul Seli for suggesting this possibility.

bias, as women have been shown to be more willing to provide information about themselves in daydreaming self-reports and are more acceptant of these experiences (Giambra, 2000b). This result highlights the relevance of having similar gender proportions in the age groups being compared.

Limitations

Our results are limited by the small number of studies in some significant moderators that constrained the assessment of interdependence. Some of the null effects in variables of interest (questions 3, 4 and 6, e.g., on-line *vs* retrospective measure, education level of the older group), may also be due to an insufficient number of cases.

Additionally, the present meta-analysis followed a broad view of MW (Smallwood, 2006) instead of ensuring the same specific MW variety was included in the studies, as recommended in recent literature (Seli et al., 2018). Our approach follows from the evolution of the field itself, that only relatively recently started to include more specific MW categories. Thus, by choosing a more broad view of MW we avoided excluding a considerable part of the prior research. Although this is a possible source of heterogeneity between studies, the strength and consistency of the effect found indicate it does not hinder the main analysis. Furthermore, within the constraints of the present studies, we addressed the impact of considering different MW varieties, namely by analyzing the impact of clearly distinguishing TRI.

Another limitation is that naturalistic and lab-based studies could not be compared (only one naturalistic study was found, Maillet et al., 2018). Given recent research showing different correlates of MW in naturalistic versus lab contexts (Kane et al., 2017), one caveat of our conclusions is that they may not always apply to age-related differences in daily-life. Still, the present results seem worth considering as there is no apparent reason why biases related with the interpretation of response options, as the ones we highlight, would not impact reporting in naturalistic contexts. For example, Maillet et al. (2018) found the age-related decrease in MW using an experience-sampling procedure in which participants were probed using a yes/no on-task response. However, daily-life MW estimates have recently been shown to vary considerably if younger participants are provided with a dichotomous or multi-level probe (Seli et al., 2018a), suggesting that the on/off-task experience is not naturally dichotomous. Instead, it seems like the dichotomous response depends on a decision process based on participants' interpretation of what means to be on/off-task. The possible influence of aging in that process and other types of response bias cannot yet be dismissed and await future research. In summary, despite some limitations, the present results align with recent MW research and provide useful recommendations for future research.

Conclusions

We conducted a meta-analysis on age-related difference in MW frequency and found a reliable decrease with age. The effect was influenced by methodological differences in reporting mode and response options, suggesting that previous research demonstrating age-related decreases in MW may have been biased by age-related differences in motivation and participants' interpretation of their experience (in line with recent MW research, Seli et al., 2018a; Weinstein, 2018; Weinstein et al., 2018). Practically, it should be considered that self-caught methods may be particularly susceptible to the impact of motivation. Probe-caught methods seem to represent the MW experience more accurately but these too may be influenced by age-related differences in motivation that should be examined in future experiments (e.g., controlled statistically). A more pronounced age-related decrease in MW frequency with higher task demands suggests that it may be more difficult to catch a considerable amount of MW with older adults in those conditions. Low demand tasks may thus be particularly useful to collect and analyze specific types of MW (e.g., stimulus-dependent vs independent, of different temporal-orientations) and compare them within participants. Additionally, open-ended procedures are emphasized for providing control for interpretation bias and allowing to analyze quantitative as well as relevant qualitative age-related differences in MW (e.g., in specificity, as in McCormick, Ciaramelli, De Luca, & Maguire, 2018, for patients with hippocampal damage). It is also recommended that future experiments include older adults of limited age ranges and similar gender proportions between age groups, in order to avoid potential confounds. Finally, given the sources of possible bias identified, the degree to which older adults may be affected by negative consequences of reduced MW frequency, like decreased spontaneous future planning, is still uncertain and awaits further research.

References

*References marked with an asterisk indicate studies included in the meta-analysis.

Antrobus, J. S., Singer, J. L., Goldstein, S., & Fortgang, M. (1970). Mindwandering and cognitive structure. *Transactions of the New York Academy of Sciences, 32*, 242-252. doi:10.1111/j.2164-0947.1970.tb02056.x

Baird, B., Smallwood, J., Mrazek, M. D., Kam, J. W. Y., Franklin, M. S., & Schooler, J. W. (2012). Inspired by distraction: Mind wandering facilitates creative incubation. *Psychological Science, 23*(10), 1117-1122. doi:10.1177/0956797612446024

Berntsen, D. (2009). *Involuntary autobiographical memories: An introduction to the unbidden past*. Cambridge: Cambridge University Press.

Berntsen, D., & Rubin, D. C. (2002). Emotionally charged autobiographical memories across the life span: The recall of happy, sad, traumatic and involuntary memories. *Psychology and Aging, 17*(4), 636-652. doi:10.1037/0882-7974.17.4.636

*Berntsen, D., Rubin, D. C., & Salgado, S. (2015). The frequency of involuntary autobiographical memories and future thoughts in relation to daydreaming, emotional distress, and age. *Consciousness and Cognition, 36*, 352-372. doi:10.1016/j.concog.2015.07.007

Borella, E., Carretti, B., & De Beni, R. (2008). Working memory and inhibition across the adult life-span. *Acta Psychologica, 128*(1), 33-44. doi:10.1016/j.actpsy.2007.09.008

Braver, T. S., & West, R. (2008). Working memory, executive control, and aging. In F. I. M. Craik & T. A. Salthouse (Eds.), *The handbook of aging and cognition* (3rd ed., Vol. 3, pp. 311-372). New York, NY: Psychology Press.

Callard, F., Smallwood, J., Golchert, J., & Margulies, D. S. (2013). The era of the wandering mind? Twenty-first century research on self-generated mental activity. *Frontiers in Psychology, 4*, 891. doi:10.3389/fpsyg.2013.00891

Christoff, K., Irving, Z. C., Fox, K. C. R., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: A dynamic framework. *Nature Reviews Neuroscience, 17*, 718-731. doi:10.1038/nrn.2016.113

Cochran, W. G. (1954). The combination of estimates from different experiments. *Biometrics, 10*, 101-129. doi:10.2307/3001666

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, N.J.: L. Erlbaum Associates.

Enns, J. T., & Di Lollo, V. (2000). What's new in visual masking? *Trends in Cognitive Sciences, 4*(9), 345-352. doi:10.1016/S1364-6613(00)01520-5

Ferreira-Santos, F. (2018). *Meta-analysis of correlated designs (repeated measures) in the context of neural responses to facial expressions of emotion.* SAGE Research Methods Cases. Thousand Oaks, CA: Sage Publications. doi:10.4135/9781526434180

*Frank, D. J., Nara, B., Zavagnin, M., Touron, D. R., & Kane, M. J. (2015). Validating older adults' reports of less mind-wandering: An examination of eye movements and dispositional influences. *Psychology and Aging, 30*(2), 266-278. doi:10.1037/pag0000031

*Giambra, L. M. (1989). Task-unrelated thought frequency as a function of age: A laboratory study. *Psychology and Aging, 4*(2), 136-143. doi:10.1037/0882-7974.4.2.136

Giambra, L. M. (1993). The influence of aging on spontaneous shifts of attention from external stimuli to the contents of consciousness. *Experimental Gerontology, 28*(4), 485-492. doi:10.1016/0531-5565(93)90073-M

*Giambra, L. M. (2000a). Daydreaming characteristics across the life-span: Age differences and seven to twenty year longitudinal changes. In R. G. Kunzendorf & B. Wallace (Eds.), *Advances in consciousness research: Vol. 20. Individual differences in conscious experience* (pp. 147-206). Amsterdam, Netherlands: John Benjamins Publishing Company.

Giambra, L. M. (2000b). Frequency and intensity of daydreaming: Age changes and age differences from late adolescent to the old-old. *Imagination, Cognition and Personality, 19*(3), 229-267. doi:10.2190/XN4W-1CRE-B0MH-84XT

*Giambra, L. M., & Grodsky, A. (1992). The influence of age on the frequency of spontaneous task-unrelated thought intrusions during reading. *Imagination, Cognition and Personality, 11*(4), 367-379. doi:10.2190/7xf1-7ra4-vc95-qk5h

Gyurkovics, M., Balota, D. A., & Jackson, J. D. (2018). Mind-wandering in healthy aging and early stage Alzheimer's disease. *Neuropsychology, 32*(1), 89-101. doi:10.1037/neu0000385

Hedges, L. V., Tipton, E., & Johnson, M. C. (2010). Robust variance estimation in meta-regression with dependent effect size estimates. *Research Synthesis Methods, 1*(1), 39-65. doi:doi:10.1002/jrsm.5

Hess, T. M. (2014). Selective engagement of cognitive resources: Motivational influences on older adults' cognitive functioning. *Perspectives on Psychological Science, 9*(4), 388-407. doi:10.1177/1745691614527465

Higgins, J. P. T., & Green, S. (2011). *Cochrane handbook for systematic reviews of interventions Version 5.1.0.* Retrieved from www.handbook.cochrane.org

Higgins, J. P. T., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analyses. *BMJ, 327*(7414), 557-560. doi:10.1136/bmj.327.7414.557

Hunter, J. E., & Schmidt, F. L. (2004). *Methods of meta-analysis: Correcting error and bias in research findings* (2nd ed.). Thousand Oaks, CA: SAGE Publications.

*Jackson, J. D., & Balota, D. A. (2012). Mind-wandering in younger and older adults: Converging evidence from the sustained attention to response task and reading for comprehension. *Psychology and Aging, 27*(1), 106-119. doi:10.1037/a0023933

*Jackson, J. D., Weinstein, Y., & Balota, D. A. (2013). Can mind-wandering be timeless? Atemporal focus and aging in mind-wandering paradigms. *Frontiers in Psychology, 4*. doi:10.3389/fpsyg.2013.00742

*Jordano, M. L., & Touron, D. R. (2017). Stereotype threat as a trigger of mind-wandering in older adults. *Psychology and Aging, 32*(3), 307-313. doi:10.1037/pag0000167

Jordano, M. L., & Touron, D. R. (2018). How often are thoughts metacognitive? Findings from research on self-regulated learning, think-aloud protocols, and mind-wandering. *Psychonomic Bulletin & Review, 25,* 1269–1286. doi:10.3758/s13423-018-1490-1

Jordão, M., Pinho, M. S., & St. Jacques, P. L. (2019). Inducing spontaneous future thoughts in younger and older adults by priming future-oriented personal goals. *Psychological Research, 83*(4), 710-726. doi:10.1007/s00426-019-01146-w

Kane, M. J., Gross, G. M., Chun, C. A., Smeekens, B. A., Meier, M. E., Silvia, P. J., & Kwapil, T. R. (2017). For whom the mind wanders, and when, varies across laboratory and daily-life settings. *Psychological Science, 28*(9), 1271-1289. doi:10.1177/0956797617706086

Killingsworth, M. A., & Gilbert, D. T. (2010). A wandering mind is an unhappy mind. *Science, 330*(6006), 932-932. doi:10.1126/science.1192439

Klinger, E. (1975). Consequences of commitment to and disengagement from incentives. *Psychological Review, 82*(1), 1-25. doi:10.1037/h0076171

*Krawietz, S. A., Tamplin, A. K., & Radvansky, G. A. (2012). Aging and mind wandering during text comprehension. *Psychology and Aging, 27*(4), 951-958. doi:10.1037/a0028831

Levinson, D. B., Smallwood, J., & Davidson, R. J. (2012). The persistence of thought: Evidence for a role of working memory in the maintenance of task-unrelated thinking. *Psychological Science, 23*(4), 375-380. doi:10.1177/0956797611431465

Lindenberger, U., & Mayr, U. (2014). Cognitive aging: Is there a dark side to environmental support? *Trends in Cognitive Sciences, 18*(1), 7-15. doi:10.1016/j.tics.2013.10.006

Lipsey, M. W., & Wilson, D. B. (2001). *Practical meta-analysis*. Thousand Oaks, CA, US: Sage Publications, Inc.

Lustig, C., Hasher, L., & Zacks, R. T. (2007). Inhibitory deficit theory: Recent developments in a "new view". In D. S. Gorfein & C. M. MacLeod (Eds.), *Inhibition in cognition.* (pp. 145-162). Washington, DC, US: American Psychological Association.

*Maillet, D., Beaty, R., Jordano, M., Touron, D., Adnan, A., Silvia, P., . . . Kane, M. (2018). Age-related differences in mind-wandering in daily life. *Psychology and Aging, 33*(4), 643-653. doi:10.1037/pag0000260

*Maillet, D., & Rajah, M. N. (2013). Age-related changes in frequency of mind-wandering and task-related interferences during memory encoding and their impact on retrieval. *Memory, 21*(7), 818-831. doi:10.1080/09658211.2012.761714

*Maillet, D., & Rajah, M. N. (2016). Assessing the neural correlates of task-unrelated thoughts during episodic encoding and their association with subsequent memory in young and older adults. *Journal of Cognitive Neuroscience, 28*(6), 826-841. doi:10.1162/jocn_a_00935

Maillet, D., & Schacter, D. L. (2016a). From mind wandering to involuntary retrieval: Age-related differences in spontaneous cognitive processes. *Neuropsychologia, 80*, 142-156. doi:10.1016/j.neuropsychologia.2015.11.017

*Maillet, D., & Schacter, D. L. (2016b). When the mind wanders: Distinguishing stimulus-dependent from stimulus-independent thoughts during incidental encoding in young and older adults. *Psychology and Aging, 31*(4), 370-379. doi:10.1037/pag0000099

McCormick, C., Ciaramelli, E., De Luca, F., & Maguire, E. A. (2018). Comparing and contrasting the cognitive effects of hippocampal and ventromedial prefrontal cortex damage: A review of human lesion studies. *Neuroscience, 374*, 295-318. doi:10.1016/j.neuroscience.2017.07.066

McVay, J. C., & Kane, M. J. (2010). Does mind wandering reflect executive function or executive failure? Comment on Smallwood and Schooler (2006) and Watkins (2008). *Psychological Bulletin, 136*(2), 188-207. doi:10.1037/a0018298

*McVay, J. C., Meier, M. E., Touron, D. R., & Kane, M. J. (2013). Aging ebbs the flow of thought: Adult age differences in mind wandering, executive control, and self-evaluation. *Acta Psychologica, 142*(1), 136-147. doi:10.1016/j.actpsy.2012.11.006

Meier, M. E. (2019). Is There a Positive Association Between Working Memory Capacity and Mind Wandering in a Low-Demand Breathing Task? A Preregistered Replication of a Study by Levinson, Smallwood, and Davidson (2012). *Psychological Science, 30*(5), 789–797. doi:10.1177/0956797619837942

*Mevel, K., Landeau, B., Fouquet, M., La Joie, R., Villain, N., Mézenge, F., . . . Chételat, G. (2013). Age effect on the default mode network, inner thoughts, and cognitive abilities. *Neurobiology of Aging, 34*(4), 1292-1301. doi:10.1016/j.neurobiolaging.2012.08.018

Mooneyham, B. W., & Schooler, J. W. (2013). The costs and benefits of mind-wandering: A review. *Canadian Journal of Experimental Psychology, 67*(1), 11-18. doi:10.1037/a0031569

Niedźwieńska, A., & Kvavilashvili, L. (2018). Reduced mind-wandering in mild cognitive impairment: Testing the spontaneous retrieval deficit hypothesis. *Neuropsychology, 32*(6), 711-723. doi:10.1037/neu0000457

O'Callaghan, C., & Irish, M. (2018). Candidate mechanisms of spontaneous cognition as revealed by dementia syndromes. In K. Christoff & K. C. R. Fox (Eds.), *The Oxford handbook of spontaneous thought: Mind-wandering, creativity, dreaming, and clinical disorders* (pp. 493-508). New York: Oxford University Press.

O'Callaghan, C., Shine, J. M., Lewis, S. J. G., Andrews-Hanna, J. R., & Irish, M. (2015). Shaped by our thoughts – A new task to assess spontaneous cognition and its associated neural correlates in the default network. *Brain and Cognition, 93,* 1-10. doi:10.1016/j.bandc.2014.11.001

*Parks, C. W., Klinger, E., & Perlmutter, M. (1989). Dimensions of thought as a function of age, gender and task difficulty. *Imagination, Cognition and Personality, 8*(1), 49-62. doi:10.2190/M6GA-J94F-VRV1-77DR

Purifoy, F. E., Grodsky, A., & Giambra, L. M. (1992). The relationship of sexual daydreaming to sexual activity, sexual drive, and sexual attitudes for women across the life-span. *Archives of Sexual Behavior, 21*(4), 369-385. doi:10.1007/bf01542026

Robison, M. K., Miller, A. L., & Unsworth, N. (2019). Examining the effects of probe frequency, response options, and framing within the thought-probe method. *Behavior Research Methods*, 1-11. doi:10.3758/s13428-019-01212-6

Salthouse, T. A. (2010). *Major issues in cognitive aging*. New York: Oxford University Press.

Schlagman, S., Kvavilashvili, L., & Schulz, J. (2008). Effects of age on involuntary autobiographical memories. In J. H. Mace (Ed.), *Involuntary memory* (pp. 87-112). New York: Blackwell.

Seli, P., Beaty, R. E., Cheyne, J. A., Smilek, D., & Schacter, D. L. (2018a). How pervasive is mind wandering, really? *Consciousness and Cognition, 66*, 74-78. doi:10.1016/j.concog.2018.10.002

Seli, P., Kane, M. J., Smallwood, J., Schacter, D. L., Maillet, D., Schooler, J. W., & Smilek, D. (2018b). Mind-wandering as a natural kind: A family-resemblances view. *Trends in Cognitive Sciences, 22*(6), 479-490. doi:10.1016/j.tics.2018.03.010

*Seli, P., Maillet, D., Smilek, D., Oakman, J. M., & Schacter, D. L. (2017). Cognitive aging and the distinction between intentional and unintentional mind wandering. *Psychology and Aging, 32*(4), 315-324. doi:10.1037/pag0000172

Seli, P., Schacter, D. L., Risko, E. F., & Smilek, D. (2019). Increasing participant motivation reduces rates of intentional and unintentional mind wandering. *Psychological Research*, *83*(5), 1057–1069. doi:10.1007/s00426-017-0914-2

*Shake, M. C., Shulley, L. J., & Soto-Freita, A. M. (2016). Effects of individual differences and situational features on age differences in mindless reading. *The Journals of Gerontology: Series B, 71*(5), 808-820. doi:10.1093/geronb/gbv012

Smallwood, J. (2013). Distinguishing how from why the mind wanders: A process–occurrence framework for self-generated mental activity. *Psychological Bulletin, 139*(3), 519-535. doi:10.1037/a0030010

Smallwood, J., McSpadden, M., & Schooler, J. W. (2007). The lights are on but no one's home: Meta-awareness and the decoupling of attention when the mind wanders. *Psychonomic Bulletin & Review, 14*(3), 527-533. doi:10.3758/bf03194102

Smallwood, J., McSpadden, M., & Schooler, J. W. (2008). When attention matters: The curious incident of the wandering mind. *Memory and Cognition, 36*(6), 1144-1150. doi:10.3758/mc.36.6.1144

Smallwood, J., Nind, L., & O'Connor, R. C. (2009). When is your head at? An exploration of the factors associated with the temporal focus of the wandering mind. *Consciousness and Cognition, 18*(1), 118-125. doi:10.1016/j.concog.2008.11.004

Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin, 132*(6), 946-958. doi:10.1037/0033-2909.132.6.946

Smallwood, J., & Schooler, J. W. (2015). The science of mind wandering: Empirically navigating the stream of consciousness. *Annual Review of Psychology, 66*(1), 487-518. doi:10.1146/annurev-psych-010814-015331

Soubelet, A., & Salthouse, T. A. (2011). Influence of social desirability on age differences in self-reports of mood and personality. *Journal of Personality, 79*(4), 741-762. doi:10.1111/j.1467-6494.2011.00700.x

*Staub, B., Doignon-Camus, N., Bacon, E., & Bonnefond, A. (2014a). Investigating sustained attention ability in the elderly by using two different approaches: Inhibiting ongoing behavior versus responding on rare occasions. *Acta Psychologica, 146*, 51-57. doi:10.1016/j.actpsy.2013.12.003

*Staub, B., Doignon-Camus, N., Bacon, É., & Bonnefond, A. (2014b). The effects of aging on sustained attention ability: An ERP study. *Psychology and Aging, 29*(3), 684-695. doi:10.1037/a0037067

Thomson, D. R., Besner, D., & Smilek, D. (2015). A resource-control account of sustained attention: Evidence from mind-wandering and vigilance paradigms. *Perspectives on Psychological Science, 10*(1), 82-96. doi:10.1177/1745691614556681

Unsworth, N., & McMillan, B. D. (2013). Mind wandering and reading comprehension: Examining the roles of working memory capacity, interest, motivation, and topic experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 39*(3), 832-842. doi:10.1037/a0029669

van Hooren, S. A. H., Valentijn, A. M., Bosma, H., Ponds, R. W. H. M., van Boxtel, M. P. J., & Jolles, J. (2007). Cognitive functioning in healthy older adults aged 64–81: A cohort study into the effects of age, sex, and education. *Aging, Neuropsychology, and Cognition, 14*(1), 40-54. doi:10.1080/138255890969483

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software, 36*(3), 1-48. http://www.jstatsoft.org/v36/i03/

Vigil-Colet, A., Morales-Vives, F., & Lorenzo-Seva, U. (2013). How social desirability and acquiescence affect the age-personality relationship. *Psicothema, 25*(3), 342-348. doi:10.7334/psicothema2012.297

Weinstein, Y. (2018). Mind-wandering, how do I measure thee with probes? Let me count the ways. *Behavior Research Methods, 50*(2), 642–661. doi:10.3758/s13428-017-0891-9

Weinstein, Y., De Lima, H. J., & van der Zee, T. (2018). Are you mind-wandering, or is your mind on task? The effect of probe framing on mind-wandering reports. *Psychonomic Bulletin & Review, 25*(2), 754-760. doi:10.3758/s13423-017-1322-8

*Zavagnin, M., Borella, E., & De Beni, R. (2014). When the mind wanders: Age-related differences between young and older adults. *Acta Psychologica, 145*, 54-64. doi:10.1016/j.actpsy.2013.10.016

Zedelius, C. M., Broadway, J. M., & Schooler, J. W. (2015). Motivating meta-awareness of mind wandering: A way to catch the mind in flight? *Consciousness and Cognition*, *36*, 44-53. doi:10.1016/j.concog.2015.05.016

Study 2. Inducing spontaneous future thoughts in younger and older adults by priming future-oriented personal goals

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Spontaneous thought has generally been defined as a class of mental contents that arises without intention and effort (Christoff, 2012). In the last 15 years, the study of spontaneous thoughts has been developing along with mind wandering research (Callard, Smallwood, Golchert, & Margulies, 2013), which refers to a shift of attention from an external task to internal thoughts and includes concepts like stimulus-independent thought and daydreaming (Smallwood & Schooler, 2006). Although mind wandering is not necessarily initiated spontaneously (as recently discussed by Seli, Risko, & Smilek, 2016), establishing connections between research on mind wandering and spontaneous thought has proved fruitful (e.g., Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016). One important development in this area is the analysis of spontaneous thoughts elicited in the laboratory and their past and future temporal orientation. Following on the idea that remembering the past and imagining the future rely on common constructive processes, such as scene construction (Hassabis & Maguire, 2007) and the recombination of episodic elements (Schacter & Addis, 2007), a number of researchers have explored the similarities and differences between past and future thoughts. In voluntary retrieval, a diverse body of data has shown that similar processes are engaged to navigate the past and the future (for a review see e.g., Schacter et al., 2012). In contrast, there are relatively fewer studies examining the relationship between past and future thoughts during involuntary retrieval (Berntsen & Jacobsen, 2008; Berntsen, Rubin, & Salgado, 2015; Cole & Berntsen, 2016; Cole, Staugaard, & Berntsen, 2016; Finnbogadóttir & Berntsen, 2011; Finnbogadóttir & Berntsen, 2013; Plimpton, Patel, & Kvavilashvili, 2015; Vannucci, Pelagatti, & Marchetti, 2017). Yet, understanding the link between the past and future within spontaneous thoughts is critical to understand, for example, how effortful or automatic the common processes between remembering and imagining are. This question is particularly important regarding age differences, considering that as age increases effortful processes are more difficult to mobilize, but automatic processes seem relatively unaffected (e.g., Balota, Dolan, & Duchek, 2000). For example, Schlagman, Kliegel, Schulz, and Kvavilashvili (2009) demonstrated an age-related decrease in the specificity of autobiographical memories for voluntary but not involuntary retrieval. Thus, the construction of past episodes under involuntary retrieval conditions seems to attenuate the typical age-related reduction in the number of episodic details in autobiographical memories under voluntary retrieval conditions (e.g., St. Jacques & Levine, 2007).

In the current study we focus on how the elicitation of spontaneous future thoughts (SFTs) in the lab can be enhanced. The development of such lab-based methods is important because it enables, for example, the ability to collect neuroimaging data and analyze neural correlates of spontaneous thoughts (e.g., Hall et al., 2014; O'Callaghan, Shine, Lewis, Andrews-Hanna, & Irish, 2015). We focused on two main issues with previous lab-based methods: the past-oriented bias of spontaneous thoughts and the decreased frequency of spontaneous thoughts in older compared to younger adults. Spontaneous thoughts elicited in lab paradigms have used verbal cues, such as meaningful words or word-phrases (Plimpton et al., 2015; Vannucci et al., 2017), and thoughts directly elicited by verbal cues are more frequently about the past than the future (Maillet, Seli, & Schacter, 2017). In contrast, when the temporal orientation of spontaneous thoughts is examined in naturalistic settings, future thoughts are reported more frequently than the past (e.g., Song & Wang, 2012, for a review see Smallwood & Schooler, 2015). These findings suggest that current lab-based methods may underrepresent the natural frequency of SFTs. The temporal bias of spontaneous thoughts towards the past seems to be specifically related to the inclusion of verbal cues in lab-based studies, as shown by comparing elicitation tasks in which they are present or absent (Vannucci et al., 2017). Despite this bias in the temporal-orientation of spontaneous thoughts, the inclusion of verbal cues is important for at least two reasons. First, because using verbal cues increases the frequency of elicited thoughts when compared to using no cues (Vannucci et al., 2017) or pictorial cues (Mazzoni, Vannucci, & Batool, 2014). Second, the inclusion of verbal cues is critical for eliciting spontaneous thoughts in older adults because they report more frequent thoughts triggered by meaningful cues (Maillet & Schacter, 2016b), as a result of an increased reliance on environmental support (e.g., Craik, 1986). Thus, the ability to induce SFTs with verbal cues is particularly relevant when examining age-related differences in the frequency of SFTs, and may help to resolve mixed findings in the literature (e.g., Jackson, Weinstein, & Balota, 2013). Additionally, we focused on key methodological factors that have been suggested to explain why older adults usually report less mind wandering and spontaneous thought than younger adults (Maillet & Schacter, 2016a). Controlling for these possible sources of bias is, again, important to provide a more accurate assessment of the age-related differences.

In sum, the aim of the present study was to develop a priming methodology to better elicit SFTs in the laboratory, and then to use this methodology to reconcile age-related differences in SFTs. The analysis of possible age-related differences in SFTs is important also in practice, considering its adaptive role, for example, in goal planning (e.g., Klinger, Koster, & Marchetti, 2018).

Priming Spontaneous Thoughts

Evidence on how SFTs can be primed comes from three main areas of research: (1) priming specific contents in involuntary autobiographical memories by using voluntary recall, (2) increasing mind wandering frequency by priming current concerns, and (3) the relation between personal goals and future thoughts.

Priming effects for involuntary autobiographical memories were first shown by Mace (2005) using voluntary retrieval of past events. Young adults were asked to record their involuntary memories in a diary during a period of two weeks, as well as to voluntarily recall memories from different time periods (e.g., high-school, 13 to 16 years-old, recent year) midway through the diary recording. There was an increase in involuntary autobiographical memories related to the time-period primed when compared to a control condition in which a different time-period was primed, suggesting that the voluntarily recall of memories influenced the content of subsequent involuntary autobiographical memories. Recently, Barzykowski and Niedźwieńska (2018) showed that the priming effect in high-school memories is not specific to the diary methodology but also replicates in a lab task. The priming effect on involuntary autobiographical memories depends upon spreading activation in the autobiographical memory system, which is proposed to be a key mechanism that underlies how memories come to conscious awareness unintentionally (Mace, 2010). However, voluntary remembering is not necessarily the only way to prime involuntary retrieval of autobiographical memories. Following evidence that goal-derived categories prime voluntary autobiographical memories (Conway, 1990), Mace (2005) suggested that goal-related concepts may also induce the spreading activation within the autobiographical memory system that is conducive to involuntary remembering. This idea is in line with research examining the relationship between mind wandering and personal goals that we present below.

Mind wandering have been suggested to be closely related with “unfinished business” (e.g., Singer, 1975) or “current concerns” (e.g., Klinger, 1975), which refer to active personal goals (for a more detailed discussion of the concepts see Berntsen, 2009, p. 27). Antrobus, Singer, and Greenberg (1966) were the first to demonstrate how current concerns can influence mind wandering. In this study (experiment III), participants listened either to music or to a radio broadcast in the waiting room. The radio broadcasts included a special news bulletin announcing the involvement of China in the Vietnamese war, against the United States (note that the experiment was performed during the escalation of the war). As expected, there was an increase in mind wandering for participants who listened to the radio broadcast compared to participants who listened to music. More recently, McVay and Kane (2013) demonstrated priming of mind wandering using current concerns. They tested the idea that current concerns increase mind wandering production (McVay & Kane, 2010), by using idiosyncratic current concern related cues in a sustained attention task, and found a small significant increase. A study using a reading comprehension task showed a medium increase in task-unrelated thoughts (TUTs), after asking participants to make a list of short-term goals compared to a control task (Kopp, D’Mello, & Mills, 2015). However, other studies (Masicampo & Baumeister, 2011; Stawarczyk, Majerus, Maj, Van der Linden, & D'Argembeau, 2011) have found no evidence for the impact of current concerns in overall mind wandering, which may be due to methodological factors (e.g., goals are still salient in the control condition, Kopp et al., 2015). Thus, the impact of current concerns activation on overall mind wandering requires further research to determine if this can be a useful tool to increase the overall number of spontaneous thoughts elicited in the lab, and allow for a more thorough analysis of this phenomenon.

Current concerns are, by definition, close to personal goals, which seem to have a special relation with future thought. For example, D'Argembeau and Mathy (2011, studies 2 and 3) found that using personal goals as cues produced a greater number of future thoughts and an increase in episodic detail in a fluency task for future-events. These results, and similar evidence (for a complete review, see D’Argembeau, 2016), support the idea that personal goals are important components of the knowledge structure underlying the production of voluntary future thoughts. Further, during involuntary retrieval, future thoughts elicited in the laboratory are also more related to current concerns than are past thoughts (Cole & Berntsen, 2016), suggesting that the association between active personal goals and future thinking is independent of retrieval mode. Similarly, mind wandering research has consistently shown that thoughts reported by participants as future-oriented are also more frequently described has being focused on the self *versus* others (e.g., Ruby, Smallwood, Engen, & Singer, 2013). As a whole, these results suggest that priming personal goals should be an effective way to elicit future thoughts, and evidence in favor of such an effect has been found with younger adults (Stawarczyk et al., 2011, Study 2). Priming of personal goals in SFTs has not yet been tested with older adults, but two main issues are important to consider before applying this technique in older groups. First, an age-related decrease in current concerns has been reported (Parks, Klinger, & Perlmutter, 1989), which may translate to less sensitivity in older adults to goal-related priming because they have fewer current concerns available to be primed. Alternatively, the age-related decrease in current concerns may be due to the reliance on the explicit generation of a current concerns list. In young adults, current concerns are related to personal goals based on cultural scripts (D'Argembeau & Mathy, 2011), but in older adults the number of cultural scripts is considerably lower (Janssen & Rubin, 2011). Thus, it may be more difficult for older adults to generate a list of current concerns/personal goals. A procedure that that does not require the explicit listing of current concerns (unlike Kopp et al., 2015) seems preferable. Second, aging also leads to qualitative changes in personal goals, from being less instrumental to more emotional-regulatory (e.g., Lang & Carstensen, 2002), which is linked to a reduced time horizon with increased age that leads to a greater focus on present emotional fulfilling goals (e.g., Carstensen & DeLiema, 2018). Greater focus on the present in aging could disrupt the relation between goals and future thinking. Importantly, the specific instructions in a goal-related priming task would need to capture the diversity of personal goals in both younger and older adults. Theoretically, the development of a successful goal-related priming task in older adults would thus provide further evidence in favor of the view that personal goals constitute a general knowledge framework that supports future thinking (e.g., D'Argembeau & Mathy, 2011), despite age-related changes in the frequency and nature of personal goals.

Age Differences in Spontaneous Thought

Recently, Maillet and Schacter (2016a) reviewed age-related differences in spontaneous thought and concluded that mind wandering decreases with age when measured in the lab. However, at least two main methodological factors could influence the pattern of age-related effects on mind wandering. First, the way mind wandering is measured in the lab may change the type of thoughts experienced by younger and older adults. For example, McVay, Meier, Touron, and Kane (2013) demonstrated an increase in spontaneous thoughts related to task performance (i.e., task-related interferences, TRIs) coupled with a decrease in TUTs in older compared to younger adults. One reason for this pattern is that being assessed in a laboratory setting may increase older adults' concerns about cognitive decline and performance and, consequently, increase TRIs. For younger adults, usually undergraduate students, the university laboratory context is associated with thoughts about their academic life that would be classified as TUTs. Supporting this idea, Jordano and Touron (2017) showed that priming younger adults' concerns related to task performance increased TRIs. It is important to note that, without distinguishing these types of thoughts, TRIs may be misclassified as on-task thought (as they refer to the task), biasing age-related differences. Additionally, these results support the idea that the decrease in the frequency of spontaneous thoughts is partially dependent on the laboratory context and may not extend to naturalistic settings, in which older adults are not influenced by an assessment situation.

Second, measuring mind wandering in the lab may affect age-related differences in how spontaneous thoughts are cued by stimuli in the environment. Many of the attention tasks used in mind wandering research do not include varied meaningful stimuli, but instead use stimuli such as numbers (e.g., Jackson et al., 2013), abstract images (e.g., Giambra, 1989), and category words (e.g., foods vs animal names, McVay et al., 2013). Meaningful stimuli usually serve as triggers to spontaneous thoughts as shown, for example, by reports that the vast majority of involuntary autobiographical memories have an identifiable cue (Berntsen, 2009). In the absence of such meaningful cues, that could work as triggers, the frequency of spontaneous thoughts should decrease in older adults because they are more dependent on environmental support to initiate cognitive processes (e.g., Craik, 1986). Maillet and Schacter (2016b) directly tested this idea by distinguishing age-related differences in thoughts triggered by a stimulus, or self-generated, in a semantic decision task including words. The authors observed that older adults had more spontaneous thoughts cued by stimuli in the task (SDTs) versus stimulus-independent thoughts (SITs), when compared to younger adults. These findings indicate that the analysis of age-related differences in spontaneous thought should take into account how the thoughts are initiated (with or without an external trigger).

The extent to which age-related decreases in mind wandering frequency are present in SFTs, in particular, is still unclear, given scarce and mixed evidence. One reason for inconsistent findings in the literature is that aging is sensitive to methodological differences in measuring SFTs. In studies using retrospective inventories to assess daily experience, SFTs decrease with age (Berntsen et al., 2015; Giambra, 2000b). In contrast, retrospective assessment of SFTs in the laboratory during resting states showed no significant age differences (Mevel et al., 2013), which may be due to low task demands that better enable older adults to reach the boredom state usually associated with spontaneous thoughts. Additionally, procedures used to measure SFTs may differ in their reliance on meta-awareness processes that are affected in aging (Maillet & Schacter, 2016a). For example, Jackson et al. (2013) found that age-related differences differed according to the way thoughts were reported. Using on-line assessment of SFTs in a sustained attention task in a laboratory setting, participants were asked either to stop themselves each time they noticed thoughts unrelated to the task (i.e., self-caught procedure) or were periodically stopped by the experimenter and asked what was on their minds at that moment (i.e., probe-caught procedure). They found a decrease in future-oriented mind wandering in the older group using self-caught procedures, but no age-related differences in the probe-caught procedure. Jackson et al. (2013) suggested that the different pattern of results was due to differences in meta-awareness between the procedures, with the self-caught procedure more dependent on meta-awareness and thus, more sensitive to age-related changes.

The Present Study

In the present study we developed a novel procedure to prime SFTs across age groups. Younger and older adults were asked to perform a vigilance task during which spontaneous thoughts were probed (e.g., Plimpton et al., 2015). However, we made the task less demanding than in previous studies, to maximize the boredom state inductive of spontaneous thoughts, and in order to more effectively examine age-related differences (following Schlagman, Kliegel, Schulz, & Kvavilashvili, unpublished). Additionally, we used an open-ended probe-caught procedure to distinguish different types of mind wandering during the probes and to avoid instructional bias (e.g., Weinstein, De Lima, & van der Zee, 2018). Critically, the vigilance task was divided in two parts and a priming task was presented prior to the second part. The priming task was used to target a future-oriented perspective using personal goals. We adapted a card-sort task developed by Lang and Carstensen (2002), which required the use of knowledge about personal goals without asking for their explicit description. Participants were given cards with possible partners and goals and then asked to organize them according to their personal preference. The task included a wide range of goals (i.e., related to emotional regulation and individual preparatory goals), which have been shown to be applicable to both younger and older adults (Lang & Carstensen, 2002). Additionally, we employed a fine-grained coding procedure to characterize the multiple types of spontaneous thoughts and their triggers. We predicted that priming would increase spontaneous TUTs overall, and particularly SFTs, based on the link between mind wandering and current concerns shown in previous research (e.g., Kopp et al., 2015). Furthermore, we analyzed whether the priming effects could be explained by other aspects of the procedure. For example, task habituation and freeing of cognitive resources in the second part of the vigilance task might induce SFTs, given that these types of thoughts have been shown to consume more cognitive resources (e.g., Smallwood, Nind, & O'Connor, 2009). To explore this possibility, we compared SFTs in the younger experimental group with an additional control group of younger participants who performed the procedure outlined above except they were asked to organize the cards based on the number of words rather than by possible partners and goals. Further, given that the vigilance task was designed to diminish the influence of methodological factors that impact aging (Maillet & Schacter, 2016a), we also predicted that there would be no age-related differences in the overall frequency of spontaneous TUTs. Using this method, we then explored the impact of age on the different types of spontaneous thoughts and their triggers.

Method

Participants

Older participants were recruited in a Third Age University and through word-of-mouth and did not receive any compensation to participate. Younger participants were undergraduate Psychology students that chose to participate for extra credit. Participants with moderate to severe depressive symptomatology were excluded, based on the Geriatric Depression Scale 30 (GDS-30, Yesavage et al., 1983; Portuguese version of Barreto, Leuschner, Santos, & Sobral, 2008), for older adults, and based on the Beck Depression Inventory II *(*BDI-II, Beck, Steer, Ball, & Ranieri, 1996; Portuguese version of Oliveira-Brochado, unpublished), for younger adults. Additional exclusion criteria included: uncorrected visual impairment, neurological problems or history of relevant psychopathology, and for older participants evidence of cognitive decline on the Montreal Cognitive Assessment (MoCA, Nasreddine et al., 2005; Portuguese version of Simões, Freitas, Santana, Firmino, Martins, Nasreddine, & Vilar, 2008). Finally, we also excluded participants in the priming condition who reported suspicions that the priming task might have been included to influence performance in the subsequent vigilance task (6 younger participants, 2 of which guessed correctly the aim of the task). One participant in the control condition was also excluded based on reporting thinking about self-related future goals during the card-sort task. The final sample comprised 27 older adults in the priming condition [21 women, mean age in years (*M)* = 67.26, *SD* = 5.30], 27 younger adults in the priming condition (26 women, *M* = 19.74, *SD* = 1.10) and 27 younger adults in the control condition (26 women, *M* = 20.30, *SD* = 1.42). There was no evidence of age-related differences in the number of years of education (based on U Mann-Whitney, *Z* = -1.60, *p* = .11) between older (*M* = 13.04, *SD* = 5.74) and younger participants in the priming group (*M* = 13.78, *SD* = .89). Additionally, there was no evidence of differences in age (U Mann-Whitney, *Z* = -.535, *p* = .593) and education (U Mann-Whitney, *Z* = -.522, *p* = .602) between younger participants in the priming group and in the control group (Mean education in years = 14.11, *SD* = 1.42). We chose to stop data collection after reaching 27 participants for each group based on a priori power calculations performed with G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) that showed that 54 participants overall was enough to identify at least a medium effect (power = .95, *p* =.05) both for a repeated measures effect and for within-between interactions. We aimed for a medium effect despite a previous study that showed a small effect in current concerns priming (McVay & Kane, 2013) because we intended to assess if the priming procedure was useful to increase the number of spontaneous thoughts elicited in lab tasks. We reasoned that the effect would only be useful in practice if at least medium in size.

Materials

Card-Sort Task

Both control and priming conditions were based on an adapted version of the card-sort task of partner preference and goals priority developed by Lang and Carstensen (2002), differing only on what participants were asked to do with the cards. Both conditions included two parts, the first presenting descriptions of possible partners (e.g., “a close friend”, “an artist whose work I admire”, “a stranger of my age”, “an attorney”) and the second presenting descriptions of personal future goals (e.g., “determine my future by myself”, “help others to find their purpose in life”, “be financially independent”, “not feel lonely”). In the control condition participants were asked to organize the cards according to the number of words presented in each card. To ensure that participants did not focus on the goal-related content of the cards we did not mention goals in the instructions and debriefed participants after the procedure, asking "while performing the card-sort task, did you find yourself thinking about your personal future?", and excluding participants who did. In the priming condition, participants were asked to organize the cards describing possible partners according to their preference for interacting with them, and the cards describing personal future goals according to personal relevance. Partner preference cards were chosen to reflect possible people who were related more with an individual’s preparatory (e.g., knowledgeable partners, “an interesting stranger”, “an author of a book that I have read”) or emotion-regulatory (e.g., family/relatives, “a close member of my family”, “a younger relative”) goal-orientations. Thus, both tasks targeted future-oriented personal goals, although the partner preference tasks did not explicitly mention personal goals. Having a non-explicit task was important to minimize age-related increases in difficulty related to listing goals explicitly, and also to avoid limiting the activation to personal goals of which participants were aware. This concern follows from research showing that participants are unaware of certain personal goals (e.g., in cases in which they closely relate with memories; for a review see Conway & Pleydell-Pearce, 2000, p. 268). For that reason, an explicit task, like asking participants to state their concerns in different areas of life and the steps they would take to change them (Personal Concerns Inventory, Cox & Klinger, 2002; which has been used in involuntary memory research, Johannessen & Berntsen, 2010) may fail to activate an important part of personal goals that are implicit. We thus selected a task in which participants establish an order of preference that have been shown to depend on personal goals (Lang & Carstensen, 2002), independently of whether participants are aware or unaware of them.

Each card was translated by the first author from English to Portuguese and then back-translated by an experienced English teacher. The original and the back-translated version were then compared, discussed and adapted accordingly. To ensure that the priming was future-oriented, a slight change was made to the original instructions of the task. For partner preference cards, participants were asked to consider how much they "would like to spend *the next* day or evening together with that person", instead of the general "one day or evening" of the original task. For goals priority cards, after the general instruction "please read each of these cards carefully and sort the cards into several piles with respect to how important these goals and plans are for you personally" we added "*when you think about the future*". In the end of the procedure, we also debriefed participants in the priming condition about priming suspicions, specifically by asking if they thought the card-sort task was meant to influence them in the subsequent task, and if so, how specifically.

Vigilance Task

The vigilance task was adapted from Schlagman and Kvavilashvili (2008) and Plimpton et al. (2015). The original task requires participants to focus on pattern lines (horizontal or vertical lines) presented every 1.5 seconds, and to identify an infrequent kind of pattern (vertical lines), saying "yes" out loud. Additionally, neutral, negative and positive word-phrases are presented, based on cues reported by participants in diary studies (e.g., "Relaxing on the beach"), and participants are asked to ignore them. Using this task, Schlagman et al. (unpublished) found that older adults were less likely to report an involuntary autobiographical memory than younger adults, which they suggested was due to an increase in task demands in older adults and might be attenuated by instructing participants to focus on the cues instead of ignoring them. Thus, in the current study we presented the cues as the main element of the task, asking participants to focus on the color of the words presented on the screen and signaling yellow words (i.e., target) vs red words (i.e., non-target).

A number of additional modifications were made to the task in order to reduce task difficulty and, thereby, age-related differences in the number of spontaneous thoughts elicited. First, we changed the presentation time of the cues to 3 seconds, instead of the original 1.5 seconds, which has been shown to increase the effectiveness of spontaneous thoughts elicitation (Vannucci, Pelagatti, Chiorri, & Mazzoni, 2015). Second, we used a 7 second inter-stimulus interval (ISI), as longer ISIs have been shown to increase TUTs in older adults (e.g., Giambra, 1989). The inclusion of this ISI also allowed controlling the frequency of the cues per presentation time. Previous research, using a task very similar to Schlagman and Kvavilashvili's method, revealed that infrequent cues were more effective in spontaneous thoughts elicitation than frequent cues, by reducing cognitive load in young adults (Vannucci, Pelagatti, Hanczakowski, Paccani, & Mazzoni, 2015). We expected this effect to be even more pronounced with older adults, given the decrease in cognitive resources with increased age (e.g., Nettelbeck & Burns, 2010). Thus, we modified the mean cue rate presentation from 8 seconds (90 cues, in 675 seconds; e.g., Vannucci, Pelagatti, Hanczakowski, et al., 2015) to 10 seconds (3 seconds presentation time and 7 seconds ISI).

We also changed the type of emotional cues presented in the vigilance task and their frequency. Because there were no Portuguese translation and emotional norms for the Portuguese language of the original set of cue-phrases (Schlagman & Kvavilashvili, 2008), we selected the cues from the Portuguese version of the Affective Norms for English Words (ANEW, original version by Bradley & Lang, 1999; Soares, Comesaña, Pinheiro, Simões, & Frade, 2012). Given the widespread use of adaptations of ANEW database in different languages (e.g., in Spanish, Redondo, Fraga, Padrón, & Comesaña, 2007; and German, Schmidtke, Schröder, Jacobs, & Conrad, 2014), gathering evidence on the effectiveness of these stimuli to elicit spontaneous thoughts could also contribute to facilitate the construction of similar vigilance tasks in other languages in the future. We selected 96 nouns from the ANEW database, 48 presented in each of the two parts of the vigilance task, equally divided in terms of negative, neutral and positive valence. The words were always presented in the same order (see Supplementary Material 2 for the full list of words). Each word in the first half of the task was matched in the second half with a word of the same valence (scored from 1 to 9; ≤ 4 was considered negative, between 4 and 6, neutral, and ≥ 6, positive valence) and arousal (scored from 1 to 9; ≤ 4 was considered low, between 4 and 6, medium; and ≥ 6, high arousal), and controlled for word-frequency (for means and SD see Supplementary Material 2). The proportion of targets was increased from the original 1.8% (Schlagman & Kvavilashvili, 2008) to 6.75% in order to include 1 target cue from each valence category in each part of the vigilance task (i.e., 3 targets in each part). We did not expect this slight increase in the proportion of targets to attenuate the boredom state in the vigilance task because in the current study the stimulus presentation rate was also much slower than in the original task. The order of presentation of the cue words was determined randomly with a minimum interval of 60 seconds between each target.

A probe-caught procedure (i.e., thoughts were recorded in relation to probes provided by the experimenter) was used to measure spontaneous thoughts elicited during the task (e.g., Plimpton et al., 2015), instead of requiring participants to stop the task themselves when aware of certain thoughts. This procedure was chosen because probe-caught reports are expected to be less dependent on meta-awareness (e.g., Smallwood & Schooler, 2015), and thus, less influenced by potential age-related differences. In each probe, participants were asked to indicate what they were thinking in order to avoid instruction bias (e.g., Weinstein et al., 2018). The number of probes was based on the proportion of probes per task presentation time in similar studies (Plimpton et al., 2015; Vannucci, Batool, Pelagatti, & Mazzoni, 2014), resulting in 5 probes in each part of the vigilance task. The probes were presented in randomly determined intervals of 60 to 120 seconds. Within these constraints, probes were presented in two different orders before and after priming, to avoid predictability. To control for the possible influence of probe presentation, the order of probes before and after priming was counterbalanced.

In sum, the vigilance task consisted of a sequence of red and yellow words, 60-point bold Arial, presented in a white rectangle of 25.5 cm (width) x 19.5 (height) cm, using E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA). Participants were asked to say “yes” out loud when a yellow word was presented. All participants successfully identified the targets presented. The task was divided in a two parts, each lasting 8 minutes, in which 48 words equated for valence and arousal were presented for 3 seconds and followed by a 7 seconds ISI. Five times in each part of the presentation, the task paused and participants were asked to describe what was on their mind at that moment to an audio recording device. The experimenter also kept a written record of the description. Additionally, participants answered some questions as described in the following section. The task was then resumed, by pressing any key on the keyboard.

Thought Questionnaire

Participants were asked to characterize their thoughts in two ways: 1) online, during each interruption of the vigilance task, and 2) post-task, for past and future spontaneous thoughts only. We chose this procedure, based on Barzykowski and Niedźwieńska (2016), in order to ensure that we collected online subjective ratings that were related with the experience of the thought in the task and that may be distorted by a retrospective assessment. In contrast, other types of questions, concerning the content of the thought, were administered later in order to diminish the time dedicated to thought assessment during the task.

During the online questionnaire, participants were asked about: (a) what triggered the thought, if identifiable; (b) the temporality of the thought (past, present, future or atemporal, in which the present was considered to be restricted to the current task as in Maillet et al., 2017); (c) level of concentration (from 1 = not at all, to 5 = fully concentrating, as in Plimpton et al., 2015; Schlagman & Kvavilashvili, 2008); (d) awareness of the thought before the probe (as in, e.g., Frank, Nara, Zavagnin, Touron, & Kane, 2015); (e) deliberate attempt bringing the thought to mind (from 1 = I wasn't trying at all, to 7 = I tried very hard, as in Barzykowski & Niedźwieńska, 2016); (f) clarity, (g) vividness, (h) detail, (i) emotional valence (from very unpleasant to extremely pleasant) and (j) emotional intensity (increasing from 1 to 7, as in Barzykowski & Niedźwieńska, 2016).

During the post-task questionnaire, participants were asked about: (a) temporal distance from the present, (b) thought specificity (selecting general thought about a repetitive event; general thought about an extended event; one-off event, as in Plimpton et al., 2015), (c) personal relevance, (d) rehearsal frequency, (e) original emotional valence of memories (increasing from 1 to 7, as in Barzykowski & Niedźwieńska, 2016), (f) the place, time and/or person/object associated with thought, when identifiable. The description of the thought written by the experimenter was read to help participants recall the thoughts that emerged, whenever they could not remember them.

Design

We used a mixed quasi-experimental design, with age as a between-subjects variable (younger and older adults) and priming (before and after priming) as a within-subject variable. To further analyze if the predicted increase in SFTs and spontaneous TUTs after priming was due to the priming task, and not to other aspect of the procedure, we used an experimental design, including card-sort task condition as a between-subjects variable (younger control and younger priming) and vigilance task part (first and second) as a within-subjects variable.

Procedure

Participants were enrolled in one or two individual sessions, according to scheduling constraints, and the tasks were always presented in the same order. Oral informed consent was obtained from all individual participants included in the study at the beginning of the experimental session. Participants undertook the vigilance task first. The vigilance task was presented in two parts, and instructions and a new training trial were presented prior to each part. Participants were instructed to pay attention to the words presented in the task and say "yes" out loud to yellow ones. Then a short training of 1 minute was performed. The subsequent instructions were very similar to those presented by Plimpton et al. (2015). The experimenter explained that, because of the monotony of the task, it was natural that at some points the attention drifted away, as in other occasions of real life in which we perform automatized tasks (e.g., driving, washing the dishes), leading to the emergence of different thoughts. Any kind of thought could come to their mind: thinking about the task, about the past, present, future or atemporally, and the nature of these thoughts could be deliberate or spontaneous. The participants were informed that to keep track of these attention fluctuations, the task would pause at some points and a screen asking "What was on your mind right now?" would appear. In these instances, participants were asked to describe the thought to an audio recorder and to answer some questions. Both the probe screen and the questions were shown at this point. It was stressed that the thoughts did not need to be interesting or anything in particular, and that if the participant considered the thought to be too private to be shared, the experiment would proceed without further questions (for a similar instruction, see for example, Berntsen & Rubin, 2002).

In between the first and second part of the vigilance task, participants performed the card-sort task. Participants in the priming condition were instructed that the task was aimed to assess different personal preferences. For the partner preference cards, they were asked to consider how much they would like spend a part of the following day with the people described in the cards and then to organize them in piles, according to their preference. For the goal priority cards, they were instructed to consider the goals presented in terms of their future and then to organize them in piles according to their priority. Alternatively, participants in the control condition were asked to organize the cards with respect to the number of words presented in each card, both for the partner preference and the goal priority cards. There was no time limit to complete these tasks.

After the completion of the second part of the vigilance task, the post-task thoughts assessment questionnaire was collected. The procedure took approximately 50 minutes with younger adults and one hour with older adults. Additional data gathering, either immediately following these tasks or in a separate experimental session, included a semi-structured interview with questions about sociodemographic and clinical history, the MoCA (for older adults only), and the GDS-30 or BDI-II. Participants also performed additional cognitive tasks that were included for other purposes.

Thoughts Coding Process

All audio records were assessed by at least two coders, except those in which participants reported having “nothing” in their mind, or having their “mind blank”. The records were classified as Task-Related Thought (TRT), TRI, TUT or no thought, according with criteria from Plimpton et al. (2015), with good inter-coder agreement (*Kappa* = .76, *SE* = .02). Specifically, TRTs were thoughts restricted to the main aim of the task, namely detecting the yellow words (e.g., "I was reminding myself to say yes when a yellow word appears"), while TRIs referred to aspects of the task not focused on the identifying the yellow words (e.g., "I was wondering if the words would repeat") and to states or emotion related to the task (e.g., "The word *sour* brought up an aversion feeling"), including thoughts about performance (e.g. "I was thinking I was more concentrated now than at the beginning of the task"). Finally, TUTs were totally unrelated with the task (e.g., “I was recalling I went to the post office today to send a package to my son”). All disagreements were discussed and those that persisted were assessed again by a different coder, blind to previous classifications. The classification that was agreed upon by the majority of raters was the final chosen.

Results

Frequency of task-unrelated spontaneous thoughts in relation to temporality and cues

Given that our focus was spontaneous thought, we first distinguished TUTs according to their spontaneity. Thoughts were classified based on how much effort participants reported bringing the thought to mind, using a 1 to 7 scale from low to high, as spontaneous (i.e., less than or equal to 3) undecided (i.e., equal to 4), or deliberate (i.e., greater than or equal to 5) (Barzykowski & Niedźwieńska, 2016). Approximately 91% of thoughts were classified as spontaneous (see Table 2.1), and there were no age-related differences either before priming (p = .162) or after priming (p = .508). There were also no differences between the two younger groups in the first (p = 1.000) or second part (p = .314) of the vigilance task. Thoughts classified as non-spontaneous were discarded from further analysis.

	Spontaneous			Undecided			Deliberate		
	YG Control	YG Priming	OG Priming	YG Control	YG Priming	OG Priming	YG Control	YG Priming	OG Priming
Vigilance task: part 1	33 (97%)	41 (93%)	47 (92%)	0	1 (2%)	4 (8%)	1 (3%)	2 (5%)	0
Vigilance task: part 2	28 (85%)	46 (90%)	50 (89%)	3 (9%)	5 (10%)	4 (7%)	2 (6%)	0	2 (4%)
Total	61 (91%)	87 (92%)	97 (91%)	3 (4.5%)	6 (6%)	8 (7%)	3 (4.5%)	2 (2%)	2 (2%)

Table 2.1. Counts (percentages) of spontaneous, undecided and deliberate instances of task-unrelated thought by group, for each part of the vigilance task.

We also analyzed spontaneous TUTs as a function of cues, by examining the percentages of different types of cues, namely, no cue, words from the task and other types of cues, that included interoceptive stimuli (e.g., physical sensations) and exteroceptive (e.g., a sound coming from outside the experimental room). As shown in Table 2.2, the majority of spontaneous TUTs (approximately 80%) are elicited in relation to identifiable cues in all groups, consistent with previous research with younger adults (Plimpton et al., 2015).

	No cue			Word from the task			Other		
	YG Control	YG Priming	OG Priming	YG Control	YG Priming	OG Priming	YG Control	YG Priming	OG Priming
Vigilance task: part 1	6 (18%)	7 (17%)	9 (19%)	24 (73%)	25 (61%)	30 (64%)	3 (9%)	9 (22%)	8 (17%)
Vigilance task: part 2	3 (11%)	7 (15%)	14 (28%)	19 (68%)	29 (63%)	27 (54%)	6 (21%)	10 (22%)	9 (18%)
Total	9 (15%)	14 (16%)	23 (24%)	43 (70%)	54 (62%)	57 (59%)	9 (15%)	19 (22%)	17 (17%)

Table 2.2. Counts (percentages) of types of cues for spontaneous task-unrelated thought by group, for each part of the vigilance task

Then we examined the influence of priming on spontaneous TUTs, according to their temporal orientation and relation to stimulus-cues. We conducted a mixed repeated measures ANOVA with 2 (age group: younger, older) × 2 (priming status: before, after) × 4 (temporal orientation: past, present, future, atemporal) × 2 (cue status: dependent, independent), on the mean proportion of spontaneous thoughts (for means and SD *per* temporality, before and after priming, see Table 2.3 and Figure 2). The Greenhouse-Geisser correction was used to adjust for violations of sphericity, here and elsewhere. We found a main effect of cue status, $F(1, 52) = 29.38$, $MSE = .55$, $p < .001$, $\eta_p^2 = .36$, which was reflected by more frequent SDTs ($M = .07$, $SD = .06$) than SITs ($M = .02$, $SD = .03$). There was also an effect of temporal orientation, $F(2.6, 135.1) = 3.06$, $MSE = .05$, $p = .037$, $\eta_p^2 = .06$, qualified by an interaction with priming status, $F(2.5, 131.9) = 8.23$, $MSE = .11$, $p < .001$, $\eta_p^2 = .14$. Post-hoc analyses based on Bonferroni correction for multiple comparisons revealed that the temporal orientation by priming status interaction was due to an increase in future spontaneous thoughts ($p < .001$), and a decrease in past spontaneous thoughts ($p = .041$) after priming. Additionally, before priming future spontaneous thoughts were less frequent than past ($p = .003$) and present ($p = .009$) thoughts. However, after priming there were no significant differences between the temporal-orientations of spontaneous thoughts ($p > .08$). There were no other main effects or interactions (all $p > .16$). Thus, as predicted, SFTs increased after priming equally in both younger and older adults, suggesting that the priming was successful.

One alternative explanation for this result is that participants became increasingly bored after priming, because of fatigue or practice, and started to experience more thoughts about what they will do when the task ends. Supporting this idea, a mixed ANOVA with 2 (age group: younger, older) × 2 (priming status: before, after) on the mean concentration levels reported by the participants revealed a main effect of priming, $F(1, 52) = 5.90$, $MSE = 1.15$, $p = .019$, $\eta_p^2 = .10$, due to a decrease in concentration after priming (from $M = 4.21$, $SD = .72$, to $M = 4.00$, $SD = .90$). There was also a main effect of group, $F(1, 52) = 7.33$, $MSE = 7.38$, $p = .009$, $\eta_p^2 = .12$, which reflected higher level of concentration in older adults ($M = 4.37$, $SD = .66$) than younger adults ($M = 3.84$, $SD = .76$). Thus, to account for the potential influence of concentration level on the temporal-orientation of spontaneous thoughts, we conducted a mixed repeated measures ANCOVA with 2 (age group: younger, older) × 2 (priming status: before, after) × 4 (temporal orientation: past, present, future, atemporal) × 2 (cue status: dependent, independent), which included the difference in concentration level between the first and second part of the task as a covariate. The ANCOVA revealed that the main effect for cue status, $F(1, 51) = 29.75$, $MSE = .56$, $p < .001$, $\eta_p^2 = .37$, and the interaction between priming and temporal orientation, $F(2.5, 127.8) = 7.77$, $MSE = .10$, $p < .001$, $\eta_p^2 = .13$, were still present. Post-hoc analyses based on Bonferroni correction for multiple comparisons showed the same pattern of effects as the previous analysis, including the increase in the number of future-oriented thoughts after priming ($p < .001$). Therefore, these findings suggest that differences in the level of concentration cannot fully account for the increase in future spontaneous thoughts due to priming.

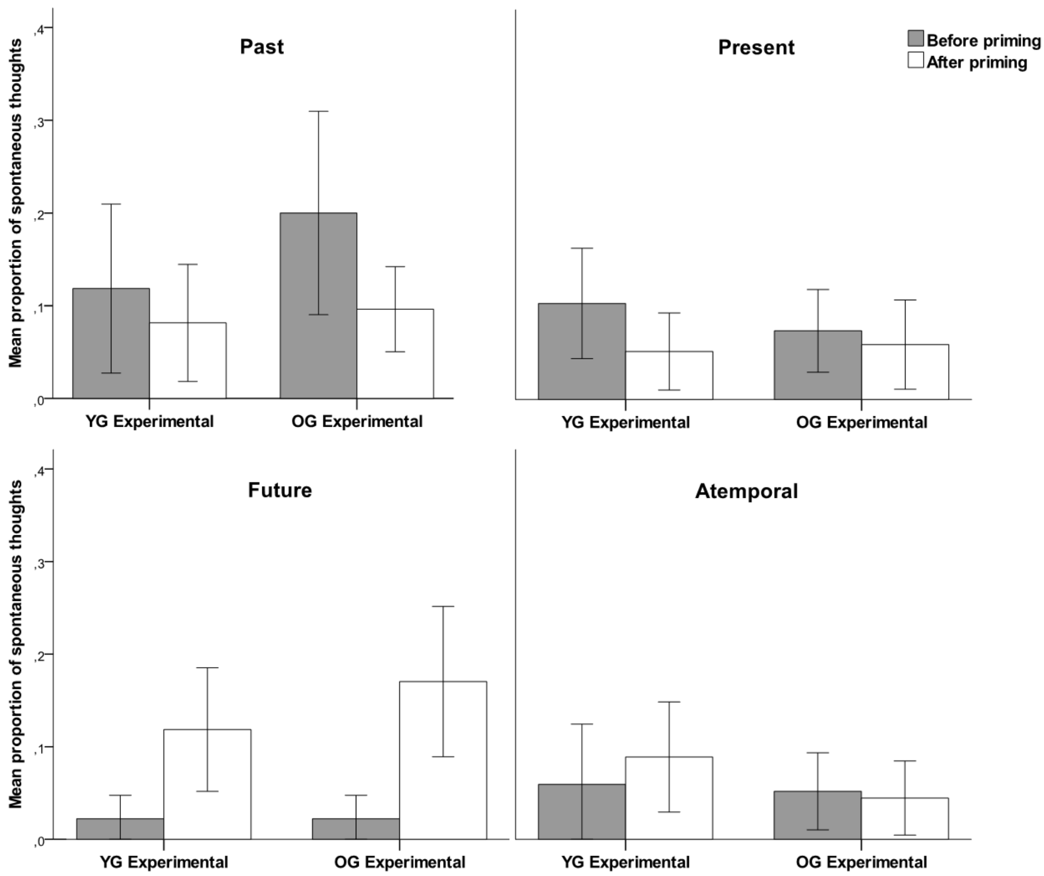

Figure 2. Mean proportions of spontaneous task-unrelated thought by temporality, before and after priming, for each experimental (priming) group (error bars represent 95% confidence interval).

To further ensure that the increase in SFTs was due to priming future-oriented personal goals, and not to other aspects of the procedure, we conducted an additional analysis that examined whether the frequency of SFTs significantly increased from part 1 to part 2 of the vigilance task for the younger priming group but not for the younger control group (for a full description of the younger control group spontaneous TUTs by temporality see Table 2.3). A mixed repeated-measures ANOVA with 2 (condition: younger priming, younger control) × 2 (vigilance task part: first, second) on the frequency of SFTs revealed a main effect of vigilance task part, $F(1, 52) = 6.35$, $MSE = .07$, $p = .015$, $\eta_p^2 = .11$, indicating that SFTs were more frequent in part 2 ($M = .08$, $SD = .14$) than part 1 ($M = .03$, $SD = .07$) of the vigilance task. Importantly, this main effect was qualified by an interaction with condition, $F(1, 52) = 4.67$, $MSE = .05$, $p = .035$, $\eta_p^2 = .08$. Post-hoc analyses based on Bonferroni correction for multiple comparisons revealed that this interaction was due to an increase in SFTs from part 1 to part 2 of the vigilance task in the younger priming group ($p = .002$), but not in the younger control group ($p = .80$). Additionally, there was no evidence of differences in SFTs frequency between the two younger groups in part 1 of the vigilance task ($p = .692$), while in part 2 SFTs were more frequent in the younger priming group than in the control group ($p = .034$). As a whole, the present evidence demonstrates as predicted that priming of future-oriented personal goals increases SFTs.

Despite the overall priming effect in SFTs, a number of participants did not experience future-oriented spontaneous thoughts after priming (48% of older and 59% of younger adults). Additionally, only 8 younger and 12 older adults reported both past and future thoughts. The overall number of past and future thoughts was also low, including 40 past and 25 future thoughts for 27 older participants, and 27 past and 19 future thoughts for the 27 younger participants. Therefore, we did not pursue an analysis of the differences in phenomenological characteristics, which would not be reliable in these conditions.

	Past			Present			Future			Atemporal		
	YG Control	YG Priming	OG Priming	YG Control	YG Priming	OG Priming	YG Control	YG Priming	OG Priming	YG Control	YG Priming	OG Priming
Vigilance task: part 1	.13 (.21)	.12 (.23)	.20 (.28)	.02 (.05)	.10 (.15)	.07 (.11)	.03 (.07)	.02 (.06)	.02 (.06)	.07 (.14)	.06 (.16)	.05 (.11)
Total (Priming)		.16 (.26)			.09 (.13)			.02 (.06)			.06 (.14)	
Vigilance task: part 2	.10 (.19)	.08 (.16)	.10 (.12)	.02 (.06)	.05 (.11)	.06 (.12)	.04 (.10)	.12 (.17)	.17 (.21)	.04 (.08)	.09 (.15)	.04 (.10)
Total (Priming)		.09 (.14)			.06 (.11)			.14 (.19)			.07 (.13)	

Table 2.3. Mean proportions (standard deviations) of spontaneous task-unrelated thought by group, for each part of the vigilance task.

	TRT			TRI			Spontaneous TUT		
	YG Control	YG Priming	OG Priming	YG Control	YG Priming	OG Priming	YG Control	YG Priming	OG Priming
Vigilance task: part 1	.07 (.16)	.09 (.13)	.13 (.26)	.37 (.26)	.22 (.25)	.36 (.31)	.24 (.29)	.30 (.30)	.35 (.30)
Vigilance task: part 2	.05 (.11)	.01 (.05)	.07 (.21)	.29 (.30)	.24 (.18)	.33 (.27)	.21 (.28)	.34 (.31)	.37 (.27)

Table 2.4. Mean proportion (standard deviation) of task-related thought (TRT), task-related interference (TRI) and spontaneous task-unrelated-thought (TUT) by group, for each part of the vigilance task.

Frequency of type of thoughts: Comparing Task-Unrelated, Related and Interfering Thoughts

A second aim of the current study was to examine the influence of priming on the frequency of spontaneous TUTs in younger and older adults. To analyze the frequency of type of thoughts we calculated the mean proportion of TRTs, TRIs, and spontaneous TUTs in the 5 probes of each part of the vigilance task (for means and SD see Table 2.4).

In this analysis we found an effect of probe order (i.e., the counterbalanced location of probes used in the vigilance task), as given by the 2 (age group: younger, older) × 2 (probe order: AB, BA) × 2 (priming status: before, after) × 2 (type of thought: TRT, TRI, spontaneous TUT) mixed ANCOVA with repeated measures in the last two factors, controlling for the difference in the level of concentration before and after priming, $F(1,49) = 4.99$, $MSE = .19$, $p = .030$, $\eta_p^2 = .09$. The effect was due to participants reporting more thoughts overall in one of the probe orders ($M = .26$, $SD = .12$ compared to $M = .21$, $SD = .11$). Critically, however, this effect was accounted for by the complete counterbalancing of probe orders in each group, and the order effect did not interact with any other variable. We found also a main effect of age group, $F(1, 49) = 9.17$, $MSE = .36$, $p = .004$, $\eta_p^2 = .16$, with older adults reporting more thoughts overall ($M = .27$, $SD = .11$) compared to younger adults ($M = .20$, $SD = .11$). Additionally, there was a significant effect of type of thought, $F(1.8, 87.5) = 17.51$, $MSE = 2.29$, $p < .001$, $\eta_p^2 = .26$, which was due to fewer TRTs ($M = .08$, $SD = .16$) compared to both TRIs ($M = .29$, $SD = .21$) and spontaneous TUTs ($M = .34$, $SD = .26$), *p's* < .001. Thus, we found no evidence of an increase in the frequency of spontaneous TUTs after priming. This finding extended to the comparison between the younger priming and control groups (for a full description of type of thought frequency in the younger control group, see Table 2.4). We conducted a mixed repeated-measures ANOVA with 2 (condition: younger priming, younger control) × 2 (vigilance task part: first, second) × 2 (probe order: AB, BA) on the frequency of spontaneous TUTs and confirmed that the interaction between condition and vigilance task part was not significant $F(1, 50) = .81$, $MSE = .03$, $p = .371$, $\eta_p^2 = .02$. There was also no evidence of overall differences between the two younger groups ($p = .151$).[6] It is

[6]An additional interaction between task and probe order $F(1, 50) = 5.05$, $MSE = .21$, $p = .029$, $\eta_p^2 = .09$ was found. Although this probe order effect does not impact the present analysis, given the complete counterbalancing used in all groups, it suggests that fixed probe orders may significantly influence spontaneous thoughts elicitation, and should be avoided in future experiments.

important to note that some participants in the priming condition did not report any spontaneous TUTs (i.e., 6 older and 9 younger adults before priming and 7 older and 7 younger adults after priming). It is unlikely that the level of task difficulty contributed to this result (as suggested for previous studies, Maillet & Schacter, 2016a), because the task demand was low. One possibility is that participants who reported no spontaneous TUTs before priming differed in terms of their current concerns. Perhaps due to individual differences in self-consciousness (Vannucci & Chiorri, 2018), they may experience a lower level of activation in their current concerns. If that is the case, then participants with no spontaneous TUTs before priming should be also be more affected by the priming manipulation than participants with spontaneous TUTs before priming. We tested this idea in a 2 (age group: younger, older) × 2 (spontaneous TUTs before priming: no, yes) × 2 (priming status: before, after) mixed ANOVA, with repeated measures in the last factor. We found the expected interaction between priming and spontaneous TUTs before priming, $F(1, 50) = 5.20$, $MSE = .19$, $p = .027$, $\eta_p^2 = .09$. Further, this interactions remained after controlling for differences in the level of concentration before and after priming, $F(1, 49) = 4.88$, $MSE = .18$, $p = .032$, $\eta_p^2 = .09$. Post-hoc analyses based on Bonferroni correction for multiple comparisons showed that the proportion of spontaneous TUTs increased after priming for participants who did not report any spontaneous TUTs before priming, $p = .031$, $\eta_p^2 = .09$, (to $M = .16$, $SD = .53$, after priming), but not for those who did[7], $p = .553$. These results suggest that priming is effective in increasing spontaneous TUTs for a subsample of participants for whom current concerns may be less activated.

Discussion

In the present study we developed a new priming procedure to induce future-oriented spontaneous thoughts in a laboratory setting and applied this method to investigate age-related differences in the frequency and temporality of spontaneous thoughts. The priming procedure focused on the activation of future-oriented personal goals, using tasks adapted to diminish the impact of methodological factors that may bias

[7]Note that the absence of evidence of significant differences in the group that reported spontaneous thoughts before priming is not due to a ceiling effect, as the mean proportion for this group before ($M = .45$, $SD = .24$) and after priming ($M = .43$, $SD = .29$) is far from the maximum 1, with no signs of skewness before (.93, $SE = .38$) or after (.25, $SE = .38$) priming.

the ability to isolate potential age-related changes in spontaneous thoughts. Additionally, we distinguished different types of mind wandering that, according to previous evidence (e.g., McVay et al., 2013), were expected to produce different patterns of age-related effects. As predicted, we found an overall increase in SFTs across both age-groups after activating future-oriented personal goals, which remained after controlling for differences in the subjective level of concentration during the vigilance task. This effect was further supported by the results of a younger control group that showed no increase in SFTs, indicating that other aspects of the procedure, like the specific words presented in the two parts of the vigilance task, task habituation or freeing of cognitive resources do not account for the priming effect. No evidence of age-related differences in the priming of SFTs was found, which suggests that age changes in the quantity and quality of personal goals do not impact how future goals relate to SFTs frequency. The lack of age-differences also suggests that the methodological changes introduced in the vigilance task were successful in controlling factors that differentially influence spontaneous thoughts in aging, and that the priming task was adequate for both younger and older adults. Consequently, no age-differences were found in spontaneous TUTs either. Further, irrespective of priming, SDTs were more frequent than SITs, suggesting that the word cues included in the task were successful in eliciting spontaneous thoughts. Below we detail these findings by discussing: (1) the role of priming in re-orienting the processing of word-cues, from past to future, (2) the temporality effects in the present task, (3) the absence of evidence for a priming effect in spontaneous TUTs overall, and (4) the absence of evidence for age-related differences.

We found several results pointing to the role of the future-oriented priming in re-orienting the processing of word-cues from past to future. First, priming future-oriented personal goals not only boosted the frequency of SFT, but also attenuated the typical bias towards past-oriented spontaneous thoughts. Previous research using verbal cues has shown that spontaneous past thoughts are more frequent than future thoughts (Plimpton et al., 2015; Vannucci et al., 2017). In the current study, we also found more past-oriented TUTs prior to priming. However, there was a significant reduction in the number of past-oriented thoughts after priming, indicating that the priming procedure was successful in controlling the past-oriented bias associated with verbal cues. Second, although the increase in SDTs compared to SITs demonstrates that the simple nouns used here were effective in cuing spontaneous thoughts, priming did not influence how cues presented during the vigilance task triggered spontaneous TUTs. The lack of a priming effect on the relationship with the cues indicates that priming future-oriented personal goals does not increase SITs *per se*, as we might expect based on the idea that thoughts related with current concerns would be more cue-independent (Maillet et al., 2017). In our study, future-oriented thoughts generated after priming were still more dependent than independent of cues, suggesting that the activation generated by the priming procedure did not impact spontaneous thoughts on its own, but also with the support of the words presented during the task. Third, the present evidence suggests that the relation between cue content and temporality is not univocal, as the temporality of the thoughts triggered by a particular cue varied between participants (e.g., the word "Christmas", which may be associated with a particular temporality because it happens in a specific time of the year, triggered past, atemporal, present and future spontaneous thoughts in different participants). As a whole, these findings are consistent with previous theoretical views (e.g., induction principle; Klinger, 1978) emphasizing the interaction between factors internal to the individual (i.e., the activation produced by the present priming procedure) and factors from the environment (i.e., specific words). In fact, this is the first study to show a SFTs priming in a task including meaningful cues that can support spontaneous thoughts elicitation (in Stawarczyk et al., 2011, the task included numbers from 1 to 9). Furthermore, verbal cues as the ones included seem to be especially effective in eliciting spontaneous thoughts because they allow participants to "complete" the cue with their own details (Mazzoni et al., 2014). Here, the priming activation seems to have led to the completion of more future-oriented spontaneous thoughts. Exploring the processes by which abstract verbal cues support SFTs elicitation is an interesting avenue of research that may contribute to further developments on the interaction between the semantic and episodic components of future thinking (Irish, 2016).

Examining temporality effects more broadly, we did not find any differences between past and present or atemporal-oriented thoughts, as has been shown in some studies (Plimpton et al., 2015; Vannucci et al., 2017). In Plimpton et al. (2015) past thoughts were more frequent than both current present and future thoughts, but an atemporal option was not available for participants. This methodological difference is important because it has been shown that the pattern of differences between thoughts of different temporalities changes when the atemporal option is present (Jackson et al., 2013), suggesting that participants may misclassify the temporality of thoughts when an atemporal option is not provided. Additionally, differences in inclusion criteria of spontaneous thoughts could also increase differences between past and present thoughts.

For example, Vannucci et al. (2017) distinguished TUTs related with sensory perceptions occurring in the moment (i.e., external distractions), excluding them from the temporality analysis, and found a significant increase in past versus present spontaneous thoughts. Given that, by definition, those thoughts are related to the present, their exclusion may have increased the differences between the frequency of present and past-oriented spontaneous thoughts. In the current study, past thoughts may also have been equally frequent to atemporal thoughts because our cues were more abstract (i.e., nouns) than ones used in previous studies (Vannucci et al., 2017), and less suggestive in the generation of temporal-related thoughts.

Contrary to our predictions, priming did not increase the overall frequency of spontaneous TUTs. According to theory regarding the influence of current concerns on mind wandering (e.g., McVay & Kane, 2010), cuing current concerns, through environment or other thoughts, should increase the number of spontaneous TUTs competing for attention. In our study we aimed to produce an increase in current concerns by using a goal-related priming task. However, we show that priming effects on spontaneous TUTs were specifically about the future, similar to previous studies that have primed involuntary autobiographical memories and shown an increase in the spontaneous past events related with the particular content activated through priming (e.g., high-school memories Barzykowski & Niedźwieńska, 2018). The generic priming task used here may not have been strong enough to increase the overall activation of current concerns. Previous research has shown variations in the effect size of the current concerns priming, from only a small increase in a lab task using self-generated cues (McVay & Kane, 2013), to medium in a reading comprehension task (Kopp et al., 2015), and to large when the priming dealt with more life-threatening topics (Antrobus et al., 1966). In this study we defined our sample size in order to have power to identify a medium effect, based on the idea that the priming would only be useful in increasing the number of spontaneous TUTs in future experiments if it had at least a medium effect size. Thus, it cannot be ruled out that a small effect of priming in spontaneous TUTs was not identified due to lack of power, and the present evidence should not be interpreted against the hypothesis that current concerns or personal goals are important factors in generating spontaneous TUTs. Additionally, we showed that a subsample of 15 participants who did not report any spontaneous TUTs before priming reported an increase in spontaneous TUTs after priming. One interpretation of this finding is that the activation level of current concerns was originally lower in this subsample, whereas for the remaining participants the activation provided by the priming task may have been redundant for boosting the overall frequency of spontaneous TUTs. Potential differences in baseline activation of current concerns may be related to individual factors, such as the amount of self-rumination (Vannucci & Chiorri, 2018), or to the tasks in which the participant was involved prior to the experimental session (as suggested by Giambra, 1989). Another possibility is that more probes and increased task time is needed for a priming effect on the overall frequency of spontaneous TUTs to be captured.

As predicted, the methodological changes to the current task led to fewer age-related differences in the frequency and nature of spontaneous thoughts and in the influence of priming. It is unlikely that our analysis failed to find main age effects due to lack of power, considering that our sample was adequate to find at least medium effects, and that age effects in mind wandering (which is closely related to spontaneous thoughts) are large (Jordão, Ferreira-Santos, Pinho, & St. Jacques, 2019). Alternatively, a number of important methodological factors likely contributed to the equivalent effects of age on spontaneous thoughts. These included: (1) clearly distinguishing between spontaneous and intentional thought (Seli, Maillet, Smilek, Oakman, & Schacter, 2017) and different types of spontaneous thought, including TRIs and TUTs (McVay et al., 2013), (2) decreasing the reliance in memory and meta-awareness for the reports by using an on-line probe-caught procedure (Smallwood & Schooler, 2015), (3) avoiding bias in temporality classification by providing an atemporal option (Jackson et al., 2013), and (4) avoiding probe framing related biases with older adults, by using an open-ended narrative description (e.g., Weinstein, 2018). We also did not find age-related differences in the pattern of SDTs and SITs, contrary to previous research (Maillet & Schacter, 2016b), which again may be due to reduced task demands in the current study. There was, however, an overall increase in the frequency of reported thoughts for older adults, when including spontaneous TUTs, TRTs, and TRIs. This finding must depend on the frequency of TRTs and TRIs, as the analysis of spontaneous TUTs revealed no age-related differences. Although we did not find an interaction between types of thought and age group (possibly due to lack of power, if this effect was small), both TRTs and TRIs frequency seem to be generally higher in the older than in the younger priming group, which would be in line with previous studies (e.g., McVay et al., 2013). In fact, despite improving methodological issues, which attenuated age-effects for spontaneous TUTs, the experimental procedure was still a laboratory task that may induce task-related concerns for older adults particularly (McVay et al., 2013), thereby increasing the overall number of thoughts for this age group. At any rate, by controlling for many of the methodological factors that are known to increase age-related differences the current findings help to resolve some of the inconsistent findings in the literature. Additionally, we also show that possible quantitative (e.g., Parks et al., 1989) and qualitative (e.g., Lang & Carstensen, 2002) differences in the personal goals of older participants did not limit the impact of priming in SFTs frequency, as the effect was similar in younger and older adults. This finding suggests that, when a personal goal is active, older adults should experience more SFTs to support goal planning in everyday life (e.g., Klinger et al., 2018). However, it is still possible that the SFTs generated may be qualitatively different, and in fact it has been suggested that age-related differences in the medial prefrontal cortex when thinking about self-relevant agendas may be related to lack of detail in older participants (Mitchell et al., 2009). In the future, it will be important to explore the impact of the goal-related priming in qualitative age-differences, such as specificity, in SFTs.

Limitations

In the present procedure, we tested the SFTs priming effect against competing explanations by (1) controlling for concentration level, and (2) analyzing the effect of the procedure in a younger control group, but it was not possible to include also an older control group. Thus, the present evidence for priming in older adults is not decisive and still warrants future research with an older control group. Nevertheless, it does not seem likely that an older control group would present an increase in SFTs after priming, for two main reasons. First, an increase in SFTs was not observed in the younger control group. Considering that there was no evidence of age-differences in spontaneous TUTs overall or by temporality, there is no reason to expect that differences between younger and older control groups would emerge. Second, in the case of age-differences, previous evidence consistently points to the prediction that younger adults would experience more spontaneous TUTs (e.g., Maillet & Schacter, 2016a). Thus, we would expect that an older control group would experience even fewer SFTs than the younger control group, for which no priming effect was found.

Despite the significant effect of priming in inducing SFTs, approximately half of participants still did not report future-oriented spontaneous thought. Our primary aim here was to test the efficacy of the priming procedure in inducing SFTs, rather than collecting a large number of SFTs. Thus, the vigilance task included a limited number of probes (i.e., only 5 after priming), to avoid increasing the overall task time, which could particularly fatigue older adults. Additionally, the number of cues presented was also much lower (96 in the complete vigilance task) compared to similar studies (e.g., 600 cues in Plimpton et al., 2015), reducing the possibility of cuing spontaneous thoughts. Again, because each cue required ten seconds, including presentation time and ISI, we wanted to avoid making the task too long. Increasing the number of probes and cues should be key in future studies aimed at analyzing SFTs induced by the present priming procedure. At any rate, our priming manipulation will be useful in future studies that aim to collect an equal amount of thoughts from each temporal orientation.

Another feature of the task that should be improved in future experiments is the counterbalancing of the order of the words presented in the vigilance task. Although this feature of the vigilance task does not explain the priming effect (as shown by the younger control and priming group comparison), the specific order of words may still have influenced participants in other ways and should be avoided (e.g., sometimes participants report thoughts about the possible semantic connection between words in the task, and some specific order of words may be more suggestive of that than others).

Finally, the generalizability of these results is limited by the high number of women in both the younger and older samples in our study. In related research, women have been shown to experience daydreaming more frequently than men (Giambra, 2000a), but no interaction between age and gender has been reported. Thus, we would expect the present results to extend in future studies including younger and older samples, with a more equal number of women and men.

Conclusions

In summary, this study presents evidence in favor of a future-oriented goal priming of SFTs, and thus of the hypothesis that personal goals support future thoughts elicitation. Importantly, we show that this effect extends from younger to older participants, which indicates that age-related changes in personal goals quantity and quality do not impact the relation between personal goals and SFTs, at least in its quantity. Practically, the priming procedure used in the current study is also useful to increase the frequency of SFTs in elicitation paradigms using word-cues, in which thoughts are typically more past-oriented (e.g., Vannucci et al., 2017), thereby improving the ability to compare past and future thoughts that arise spontaneously and contributing to a better understanding about the processes that support remembering and imagining.

Additionally, we found no evidence of age-related differences in spontaneous thoughts when task demands were very low, meaningful cues were used, and reporting techniques were open-ended and did not rely heavily on retrospection and meta-awareness. These methodological factors should thus be taken into account in future studies analyzing age-related differences in spontaneous thought.

References

Antrobus, J. S., Singer, J. L., & Greenberg, S. (1966). Studies in the stream of consciousness: Experimental enhancement and supression of spontaneous cognitive processes. *Perceptual and Motor Skills, 23,* 399-417.

Balota, D. A., Dolan, P. O., & Duchek, J. M. (2000). Memory changes in healthy young and older adults. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford handbook of memory* (pp. 395-410). New York: Oxford University Press.

Barreto, J., Leuschner, A., Santos, F., & Sobral, M. (2008). Escala de Depressão Geriátrica [Geriatric Depression Scale]. In Grupo de Estudos de Envelhecimento Cerebral e Demência (GEECD), *Escalas e Testes na Demência* (2ª ed., pp. 71-72). Lisboa: Novartis.

Barzykowski, K., & Niedźwieńska, A. (2016). The effects of instruction on the frequency and characteristics of involuntary autobiographical memories. *PloS One, 11*(6), e0157121. doi: 10.1371/journal.pone.0157121

Barzykowski, K., & Niedźwieńska, A. (2018). Priming involuntary autobiographical memories in the lab. *Memory, 26*(2), 277-289. doi: 10.1080/09658211.2017.1353102

Beck, A. T., Steer, R. A., Ball, R., & Ranieri, W. F. (1996). Comparison of Beck Depression Inventories-IA and-II in psychiatric outpatients. *Journal of Personality Assessment*, *67*(3), 588-597. doi: 10.1207/s15327752jpa6703_13

Berntsen, D. (2009). *Involuntary autobiographical memories: An introduction to the unbidden past*. Cambridge: Cambridge University Press.

Berntsen, D., & Jacobsen, A. S. (2008). Involuntary (spontaneous) mental time travel into the past and future. *Consciousness and Cognition, 17*(4), 1093-1104. doi: 10.1016/j.concog.2008.03.001

Berntsen, D., & Rubin, D. C. (2002). Emotionally charged autobiographical memories across the life span: The recall of happy, sad, traumatic and involuntary memories. *Psychology and Aging, 17*(4), 636-652. doi: 10.1037/0882-7974.17.4.636

Berntsen, D., Rubin, D. C., & Salgado, S. (2015). The frequency of involuntary autobiographical memories and future thoughts in relation to daydreaming, emotional distress, and age. *Consciousness and Cognition, 36*, 352-372. doi: 10.1016/j.concog.2015.07.007

Bradley, M. M., & Lang, P. J. (1999). *Affective Norms for English Words (ANEW): Instruction manual and affective Ratings*: Technical Report C-1, The Center for Research in Psychophysiology, University of Florida.

Callard, F., Smallwood, J., Golchert, J., & Margulies, D. S. (2013). The era of the wandering mind? Twenty-first century research on self-generated mental activity. *Frontiers in Psychology, 4*, 1-11. doi: 10.3389/fpsyg.2013.00891

Carstensen, L. L., & DeLiema, M. (2018). The positivity effect: A negativity bias in youth fades with age. *Current Opinion in Behavioral Sciences, 19*, 7-12. doi: 10.1016/j.cobeha.2017.07.009

Christoff, K. (2012). Undirected thought: Neural determinants and correlates. *Brain Research, 1428*, 51-59. doi: 10.1016/j.brainres.2011.09.060

Christoff, K., Irving, Z. C., Fox, K. C. R., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: A dynamic framework. *Nature Reviews Neuroscience, 17*(11), 718-731. doi: 10.1038/nrn.2016.113

Cole, S. N., & Berntsen, D. (2016). Do future thoughts reflect personal goals? Current concerns and mental time travel into the past and future. *The Quarterly Journal of Experimental Psychology, 69*(2), 273-284. doi: 10.1080/17470218.2015.1044542

Cole, S. N., Staugaard, S. R., & Berntsen, D. (2016). Inducing involuntary and voluntary mental time travel using a laboratory paradigm. *Memory and Cognition, 44*(3), 376-389. doi: 10.3758/s13421-015-0564-9

Conway, M. A. (1990). Associations between autobiographical memories and concepts. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*(5), 799-812. doi: 10.1037/0278-7393.16.5.799

Conway, M. A., & Pleydell-Pearce, C. W. (2000). The construction of autobiographical memories in the self-memory system. *Psychological Review, 107*(2), 261-288. doi: 10.1037/0033-295X.107.2.261

Cox, W. M., & Klinger, E. (2002). Motivational structure: Relationships with substance use and processes of change. *Addictive Behaviors, 27*(6), 925-940. doi: 10.1016/S0306-4603(02)00290-3

Craik, F. (1986). A functional account of age differences in memory. In F. Klix & H. Hagendorf (Eds.), *Human memory and cognitive capabilities: Mechanisms and Performances* (pp. 409-422). Amsterdam, North-Holland: Elsevier Science Publishing Company.

D'Argembeau, A. (2016). The role of personal goals in future-oriented mental time travel. In K. Michaelian, S. B. Klein, & K. K. Szpunar (Eds.), *Seeing the future: Theoretical perspective on future-oriented mental time travel* (pp. 199-214). New York: Oxford University Press.

D'Argembeau, A., & Mathy, A. (2011). Tracking the construction of episodic future thoughts. *Journal of Experimental Psychology: General, 140*(2), 258-271. doi: 10.1037/a0022581

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175-191. doi: 10.3758/bf03193146

Finnbogadóttir, H., & Berntsen, D. (2011). Involuntary and voluntary mental time travel in high and low worriers. *Memory, 19*(6), 625-640. doi: 10.1080/09658211.2011.595722

Finnbogadóttir, H., & Berntsen, D. (2013). Involuntary future projections are as frequent as involuntary memories, but more positive. *Consciousness and Cognition, 22*(1), 272-280. doi: 10.1016/j.concog.2012.06.014

Frank, D. J., Nara, B., Zavagnin, M., Touron, D. R., & Kane, M. J. (2015). Validating older adults' reports of less mind-wandering: An examination of eye movements and dispositional influences. *Psychology and Aging, 30*(2), 266-278. doi: 10.1037/pag0000031

Giambra, L. M. (1989). Task-unrelated thought frequency as a function of age: A laboratory study. *Psychology and Aging, 4*(2), 136-143. doi: 10.1037/0882-7974.4.2.136

Giambra, L. M. (2000a). Frequency and intensity of daydreaming: Age changes and age differences from late adolescent to the old-old. *Imagination, Cognition and Personality, 19*(3), 229-267. doi: 10.2190/xn4w-1cre-b0mh-84xt

Giambra, L. M. (2000b). The temporal setting, emotions, and imagery of daydreams: age changes and age differences from late adolescent to the old-old. *Imagination, Cognition and Personality, 19*(4), 367-413.

Hall, S. A., Rubin, D. C., Miles, A., Davis, S. W., Wing, E. A., Cabeza, R., & Berntsen, D. (2014). The neural basis of involuntary episodic memories. *Journal of Cognitive Neuroscience, 26*(10), 2385-2399. doi: 10.1162/jocn_a_00633

Hassabis, D., & Maguire, E. A. (2007). Deconstructing episodic memory with construction. *Trends in Cognitive Sciences, 11*(7), 299-306. doi: 10.1016/j.tics.2007.05.001

Irish, M. (2016). Semantic memory as the essential scaffold for future-oriented mental time travel. In K. Michaelian, S. B. Klein, & K. K. Szpunar (Eds.), *Seeing the future: Theoretical perspective on future-oriented mental time travel* (pp. 389-408). New York: Oxford University Press.

Jackson, J. D., Weinstein, Y., & Balota, D. A. (2013). Can mind-wandering be timeless? Atemporal focus and aging in mind-wandering paradigms. *Frontiers in Psychology, 4*(742), 1-16. doi: 10.3389/fpsyg.2013.00742

Janssen, S. M. J., & Rubin, D. C. (2011). Age effects in cultural life scripts. *Applied Cognitive Psychology, 25*(2), 291-298. doi:10.1002/acp.1690

Johannessen, K. B., & Berntsen, D. (2010). Current concerns in involuntary and voluntary autobiographical memories. *Consciousness and Cognition, 19*(4), 847-860. doi: 10.1016/j.concog.2010.01.009

Jordano, M. L., & Touron, D. R. (2017). Priming performance-related concerns induces task-related mind-wandering. *Consciousness and Cognition, 55*, 126-135. doi: 10.1016/j.concog.2017.08.002

Jordão, M., Ferreira-Santos, F., Pinho, M. S., & St. Jacques, P. L. (2019). Meta-analysis of aging effects in mind wandering: Methodological and sociodemographic factors. *Psychology and Aging, 34*(4), 531–544. doi:10.1037/pag0000356

Klinger, E. (1975). Consequences of commitment to and disengagement from incentives. *Psychological Review, 82*(1), 1-25. doi: 10.1037/h0076171

Klinger, E. (1978). Modes of normal conscious flow. In K. S. Pope & J. L. Singer (Eds.), *The stream of consciousness: Scientific investigations into the flow of human experience* (pp. 225–258). New York: Plenum Press.

Klinger, E., Koster, E. H. W., & Marchetti, I. (2018). Spontaneous thought and goal pursuit from functions such as planning to dysfunctions such as rumination. In K.

Christoff & K. C. R. Fox (Eds.), *The Oxford handbook of spontaneous thought: Mind-wandering, creativity, and dreaming*. Retrieved from https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780190464745.001.0001/oxfordhb-9780190464745-e-24

Kopp, K., D'Mello, S., & Mills, C. (2015). Influencing the occurrence of mind wandering while reading. *Consciousness and Cognition, 34*, 52-62. doi: 10.1016/j.concog.2015.03.003

Lang, F. R., & Carstensen, L. L. (2002). Time counts: Future time perspective, goals, and social relationships. *Psychology and Aging, 17*(1), 125-139. doi: 10.1037/0882-7974.17.1.125

Mace, J. H. (2005). Priming involuntary autobiographical memories. *Memory, 13*(8), 874-884. doi: 10.1080/09658210444000485

Mace, J. H. (2010). Understanding autobiographical remembering from a spreading activation perspective. In J. H. Mace (Ed.), *The act of remembering* (pp. 181-201). Oxford, UK: Wiley-Blackwell.

Maillet, D., & Schacter, D. L. (2016a). From mind wandering to involuntary retrieval: Age-related differences in spontaneous cognitive processes. *Neuropsychologia, 80*, 142-156. doi: 10.1016/j.neuropsychologia.2015.11.017

Maillet, D., & Schacter, D. L. (2016b). When the mind wanders: Distinguishing stimulus-dependent from stimulus-independent thoughts during incidental encoding in young and older adults. *Psychology and Aging, 31*(4), 370-379. doi: 10.1037/pag0000099

Maillet, D., Seli, P., & Schacter, D. L. (2017). Mind-wandering and task stimuli: Stimulus-dependent thoughts influence performance on memory tasks and are more often past- versus future-oriented. *Consciousness and Cognition, 52*, 55-67. doi: 10.1016/j.concog.2017.04.014

Masicampo, E. J., & Baumeister, R. F. (2011). Consider it done! Plan making can eliminate the cognitive effects of unfulfilled goals. *Journal of Personality and Social Psychology, 101*(4), 667-683. doi: 10.1037/a0024192

Mazzoni, G., Vannucci, M., & Batool, I. (2014). Manipulating cues in involuntary autobiographical memory: Verbal cues are more effective than pictorial cues. *Memory and Cognition, 42*(7), 1076-1085. doi: 10.3758/s13421-014-0420-3

McVay, J. C., & Kane, M. J. (2010). Does mind wandering reflect executive function or executive failure? Comment on Smallwood and Schooler (2006) and Watkins (2008). *Psychological Bulletin, 136*(2), 188-207. doi: 10.1037/a0018298

McVay, J. C., & Kane, M. J. (2013). Dispatching the wandering mind? Toward a laboratory method for cuing "spontaneous" off-task thought. *Frontiers in Psychology, 4,* 1-16. doi: 10.3389/fpsyg.2013.00570

McVay, J. C., Meier, M. E., Touron, D. R., & Kane, M. J. (2013). Aging ebbs the flow of thought: Adult age differences in mind wandering, executive control, and self-evaluation. *Acta Psychologica, 142*(1), 136-147. doi: 10.1016/j.actpsy.2012.11.006

Mevel, K., Landeau, B., Fouquet, M., La Joie, R., Villain, N., Mézenge, F., . . . Chételat, G. (2013). Age effect on the default mode network, inner thoughts, and cognitive abilities. *Neurobiology of Aging, 34*(4), 1292-1301. doi: 10.1016/j.neurobiolaging.2012.08.018

Mitchell, K. J., Raye, C. L., Ebner, N. C., Tubridy, S. M., Frankel, H., & Johnson, M. K. (2009). Age-group differences in medial cortex activity associated with thinking about self-relevant agendas. *Psychology and Aging, 24*(2), 438-449. doi: 10.1037/a0015181

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., . . . Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A brief screening tool for Mild Cognitive Impairment. *Journal of the American Geriatrics Society, 53*(4), 695-699. doi: 10.1111/j.1532-5415.2005.53221.x

Nettelbeck, T., & Burns, N. R. (2010). Processing speed, working memory and reasoning ability from childhood to old age. *Personality and Individual Differences, 48*(4), 379-384. doi: 10.1016/j.paid.2009.10.032

O'Callaghan, C., Shine, J. M., Lewis, S. J. G., Andrews-Hanna, J. R., & Irish, M. (2015). Shaped by our thoughts – A new task to assess spontaneous cognition and its associated neural correlates in the default network. *Brain and Cognition, 93*, 1-10. doi: 10.1016/j.bandc.2014.11.001

Parks, C. W., Klinger, E., & Perlmutter, M. (1989). Dimensions of thought as a function of age, gender and task difficulty. *Imagination, Cognition and Personality, 8*(1), 49-62. doi: 10.2190/M6GA-J94F-VRV1-77DR

Piolino, P., Desgranges, B., Clarys, D., Guillery-Girard, B., Taconnat, L., Isingrini, M., & Eustache, F. (2006). Autobiographical memory, autonoetic consciousness, and self-perspective in aging. *Psychology and Aging, 21*(3), 510-525. doi: 10.1037/0882-7974.21.3.510

Plimpton, B., Patel, P., & Kvavilashvili, L. (2015). Role of triggers and dysphoria in mind-wandering about past, present and future: A laboratory study. *Consciousness and Cognition, 33*, 261-276. doi: 10.1016/j.concog.2015.01.014

Redondo, J., Fraga, I., Padrón, I., & Comesaña, M. (2007). The Spanish adaptation of ANEW (Affective Norms for English Words). *Behavior Research Methods, 39*(3), 600-605. doi: 10.3758/BF03193031

Ruby, F. J. M., Smallwood, J., Engen, H., & Singer, T. (2013). How self-generated thought shapes mood—The relation between mind-wandering and mood depends on the socio-temporal content of thoughts. *PloS One, 8*(10), 1-7. doi: 10.1371/journal.pone.0077554

Schacter, D. L., & Addis, D. R. (2007). The cognitive neuroscience of constructive memory: remembering the past and imagining the future. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 362*(1481), 773-786. doi: 10.1098/rstb.2007.2087

Schacter, D. L., Addis, D. R., Hassabis, D., Martin, V. C., Spreng, R. N., & Szpunar, K. K. (2012). The future of memory: Remembering, imagining, and the brain. *Neuron, 76*(4), 677-694. doi: 10.1016/j.neuron.2012.11.001

Schlagman, S., & Kvavilashvili, L. (2008). Involuntary autobiographical memories in and outside the laboratory: How different are they from voluntary autobiographical memories? *Memory and Cognition, 36*(5), 920-932. doi: 10.3758/mc.36.5.920

Schlagman, S., Kliegel, M., Schulz, J., & Kvavilashvili, L. (2009). Differential effects of age on involuntary and voluntary autobiographical memory. *Psychology and Aging, 24*(2), 397-411. doi: 10.1037/a005785

Schmidtke, D. S., Schröder, T., Jacobs, A. M., & Conrad, M. (2014). ANGST: Affective norms for German sentiment terms, derived from the affective norms for English words. *Behavior Research Methods, 46*(4), 1108-1118. doi: 10.3758/s13428-013-0426-y

Seli, P., Maillet, D., Smilek, D., Oakman, J. M., & Schacter, D. L. (2017). Cognitive aging and the distinction between intentional and unintentional mind wandering. *Psychology and Aging, 32*(4), 315-324. doi: 10.1037/pag0000172

Seli, P., Risko, E. F., & Smilek, D. (2016). On the necessity of distinguishing between unintentional and intentional mind wandering. *Psychological Science, 27*(5), 685-691. doi: 10.1177/0956797616634068

Simões, M. R., Freitas, S., Santana, I., Firmino, H., Martins, C., Nasreddine, Z., & Vilar, M. (2008). Montreal Cognitive Assessment (MoCA): versão portuguesa [Montreal Cognitive Assessment (MoCA): portuguese version]. Serviço de Avaliação Psicológica da Faculdade de Psicologia e de Ciências da Educação da Universidade de Coimbra, Coimbra.

Singer, J. L. (1975). Navigating the stream of consciousness: Research in daydreaming and related inner experience. *American Psychologist, 30*(7), 727-738. doi: 10.1037/h0076928

Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin, 132*(6), 946-958. doi: 10.1037/0033-2909.132.6.946

Smallwood, J., & Schooler, J. W. (2015). The science of mind wandering: Empirically navigating the stream of consciousness. *Annual Review of Psychology, 66*(1), 487-518. doi: 10.1146/annurev-psych-010814-015331

Smallwood, J., Nind, L., & O'Connor, R. C. (2009). When is your head at? An exploration of the factors associated with the temporal focus of the wandering mind. *Consciousness and Cognition, 18*(1), 118-125. doi: 10.1016/j.concog.2008.11.004

Soares, A. P., Comesaña, M., Pinheiro, A. P., Simões, A., & Frade, C. S. (2012). The adaptation of the Affective Norms for English Words (ANEW) for European Portuguese. *Behavior Research Methods, 44*(1), 256-269. doi: 10.3758/s13428-011-0131-7

Song, X., & Wang, X. (2012). Mind wandering in Chinese daily lives – An experience sampling study. *PloS One, 7*(9), 1-9. doi: 10.1371/journal.pone.0044423

St. Jacques, P. L., & Levine, B. (2007). Ageing and autobiographical memory for emotional and neutral events. *Memory, 15*(2), 129-144. doi: 10.1080/09658210601119762

Stawarczyk, D., Majerus, S., Maj, M., Van der Linden, M., & D'Argembeau, A. (2011). Mind-wandering: Phenomenology and function as assessed with a novel experience sampling method. *Acta Psychologica, 136*(3), 370-381. doi: 10.1016/j.actpsy.2011.01.002

Vannucci, M., & Chiorri, C. (2018). Individual differences in self-consciousness and mind wandering: Further evidence for a dissociation between spontaneous and deliberate mind wandering. *Personality and Individual Differences, 121*, 57-61. doi: 10.1016/j.paid.2017.09.022

Vannucci, M., Batool, I., Pelagatti, C., & Mazzoni, G. (2014). Modifying the frequency and characteristics of involuntary autobiographical memories. *PloS One, 9*(4), 1-7. doi: 10.1371/journal.pone.0089582

Vannucci, M., Pelagatti, C., & Marchetti, I. (2017). Manipulating cues in mind wandering: Verbal cues affect the frequency and the temporal focus of mind wandering. *Consciousness and Cognition, 53*, 61-69. doi: 10.1016/j.concog.2017.06.004

Vannucci, M., Pelagatti, C., Chiorri, C., & Mazzoni, G. (2015). Visual object imagery and autobiographical memory: Object Imagers are better at remembering their personal past. *Memory, 24*(4), 455-470. doi: 10.1080/09658211.2015.1018277

Vannucci, M., Pelagatti, C., Hanczakowski, M., Mazzoni, G., & Paccani, C. R. (2015). Why are we not flooded by involuntary autobiographical memories? Few cues are more effective than many. *Psychological Research, 79*(6), 1077-1085. doi: 10.1007/s00426-014-0632-y

Weinstein, Y. (2018). Mind-wandering, how do I measure thee with probes? Let me count the ways. *Behavior Research Methods, 50*(2), 642-661. doi: 10.3758/s13428-017-0891-9

Weinstein, Y., De Lima, H. J., & van der Zee, T. (2018). Are you mind-wandering, or is your mind on task? The effect of probe framing on mind-wandering reports. *Psychonomic Bulletin & Review, 25*(2), 754-760. doi: 10.3758/s13423-017-1322-8

Yesavage, J. A., Brink, T. L., Rose, T. L., Lum, O., Huang, V., Adey, M., & Leirer, V. O. (1983). Development and validation of a geriatric depression screening scale: A preliminary report. *Journal of Psychiatric Research, 17*(1), 37-49.

Study 3. The effects of aging and an episodic specificity induction on spontaneous task-unrelated thought

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Age-related differences are typically attenuated when the amount of self-initiated processing is minimal (Craik, 2020). Currently, it is unclear if this is also the case for spontaneous thoughts which are not self-initiated and come into awareness with reduced intentionality and effort (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Cole & Kvavilashvili, 2019). Spontaneous thoughts are frequent daily occurrences (Kane et al., 2017) and play an important role in planning, creativity, and memory consolidation (Klinger, Koster, & Marchetti, 2018). Past-oriented spontaneous thoughts, in particular, are at least as frequent as deliberate memories (Rasmussen, Ramsgaard, & Berntsen, 2015) and contribute to maintaining a sense of time and personal continuity (Rasmussen & Berntsen, 2009). Aging research has mainly focused on the occurrence of spontaneous thoughts, with a recent meta-analysis finding a reduced frequency of spontaneous thoughts in older compared to younger adults (Jordão, Ferreira-Santos, Pinho, & St. Jacques, 2019). In contrast, the impact of aging on qualitative aspects of spontaneous thoughts, such as episodic specificity, remains largely unexplored. Aging typically reduces episodic specificity during deliberate retrieval of autobiographical memories and imagined events (for a review, see Devitt, Addis, & Schacter, 2017). However, recent research has shown that an episodic specificity induction (ESI) that involves training in recollecting details of past events can increase episodic specificity in aging (Madore, Gaesser, & Schacter, 2014) by targeting episodic retrieval processes that support the construction of event representations (Schacter & Madore, 2016). In the current study we analyzed the impact of aging on episodic specificity and used the ESI to determine whether constructive processes contribute to the episodic specificity of spontaneous thoughts.

Aging and Spontaneous Thought

A growing number of studies have examined the influence of aging on spontaneous thought frequency as the result of increasing interest in mind wandering. Mind wandering

(MW) describes a shift of attention from an external task to internal contents (Smallwood & Schooler, 2006). Although MW can sometimes be deliberate (Seli, Carriere, & Smilek, 2015), it is typically characterized as spontaneous thought (Christoff et al., 2016), such that spontaneous MW is three times more frequent than deliberate MW across age groups (Seli, Maillet, Smilek, Oakman, & Schacter, 2017). Older adults typically have a reduction in MW frequency (Maillet & Schacter, 2016), but in a recent meta-analysis we found that methodological differences related to reporting mode, response options, task difficulty, and socio-demographical variables contributed to the pattern of age-related differences (Jordão, Ferreira-Santos, et al., 2019). Importantly, when controlling for these methodological variables, we found no evidence of age-related differences in the frequency of spontaneous task-unrelated thoughts (Jordão, Pinho, & St. Jacques, 2019).

Research on involuntary autobiographical memory (IAM) also contributes to the understanding of age effects in spontaneous thoughts. Involuntary memories come to mind effortlessly and without a previous retrieval attempt (Berntsen, 2009), and are thus a type of spontaneous thought. Several studies have demonstrated a lack of age-related differences in IAM frequency as measured by inventory (Berntsen, Rubin, & Salgado, 2015), questionnaire (Berntsen & Rubin, 2008; Rubin & Berntsen, 2009), or diary studies (Schlagman, Kliegel, Schulz, & Kvavilashvili, 2009). Would the lack of age-related changes in the frequency of MW and IAM extend to qualitative aspects of spontaneous thought? In the next section, we explore this question for episodic specificity.

Aging and Episodic Specificity

Episodic specificity refers to the degree to which a content includes specific event information ("what", "when" and "where") and experiential detail (Tulving, 2002). Aging leads to a decrease in episodic specificity during deliberate recall of personally experienced past events (i.e., autobiographical memories; e.g., Devitt et al., 2017; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002; Piolino et al., 2010; Schlagman et al., 2009; St. Jacques & Levine, 2007) and future events (e.g., Addis, Musicaro, Pan, & Schacter, 2010; Cole, Morrison, & Conway, 2013; Zavagnin, De Beni, Borella, & Carretti, 2016). The age-related decrease in episodic specificity has been shown using different measures, ranging from the simplest distinction between a specific versus general event to more complex classification systems such as the objective assessment of participants' descriptions using the Autobiographical Interview (AI; Levine et al., 2002) and the *Test Episodique de la*

Mémoire du Passé lointain autobiographique (TEMPau; Piolino et al., 2002). Both of these objective assessments of episodic specificity are less susceptible to age-related biases than detail ratings provided by participants (in which different age patterns are found; Addis et al., 2010; Gallo, Korthauer, McDonough, Teshale, & Johnson, 2011).

In terms of mechanisms, the age-related decrease in episodic specificity is associated with reductions in strategic elaboration (St. Jacques, Rubin, & Cabeza, 2012) and effortful processes such as executive functions, both in past (Piolino et al., 2010; Ros et al., 2009) and future thoughts (Cole et al., 2013; Zavagnin et al., 2016). Thus, we would expect age-related differences in episodic specificity to be reduced when retrieval is less reliant on strategic processes, such as in spontaneous thoughts. In fact, a key difference between deliberate and spontaneous retrieval is that the former is more effortful as shown, for example, by slower retrieval times (Schlagman & Kvavilashvili, 2008) and by the involvement of brain regions associated with monitoring and cognitive control (Cabeza & St. Jacques, 2007). Effortful retrieval processes are associated with generative retrieval, that is, a strategic process of search that begins at the most general level of knowledge about oneself and by successive iterations accesses a specific event (Conway, 2005). Alternatively, event representations about the past (Uzer, Lee, & Brown, 2012) and future (Jeunehomme & D'Argembeau, 2016) may be accessed effortlessly in a direct or associative fashion (Conway, 2005; Moscovitch, 1995), purportedly based on a process of cue-item discriminability by which a distinctive cue isolates a specific event by automatic spreading activation (Berntsen, 2009; Rubin, 1995). Spontaneous retrieval by definition involves more direct than strategic search processes, and by its effortless nature, should make it easier for older adults to access event specific information.

In contrast with the wealth of data for deliberate retrieval, less is known about age-related changes in episodic specificity for spontaneous retrieval. The current evidence suggests that aging does not reduce episodic specificity for spontaneous thoughts. Schlagman and collaborators investigated IAMs in diary studies in which younger and older adults recorded every memories that came to mind and classified them as referring to a single, extended, or repeated events, and found no age-related differences (Schlagman et al., 2009; Schlagman, Kvavilashvili, & Schulz, 2007). However, these findings were based solely on self-report, which could introduce biases (e.g., participants classify IAMs as more specific when asked to report only memories versus any type of content; Vannucci, Batool, Pelagatti, & Mazzoni, 2014). In sum, it is necessary to examine age-related differences in episodic specificity based on the independent assessment of participants' descriptions, which will also facilitate comparisons between age-related differences in spontaneous and deliberate retrieval (as in Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002; Piolino et al., 2006).

Episodic Specificity Induction

Recent research has shown that episodic specificity can be increased experimentally, in both younger and older adults, using an episodic specificity induction (ESI; Schacter & Madore, 2016). The ESI increases episodic detail by leading to a specific retrieval orientation that facilitates the construction of specific episodes, that is "the assembly of a mental scenario bound in space and time with details related to settings, people, and actions" (Madore, Jing, & Schacter, 2019, p. 2)[8]. The ESI consists of a brief training based on the cognitive interview (Fisher & Geiselman, 1992) that focuses on the recall of specific details. For example, Madore, Gaesser, & Schacter (2014) used the ESI to look at event construction in memory and imagination. In this study, participants watched a brief video and subsequently recalled it. During the ESI, the experimenter asked participants to recall the video focusing on the details (objects, people, and actions) using pre-determined questions. During the control condition, participants were instructed to focus on their general impressions about the video. Following the ESI or control condition, participants were asked to describe memories and future thoughts. More episodic details (as measured by the Autobiographical Interview coding; Levine et al., 2002) were recalled in both memories and future thoughts following the ESI compared to the control condition. Several studies have replicated these finding in other deliberate tasks (creative thinking in Madore, Jing, & Schacter, 2016; problem-solving in Madore & Schacter, 2014). Thus, the ESI is a robust method to target event construction and increase episodic specificity.

Whether the ESI effect will also impact episodic specificity in spontaneous thoughts is currently unknown. By nature, spontaneous thoughts do not involve the type of goal-directed and deliberate nature of tasks that have been shown to be influenced by ESI. Despite the lack of intention and seemingly ease with which spontaneous thoughts come to mind, it has been suggested that spontaneous thoughts still rely on event construction

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[8]Please note that the term "construction" is frequently used in memory literature to refer to different concepts and/or processes (Michaelian, 2011). Here, we are consistent with other ESI studies and define construction focusing on the process of binding the different types of episodic details that constitute an event.

because they share the same episodic memory system and differ only in the effort required at retrieval (for a review, see Berntsen, 2010). Specifically, during spontaneous thoughts a cue, instead of an effortful search process, would "activate event-relevant units, or nodes, in the network and deactivate irrelevant units that would otherwise interfere with the construction of the memory" (Berntsen, 2009, p. 106). Alternatively, it has been suggested that direct retrieval processes that characterize spontaneous thought imply the existence of pre-stored event representations, independent of event construction (Uzer et al., 2012). According to this perspective, we would not expect an effect of the ESI on spontaneous thought. Thus, investigating the influence of the ESI will reveal whether spontaneous thoughts involve event construction. In practice, it will indicate whether the ESI is useful to increase episodic specificity in spontaneous thought.

The Present Study

In the present study we examined the effects of aging on episodic specificity of spontaneous thoughts reported by healthy younger and older adults in a laboratory task. In two sessions separated by approximately a week, we used either the ESI or a control induction followed by a vigilance task to elicit spontaneous thoughts, which were audio-recorded at random stops and later analyzed by independent coders for episodic specificity. We had two main aims. First, we investigated whether the lack of age-related differences in the episodic specificity of IAMs would generalize: (1) in a lab-task, (2) from past to spontaneous thoughts in general, and future thoughts particularly, and (3) when episodic specificity was assessed by independent coders. The lack of age-related differences in our study would indicate that age effects in episodic specificity are diminished in spontaneous retrieval. Second, we examined whether the episodic specificity of spontaneous thoughts depends upon the deliberate involvement of event construction by comparing the influence of the ESI to a control induction procedure prior to the elicitation of spontaneous thoughts (Schacter & Madore, 2016). Additionally, given the novelty of the present approach and the scarce evidence on the topic, we analyzed several phenomenological variables including emotional valence and arousal (that have been shown to interact with specificity in deliberate retrieval; Kensinger, 2009; St. Jacques & Levine, 2007), visual/verbal imagery, and detail based on subjective ratings.

Method

Sample

To determine the sample size necessary to identify an ESI effect, we reviewed previous studies with younger and older adults. For memories and imagined scenarios the effect ranges from .62 to .78 (Jing, Madore, & Schacter, 2016; Madore et al., 2014; Madore & Schacter, 2014). Based on an a priori power analysis, considering an effect of *d* = .60, power =.80 and a two-tailed repeated measures test we determined a sample of 24 participants for each age group (Faul, Erdfelder, Lang, & Buchner, 2007). This sample size is adequate to identify large overall age-differences in specificity (*d* > .80, power =.80, one-tailed test) similar to studies investigating memory and imagination (e.g., Madore, Gaesser, & Schacter, 2014; Madore & Schacter, 2014). This should ensure that when overall age-related differences in episodic specificity in spontaneous thoughts are similar to those found in deliberate thoughts, we will be able to identify them.

Participants were excluded if they reported a history of neurological and psychiatric diagnosis, and/or moderate to severe depressive symptomatology, which was assessed using the Beck Depression Inventory II (BDI-II, Beck, Steer, & Brown, 1996; Oliveira-Brochado, Simões, & Paúl, 2014). Older adults also performed a cognitive function test and no participant showed evidence of cognitive decline (based on Portuguese norms, cut-off 2 standard deviations below the mean for age and education level; Montreal Cognitive Assessment, MoCA, Nasreddine et al., 2005; Simões, 2008).

The final sample comprised 24 younger adults [22 women, mean age in years (*M*) = 20.21, *SD* = 2.75] and 24 older adults (22 women, *M* = 67.58, *SD* = 3.92). There was no evidence of age-related differences in the number of years of education (based on *U* Mann–Whitney, *Z* = - 0.95, *p* = .34) between younger (*M* = 13.98, *SD* = 1.62) and older participants (*M* = 13.17, *SD* = 4.54).

Design

The study used a quasi-experimental design, with type of induction (episodic specificity induction, control induction) as a within-subjects variable and age group (younger, older) as a between-subjects variable.

Procedure

The experimental procedure is represented in Figure 3. Participants attended two sessions, approximately 7 days apart (*M* = 7.13, *SD* = 1.30). Both sessions included a (episodic or control) induction, in which a video was presented, and a vigilance task to elicit spontaneous thoughts. Task presentation was counterbalanced in all eight possible combinations for order of induction (control, episodic specificity), video (version A, version B) and vigilance task (version A, version B),[9] to rule out order effects. At the end of the first session, we collected sociodemographic and clinical information, and older adults were administered the cognitive screening test. At the end of the second session, both groups filled in a depressive symptomatology inventory and were asked about what they thought the aim of the experiment was. No participant mentioned that the experiment aimed to analyze specificity.

Episodic Specificity and Control Induction

For the episodic specificity and control induction we followed the procedure applied previously (Madore et al., 2014; Madore, Jing, et al., 2016; Madore & Schacter, 2014). Participants were assigned to two sessions, beginning with a 2-minute video. The video was different in each session, but both depicted actions in a kitchen. This was followed by a 3-minute filler task (addition/subtraction math problems). Then, in the ESI, participants were asked to create a mental image and describe the details of the surroundings, people and actions depicted in the video as completely as possible. In contrast, in the control induction, participants were asked to solve more math problems (Madore, Jing, et al., 2016), as this has been identified as the most neutral control condition (see Madore et al., 2014). The instructions were translated from English to European Portuguese by one of the authors (MJ) and edited for clarity with two Portuguese native speakers with research experience.

[9]There is an exception to the full counterbalance for one participant in the older adults' group. In this case, the order of presentation of the videos was switched, so that there is one more participant in this group with one of the two possible orders for video presentation. Importantly, this did not affect the other variables being counterbalanced, namely, vigilance task version and control/episodic specificity induction, which were fully counterbalanced. Thus, it was unlikely that this case would impact the results and it was included in the final sample.

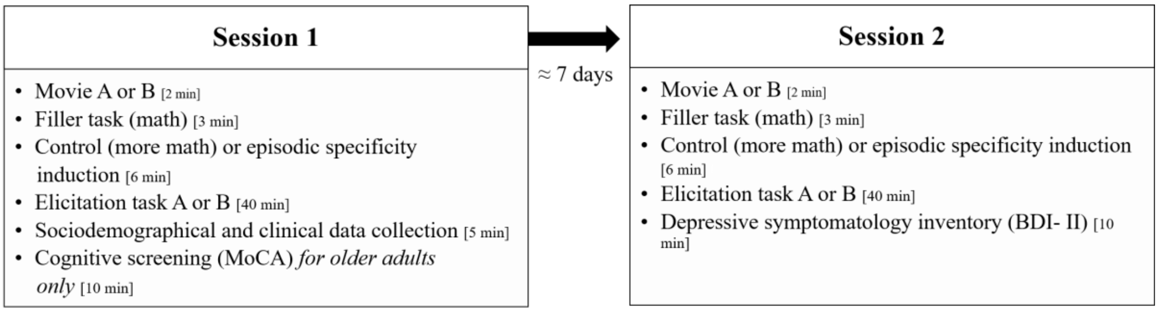

Figure 3. Experimental procedure.

Vigilance Task

After the induction procedure, participants performed a vigilance task in order to elicit spontaneous task-unrelated thoughts (sTUTs). Prior to starting the task participants assessed their motivation level, to avoid the influence of perceived performance on these ratings (Frank et al., 2015). There were two versions of the vigilance tasks for each session. Each version included 72 different words that were matched in terms of valence, arousal (Soares, Comesaña, Pinheiro, Simões, & Frade, 2012), frequency, concreteness and imageability (Soares, Costa, Machado, Comesaña, & Oliveira, 2017, see Supplementary Material 3.1 for word characteristics). The cue frequency was approximately one cue-word every 13.33 seconds (*SD* = 3.85).

The vigilance task was based on our previous adaptation (Jordão, Pinho, et al., 2019) of a task created by Schlagman and Kvavilashvili (2008). Our earlier study found no evidence of age differences in MW frequency (Jordão, Pinho, et al., 2019), suggesting that the adaptation controlled for confounding factors. In the current study, we made three additional improvements. First, we increased the number of probes to 12, increasing the ability to capture sTUTs. Second, we controlled for the number and characteristics of the word cues presented between each probe. Third, we changed the ISI from 7 to 3 seconds, which was important because longer ISIs require spontaneous thoughts triggered by word-cues to be maintained longer to be caught in the probes. Thus, by reducing the ISI, we are able to record both longer and shorter thoughts.

The final task took 15.9 minutes, and randomly presented 72 words and 87 five-point sequences for 3 seconds, followed by a 3 seconds ISI. These stimuli were presented in either black or yellow, 64-point bold Arial, in a 1366 pixels (width) x 768 pixels (height) screen, using E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA). Participants were asked to say “yes” out loud when a yellow stimulus was presented, which happened three times (1.9% of the stimuli, similar to Schlagman & Kvavilashvili, 2008). An experimenter registered task performance. Randomized probes were presented in intervals of 54, 78 and 108 seconds, similar to previous studies (e.g., 52.5 to 105 seconds, Plimpton et al., 2015). When probes were presented, participants were asked to stop and "describe out loud everything you can about what was on you mind immediately before you saw this screen" to an audio recorder. To make sure the participants reported everything that came to mind, a standardized probe was used after every description ("Can you describe anything else about that thought? I want to know all the details that you thought about"). Immediately after, participants answered additional questions presented by the experimenter, including ratings for spontaneity, triggers, temporality, visual imagery, valence, arousal and detail. For spontaneity, participants used a scale from 1 = I wasn't trying to bring this to my mind at all, to 7 = I tried very hard (as in e.g., Barzykowski & Niedźwieńska, 2016). For triggers, participants were asked to indicate whether the content was triggered by an external stimulus, and if so, what stimulus. For temporality, participants classified a thought as past, present and future-oriented if it was related to something occurring before, during or after the task, respectively, and atemporal if the thought lacked a temporal orientation (following Maillet, Seli, & Schacter, 2017). For visual imagery, participants classified their thoughts as predominantly verbal or visual, following McCormick et al. (2018). For valence, arousal and detail, participants used a 1 to 7 scale (from very unpleasant to extremely pleasant, not intense at all to extremely intense and not detailed at all to extremely detailed). After the completion of the vigilance task, participants were asked to indicate their level of concentration and the difficulty of the task (from 1 = not concentrated/motivated/difficult at all to 5 = extremely concentrated/motivated/difficult).

Experimenter Coding

Type of Thought

To classify thoughts elicited during the vigilance task, we followed a family resemblances view of MW (Seli et al., 2018). According to this approach, MW is a naturally heterogeneous concept that includes sTUTs, and the main concern of experiments should be to specify the type of MW being assessed. Here, we determined if thoughts were related or unrelated to the task based on independent coders' assessment of the descriptions provided by participants.[10] Additionally, independent coders identified two types of sTUTs

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[10]We started by asking participants to classify task-relatedness in a 1 to 7 scale (not at all related to completely related), but a preliminary analysis of the responses suggested that this question was

that were not suitable for the episodic specificity analysis: external distractions and earworms. First, we defined external distractions (EDs) as “sensory perceptions/sensations irrelevant to the current task” (Stawarczyk, Majerus, Maj, Van der Linden, & D’Argembeau, 2011, p. 371), associated with situations in which environmental features capture the participant’s attention, in line with previous research (Stawarczyk et al., 2011; Unsworth & McMillan, 2014). Second, we separately defined earworms or involuntary musical imagery in which participants described having only music in mind (Williamson, Liikkanen, Jakubowski, & Stewart, 2014). There is evidence that musical memories rely on a different cognitive system and show distinct age-related patterns (e.g., Cuddy, Sikka, & Vanstone, 2015), suggesting possible interactions with aging also in spontaneous retrieval. For this reason, we analyzed these spontaneous thoughts separately.

Episodic Specificity

Unlike previous studies using the ESI (e.g., Madore et al., 2014), we were not able to assess specificity based on the number of internal and external details (Levine et al., 2002). This was due to the nature of the descriptions provided by participants in which much of the information related with time and place was provided implicitly. Take the following example: “I was thinking that my roommate let olive oil burn and then we had to be lightening up candles to see if that smell went away". Here, there is no explicit mention of a specific time and place, and, thus, this information would not be scored based on the number of internal and external details (Addis et al., 2008). However, the description does imply a specific event, in contrast with descriptions in which time and place details are not mentioned such as: "I was thinking about my brother, I imagined his image and his way of being". Additionally, the descriptions were usually short. In contrast, participants typically provide a narrative with a beginning, middle and end when asked to explicitly recall memories, and are thus more likely to naturally mention details related to time and place. To better capture episodic aspects of spontaneous thoughts we used the coding scheme of the TEMPau (Piolino et al., 2006), which focuses on the nature of the event described (repeated or extended in time, with or without a place) while still enabling the identification of situations in which additional detail (such as feelings or visual imagery)

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confusing. Specifically, some participants would automatically classify a thought as task-related if it was triggered by a stimulus presented in the task, irrespective of the content being related to the task or not, thereby confounding the stimulus-(in)dependency and task-(un)relatedness dimensions.

is provided. Importantly, the TEMPau can capture age-related differences in episodic specificity for voluntary thoughts (e.g., Piolino et al., 2006). One minor change was introduced to the coding scheme to account for atemporal scenarios (e.g., “I saw many refugees in a small boat, struggling”). Atemporal scenarios were coded 1 although they did not include time information (see Supplementary Material 3.2 for instructions) in order to distinguish these more detailed descriptions from general information statements (in line with McCormick et al., 2018).

Interrater Reliability

Two coders categorized each thought record according to whether: (1) they were a case of external distraction, earworm or none of those two, (2) they were task-related or unrelated, (3) episodic specificity. Situations in which participants reported they had nothing on their mind, and/or non-spontaneous thinking were not coded, but instead were excluded from further analyses. Coders were blind to the experimental conditions and hypotheses; however, participant age could sometimes be inferred from the audio record. Disagreements were analyzed by a third independent coder who was also blind to experimental condition and hypotheses. The interrater reliability was good (for OAs; *Kappa* = .73) or very good (for YAs; *Kappa* = .80) for identifying external distractions and earworms, very good (*Kappa* = .87 for OAs; *Kappa* = .89 for YAs) for task-(un)relatedness, and good (weighted *Kappa* = .79 for OAs; weighted *Kappa* = .72 for YAs) for episodic specificity.

Results

Statistical Analyses

We were interested in possible null effects for sTUTs frequency and episodic specificity. Thus, for these variables we followed null results in the frequentist analyses with Bayesian analyses. These were performed with the JASP software (JASP Team, 2019) and, if not indicated otherwise, are based on the JASP default settings (fixed effects with r scale prior width of 0.5 for repeated-measures ANOVAs).

Self-rated Motivation, Concentration and Task Difficulty

We investigated motivation, concentration and task difficulty ratings separately in 2 (age group: young, older) × 2 (type of induction: ESI, control) mixed ANOVAs (see variable description by group and induction in Table 3.1). We found no main effects or interactions (*p*'s > .11), except for concentration, in which older adults reported greater concentration levels (M = 4.29, SD = 0.72) than younger adults (M = 3.71, SD = 0.72) across type of induction, $F(1,46) = 7.69$, $MSE = 8.17$, $p = .008$, $\eta_p^2 = .14$.

	Motivation		Concentration		Difficulty	
	Younger	Older	Younger	Older	Younger	Older
ESI	4.17 (0.70)	4.42 (0.93)	3.75 (1.03)	4.29 (0.75)	1.58 (1.10)	1.13 (0.45)
Control	4.21 (0.78)	4.46 (0.72)	3.67 (0.82)	4.29 (0.75)	1.46 (0.72)	1.42 (0.78)

Table 3.1. Mean ratings (standard deviation) of motivation, concentration and difficulty by age group in the episodic specificity induction and in the control induction.

Type of Thought

We started by analyzing spontaneity based on the ratings given by participants. Thoughts rated from 1 to 3 were categorized as spontaneous, 4 as undecided, and 5 to 7 as deliberate. The majority of the thoughts were spontaneous (84% in YA and 86% in OA). The mean frequency and standard deviation of each type of spontaneous thought by type of induction and age group is presented in Table 3.2. Inspection of the frequency distributions of earworms, external distractions and task-related thoughts revealed that they were not normal (Shapiro-Wilk test, $p < .001$) and variances were mainly heterogeneous ($p \leq .001$, except task-related thoughts in ESI, $p = .310$), thus we used the Mann-Whitney U test to test for differences due to age-group. Earworms were more frequent for younger than older adults in both the control ($Z = - 2.34$, $p = .02$) and ESI ($Z = - 2.59$, $p = .01$). Younger adults also experienced significantly fewer EDs than older adults in the control induction ($Z = - 2.54$, $p = .01$).

	Earworm		External distraction		Task-related		Task-unrelated	
	Younger	Older	Younger	Older	Younger	Older	Younger	Older
ESI	0.33 (0.64)	None	0.13 (0.34)	0.50 (0.93)	1.25 (1.60)	1.54 (1.69)	4.58 (3.23)	4.29 (3.52)
Control	0.25 (0.53)	None	0.13 (0.34)	0.54 (0.72)	0.96 (1.12)	1.92 (1.98)	4.75 (3.25)	4.33 (3.33)

Table 3.2. Mean number (standard deviation) of earworms, external distractions, task-related thought, and task-unrelated thought reported by each age group, in the episodic specificity induction and in the control induction.

Spontaneous TUTs Frequency

To examine the frequency of sTUTs we performed a 2 (age group: young, older) × 2 (type of induction: ESI, control) mixed ANOVA. As expected, there was no main effect for age group (p = .695), type of induction (p = .765), or their interaction (p = .857). To characterize whether the lack of finding reflected a true null effect we conducted a Bayesian analysis including the same factors 2 (age group: young, older) × 2 (type of induction: ESI, control). The inverse Bayes factor for age group indicates that the present data is twice as more likely under a null effects model (BF_{01} = 2.23), providing weak support for the null hypothesis (following guidelines in van Doorn et al., 2019). If we consider that the medium effect size of age-related differences in MW in previous studies has been shown to be 0.89 (Jordão, Ferreira-Santos, et al., 2019) and adapt the prior information accordingly, the inverse Bayes factor for age group (BF_{01} = 3.20) indicates moderate support for the null hypothesis. For type of induction (BF_{01} = 4.55) the evidence in favor of the null was moderate. Thus, these findings suggest that training participants to report episodic details with the ESI does not change the amount of sTUT experienced by participants. The comparison between younger and older adults is in line with the absence of age-related effects found previously. When the size of previous age effects is considered, there is moderate evidence that such difference in the amount of sTUTs experienced by younger and older adults is not observed here.

Participant-based Classifications

We also investigated the impact of several key variables based on participants' classification on the frequency of sTUTs by including them in separate ANOVAs (see the descriptive statistics for trigger status, temporality and visual/verbal form in the Supplementary Material 3.3). To examine the impact of trigger status, we performed a 2 (age group: young, older) × 2 (type of induction: ESI, control) × 2 (trigger status: without trigger, with trigger) mixed ANOVA on the frequency of sTUT. We found a main effect of trigger status, $F(1,46) = 45.22$, $MSE = 475.02$, $p < .001$, $\eta_p^2 = .50$, as sTUTs with a trigger (M = 3.82, SD = 3.10) were more frequent than sTUTs without a trigger (M = .68, SD = .72). No other effects or interactions were found (p's > .67). The Bayesian analyses were consistent with these results, showing moderate to extreme support for models excluding all effects and interactions ($BF_{Exclusion} > 9.16$) but trigger status ($BF_{Exclusion} < 0.01$).

To examine the impact of temporality, we performed a 2 (age group: young, older) × 2 (type of induction: ESI, control) × 4 (temporality: past, present, future, atemporal) mixed ANOVA on the frequency of sTUTs. The Greenhouse-Geisser correction was used here and elsewhere to adjust for violations of sphericity. We found a main effect of temporality, $F(2.40,110.36) = 5.25$, $MSE = 22.20$, $p = .004$, $\eta_p^2 = .10$, and post-hoc analyses revealed that present sTUTs ($M = 0.69$, $SD = 0.75$) were less frequent ($p = .003$) than past sTUTs ($M = 1.56$, $SD = 1.66$). Additionally, temporality interacted with age group, $F(2.40,110.36) = 3.49$, $MSE = 14.74$, $p = .026$, $\eta_p^2 = .07$, with post-hoc analyses showing that present sTUTs were more frequent in older than younger adults ($p < .001$, $M = 0.25$, $SD = 0.74$ for YAs and $M = 1.13$, $SD = 0.74$ for OAs), with no evidence of age differences in other temporalities ($p \geq .07$). No other effects or interactions were found (p's $> .16$). The Bayesian analyses supported models including the temporality effect and the interaction with age group ($BF_{Exclusion} < 0.10$). For age group the evidence arising from the Bayesian analysis was inconclusive ($BF_{Exclusion} = 0.47$), while there was strong to extreme support for models excluding type of induction and remaining interactions ($BF_{Exclusion} > 20.40$).

We examined the impact of the verbal or visual form on the frequency of sTUTs, in a 2 (age group: young, older) × 2 (type of induction: ESI, control) × 2 (form: verbal, visual) mixed ANOVA. This revealed a main effect of form, $F(1,46) = 4.54$, $MSE = 26.25$, $p = .038$, $\eta_p^2 = .09$, which was reflected by less frequent verbal sTUTs ($M = 1.85$, $SD = 1.47$) than visual sTUTs ($M = 2.59$, $SD = 2.34$). There was also interaction between form and age group, $F(1,46) = 7.46$, $MSE = 43.13$, $p = .009$, $\eta_p^2 = .14$. Post-hoc analyses revealed that verbal sTUTs ($M = 1.50$, $SD = 1.47$) were less frequent ($p = .001$) than visual sTUTs ($M = 3.19$, $SD = 2.34$) in younger adults, but frequency did not differ according to form in older adults (verbal: $M = 2.21$, $SD = 1.47$; visual: $M = 2.00$, $SD = 2.34$). No other effects or interactions were found (p's $> .34$). This was in line with the Bayesian analysis that showed moderate to extreme support for a model excluding all effects and interactions ($BF_{Exclusion} > 7.99$) but age group ($BF_{Exclusion} = 0.07$), form ($BF_{Exclusion} = 0.01$) and their interaction ($BF_{Exclusion} = 0.02$).

Finally, we conducted analyses for detail, valence, and arousal on a subsample of 21 YAs and 18 OAs who reported sTUTs in both sessions (ESI and control), in order to assess potential changes on these phenomenological dimensions (see Table 3.3 for descriptive statistics). We conducted a 2 (age group: young, older) × 2 (type of induction:

ESI, control) mixed ANOVA separately for each rating, however, there were no effects or interactions (all p's > .18).

	Detail		Valence		Arousal	
	Younger	Older	Younger	Older	Younger	Older
ESI	4.07 (1.26)	3.56 (1.54)	3.93 (0.96)	4.21 (0.86)	3.05 (1.39)	3.25 (1.31)
Control	4.27 (0.91)	3.94 (1.09)	3.98 (0.53)	4.14 (0.98)	2.85 (1.19)	3.33 (1.34)

Table 3.3. Mean ratings (standard deviation) of detail, valence and arousal by age group in the episodic specificity induction (ESI) and in the control induction.

Spontaneous TUTs Episodic Specificity

To examine episodic specificity we calculated overall and strictly episodic scores, based on the TEMPau (Piolino et al., 2006). The overall score includes all instances in which participants described an event, either specific or generic (levels 1 to 4 in the TEMPau), which allowed us to characterize thoughts associated with events irrespective of whether they referred to a unique experience or not. This is important following the idea that events are key to mental time travel and provide a better contrast to semantic memory than the unique occurrences emphasized by episodic memory (Rubin & Umanath, 2015). In contrast, the strictly episodic score includes only specific events described with detail (level 4 in the TEMPau). The presence of phenomenological detail associated with a specific event is considered diagnostic of the degree of episodicity and reliving (Piolino et al., 2006, based on Brewer, 1996; Wheeler, Stuss, & Tulving, 1997), which was a central focus of the current study. We included one additional measure of episodic specificity to capture thoughts referring to specific events with and without detail (levels 3 and 4 in the TEMPau; based on Schlagman et al., 2009). This is a widely accepted definition of episodic specificity that has been shown to adequately distinguish psychopathological memory changes (Williams et al., 2007). Additionally, including the same measure used as a previous diary study on IAMs (Schlagman et al., 2009) is important to assess whether the null age-related effect generalizes here.

Finally, we also investigated differences in episodic specificity using all of the categories distinguished in the TEMPau coding scheme (Piolino et al., 2006). These included: general knowledge, repeated/extended event not situated in time and place, repeated/extended event situated in time and place, specific event situated in time (<24h) and place without additional details, and specific event situated in time (<24h) and place with additional details. This was an exploratory analysis deemed important by the scarcity of studies analyzing the specificity of sTUTs and aging.

Episodic Specificity Measures

We conducted 2 (age group: young, older) × 2 (type of induction: ESI, control) mixed ANOVAs on the overall, strictly episodic scores, and episodic events with and without detail. There were no significant main effects or interactions (all *p*'s > .10). To characterize whether the lack of significant findings reflected a true null effect we conducted additional Bayesian analyses. For the overall episodic specificity score, there was weak support for the null or the alternative hypothesis for either the effect of age group (BF_{01} = 1.80) and induction (BF_{01} = 2.13). However, there was strong evidence in favor of the null (BF_{01} = 13.21) for the interaction. If we consider that the effect size of age-related differences in deliberate retrieval for the same episodic specificity measure in a previous study has been shown to be 1.08 (Piolino et al., 2006), and adapt the prior information accordingly, the inverse Bayes factor for age group (BF_{01} = 2.99) indicates moderate support for the null hypothesis. This suggests that episodic specificity in younger and older adults does not differ here as in deliberate retrieval. For the strictly episodic score, there was moderate to strong support for the null hypothesis for both main effects and the interaction (BF_{01} > 3.88). A similar result was found for the age effect (BF_{01} = 5.51) when adapting the prior based on a previous effect size of 0.74 (Piolino et al., 2006). For the episodic events with and without detail there was no clear support for age-related differences or their absence (BF_{01} = 1.03), but moderate evidence in favor of the null hypothesis for the type of induction and the interaction (BF_{01} > 4.68). A similar result is found for the age effect (BF_{01} = 1.97) when adapting the prior based on a previous effect size of 1.38 (Schlagman et al., 2009). These findings demonstrate that inducing a targeting event construction does not increase the specificity of thoughts retrieved spontaneously. Additionally, older adults do not show a reduction in the number of events and detailed specific events to the degree they do in deliberate retrieval. However, for specific events (with or without detail) the results were inconclusive.

Episodic Specificity Categories

Finally, we investigated the frequency of all types of thoughts as defined by the TEMPau (see Table 3.4). We conducted a 2 (age group: young, older) × 2 (type of induction: ESI, control) × 5 (TEMPau category: general knowledge, repeated/extended event not situated in time and place, repeated/extended event situated in time and place, specific event situated in time and place without additional details, specific event situated in time and place with additional details) mixed ANOVA. We found a main effect of TEMPau category, $F(2.50,114.92) = 48.36$, $MSE = 16.57$, $p < .001$, $\eta_p^2 = .27$. Post-hoc analyses revealed that general knowledge sTUTs ($M = 1.77$, $SD = 1.50$) were more frequent than sTUTs in any other category (p's <.001) except for specific events without detail ($p = .09$, $M = 1.04$, $SD = 1.01$), which were more frequent compared to specific events with detail ($p = .012$, $M = 0.52$, $SD = 1.50$) and to repeated/extended events situated in time and place ($p < .001$, $M = 0.32$, $SD = 0.51$). Additionally, the interaction between TEMPau category and type of induction was marginally significant, $F(3.40,156.47) = 2.51$, $MSE = 2.78$, $p = .054$, $\eta_p^2 = .05$. Post-hoc analyses revealed a reduction ($p = .018$) of general knowledge sTUTs in the ESI ($M = 1.50$, $SD = 1.52$) compared to the control induction ($M = 2.00$, $SD = 1.84$). The Bayesian analysis showed extreme support of a model including the main effect of TEMPau category ($BF_{Inclusion} > 100$). Additionally, we found moderate and extreme evidence for models excluding all other factors and possible interactions ($BF_{Exclusion} > 7.45$). These results suggest that the interaction found between TEMPau category and type of induction should be taken with caution. In sum, when thoughts were considered in terms of all the TEMPau categories the findings show that thoughts retrieved spontaneously are more frequently either about general knowledge or about non-detailed specific events. Additionally, there was anecdotal support for a reduction in the number of sTUTs describing general knowledge after targeting event construction with the ESI. Importantly, this did not translate in an increase of sTUTs in more specific events categories, for which there were no differences. Finally, the frequency of sTUTs in different TEMPau categories was the same for younger and older adults, supporting the role of spontaneous retrieval in reducing age effects.

	General knowledge		Repeated/extended event not situated in time and place		Repeated/extended event situated in time and place		Specific event situated in time (<24h) and place without additional details		Specific event situated in time (<24h) and place with additional details	
	Younger	Older	Younger	Older	Younger	Older	Younger	Older	Younger	Older
ESI	1.29 (1.23)	1.71 (1.76)	1.08 (1.72)	0.92 (1.56)	0.21 (0.51)	0.50 (0.93)	1.29 (1.16)	0.79 (1.14)	0.71 (1.12)	0.38 (0.88)
Control	1.96 (1.99)	2.13 (1.68)	0.71 (1.08)	0.67 (1.24)	0.33 (0.56)	0.25 (0.53)	1.42 (1.41)	0.67 (1.20)	0.38 (.58)	0.63 (1.17)

Table 3.4. Mean number (standard deviation) of spontaneous task-unrelated thought (TUT) in each TEMPau specificity category, for each age group in the episodic specificity induction (ESI) and in the control induction.

Episodic Specificity in Past vs Future-oriented sTUTs

To investigate whether the present data replicate previous findings with respect to the similarities and differences between past and future sTUTs, we included temporality as a factor and repeated the analysis by including the overall and strictly episodic score, specific events, and TEMPau category. In order to directly compare past and future, we did not include present and atemporal sTUTs in these analyses. Thus, we conducted separate 2 (age group: young, older) × 2 (type of induction: ESI, control) × 2 (temporality: past, future) mixed ANOVA on each of the measures. First, turning to the overall specificity score, we found a main effect of temporality, $F(1,46) = 8.88$, $MSE = 27.00$, $p = .005$, $\eta_p^2 = .16$, which was due to a greater frequency of past-oriented ($M = 1.41$, $SD = 1.54$) than future-oriented ($M = 0.66$, $SD = 0.84$) sTUTs. Second, for the strictly episodic score we found a similar pattern of results, with a main effect of temporality, $F(1,46) = 13.66$, $MSE = 6.75$, $p = .001$, $\eta_p^2 = .23$, such that past-oriented sTUTs were more frequent ($M = 0.43$, $SD = 0.67$) than future-oriented ones ($M = 0.05$, $SD = 0.21$). Third, we found a main effect of temporality on specific events (with and without detail), $F(1,46) = 5.60$, $MSE = 11.02$, $p = .022$, $\eta_p^2 = .11$, with more past ($M = 0.97$, $SD = 1.15$) than future-oriented thoughts ($M = 0.49$, $SD = 0.72$). There were no other significant main effects or interactions (all p's > .06). Consistently, the Bayesian analyses showed moderate to extreme evidence for models excluding all variables and interactions but temporality ($BF_{Inclusion} > 100$) for both the overall and strictly episodic scores ($BF_{Exclusion} > 3.88$). For specific events, we found moderate to extreme evidence for models excluding in all variables and interactions ($BF_{Exclusion} > 4.73$) but temporality ($BF_{Inclusion} = 8.88$) and age group ($BF_{Inclusion} = 0.40$). A main effect of temporality described the best model ($BF_{10} = 21.56$), and adding the age group effect decreased the support for the model by a factor of 1.25. Thus, the impact of the age group is inconclusive in this case. In sum, across all three measures of episodic specificity we found more frequent sTUTs related to the past than the future, and no evidence of differences for other variables, including age. For specific events a null effect of age could not be confirmed. Importantly, these findings show that the overall and strictly specificity of past sTUTs is the same in both younger and older adults, and that pattern extends to future sTUTs.

Finally, we included temporality as an additional factor and reexamined the frequency of TEMPau category by conducting a 2 (age group: young, older) × 2 (type of induction: ESI, control) × 5 (TEMPau category: general knowledge, repeated/extended event not situated in time and place, repeated/extended event situated in time and place, specific event situated in time and place without additional details, specific event situated in time and place with additional details) × 2 (temporality: past, future) mixed ANOVA. We found a main effect of TEMPau category, F (2.78,128.27) = 10.85, MSE = 6.12, p < .001, η_p^2 = .19. Post-hoc analyses revealed that the main effect of TEMPau category was due to a pattern of differences between categories that was distinct from the overall analysis (including all temporalities). When including past and future sTUTs only, specific events without detail were more frequent than sTUTs in any other category of the TEMPau (*p's* ≤ .045). There was also a main effect of temporality, $F(1,46)$ = 8.13, MSE = 5.70, p = .007, η_p^2 = .15, which was due to a greater frequency of past-oriented sTUTs (M = 0.31, SD = 0.33) than future sTUTs (M = 0.16, SD = 0.19). There were no other main effects or interactions (all *p*'s > .07). These results were consistent with the Bayesian analyses that showed moderate to extreme evidence for models excluding all variables and interactions ($BF_{Exclusion}$ > 14.49), but TEMPau ($BF_{Inclusion}$ > 100), temporality ($BF_{Inclusion}$ = 63.74) and their interaction ($BF_{Inclusion}$ = 0.72). In sum, we found that past sTUTs were more frequent than future sTUTs, and both seem to describe specific events, with no differences between younger and older groups.

Discussion

The present study examined episodic specificity in descriptions of spontaneous thought in aging. We also tested whether an ESI influenced the nature of information reported during spontaneous retrieval. Overall, we found no effects of age or the ESI, and moderate to extreme evidence for null effects in some of the episodic specificity measures. Our findings suggest that spontaneous retrieval bypasses event constructive processes that support episodic specificity, namely, by providing access to pre-stored event representations (Uzer et al., 2012). The absent or minimal involvement of event construction during spontaneous retrieval may also contribute to the attenuation of age-related changes in episodic specificity as found here. Below, we discuss these results by exploring the mechanisms supporting episodic specificity in spontaneous thought in aging.

Age-Related Differences

Replicating our previous study (Jordão, Pinho, et al., 2019), we found no evidence for an age-related decrease in sTUTs frequency when key methodological confounds were controlled for (e.g., involvement of meta-awareness). The absence of age-related differences was supported by moderate evidence for a null age effect, and extended to a more fine-grained analysis of the data that focused only on past-oriented sTUTs (in line with IAM research; e.g., Rubin & Berntsen, 2009) and future-oriented sTUTs. For episodic specificity, we also found no age-related differences irrespective of how events were defined. Additionally, there was moderate support for a null effect in the number of events and specific events with detail. When focusing on past and future-oriented sTUTs, we found the same pattern of results. These results demonstrate that there is no consistent age-related decrease in episodic specificity for spontaneous retrieval, in line with previous results using self-report measures (Schlagman et al., 2009).

Our findings are in accordance with the idea that the recall of specific episodic information is supported by different mechanisms depending upon whether retrieval is involuntary/spontaneous or voluntary/deliberate (Berntsen, 2009). In particular, it has been suggested that involuntary autobiographical memories and future thoughts emerge through a process based on cue-item discriminability (Berntsen, 2009), which accesses specific information, bypassing age-related differences in the top-down strategic processes required in deliberate recall. Two additional findings support this interpretation. First, we found that the majority of sTUTs were triggered by a cue, across age-group and type of induction. Second, both past and future sTUTs were more likely to reflect specific events across age-group. In sum, we found support for the role of spontaneous retrieval in attenuating age-related difficulties to access specific episodic information. In the context of the theories of cognitive aging, the present results extend the empirical support for the key role of reduced cognitive resources in age-related changes (e.g., Craik, 1986). Consistent with this view, we did not found age-related differences in spontaneous retrieval when self-initiated processes are not required (for a review see Craik, 2020).

Episodic Specificity Induction Effect

We found no evidence of an ESI effect in either the frequency or episodic specificity of spontaneous thoughts. The ESI did not increase the number of specific events, either with or without detail, as shown by moderate evidence for a null effect in these measures. These findings are in line with a direct and automatic route involved in spontaneous retrieval (for a review, see Mace, 2007) and support the view that self-initiated processes are the main source of age-related differences in episodic detail (e.g., De Beni et al., 2013). We also found the same results when looking at past and future sTUTs separately. During deliberate retrieval, future events have been shown to require more event construction than past events (for a review, see Schacter et al., 2012). However, here, we found the same pattern of results for both temporal orientations, further supporting the view that spontaneous representations are similarly independent of event construction irrespective of whether they are temporally oriented to the past or future.

An alternative interpretation for the null ESI effect would be that cue-item discriminability mechanism supports the event construction of episodic details in an automatic fashion. More specifically, event construction would still be required but facilitated and accelerated by a "potent" cue (e.g., Conway, 2001), which would constitute a bottom-up constructive route, in addition to the deliberate top-down constructive process (Harris, O'Connor, & Sutton, 2015). In this case, the spontaneous retrieval process would by itself increase episodic specificity and make the ESI effect redundant. However, if this was the case, there should be a ceiling effect in episodic specificity of spontaneous thoughts. On the contrary, we found only a small number of specific events with detail, indicating that there was room for the ESI effect to influence episodic specificity if spontaneous thoughts rely on event construction.

How can we explain the existence of pre-stored event representations? Mace (2007) proposes an explanation for involuntary memory retrieval based on "literal" representations of events, which are conceptually equivalent to pre-stored event representations. He explains these representations in the context of constructive views that admit that "literal" event representation may stem from the episodic memory system (Conway, 2001). Namely, these would be long-term fragments of event representations that have been previously constructed. However, there has not been, to our knowledge, an experimental test of this idea. Thus, further research is needed to understand how retrieval of events is possible in the absence of event construction. This is particularly important for spontaneous future events. If there is minimal event construction in spontaneous retrieval, novel future events cannot be spontaneously retrieved. Instead, spontaneous future thoughts would more appropriately be characterized as memories of future thoughts that have been deliberately recalled (and constructed) before. In fact, previous research supports the view that spontaneous future thoughts are "prestored representations of previously imagined events" (Jeunehomme & D'Argembeau, 2016, p. 269).

In sum, we found that the ESI does not increase the number of specific events in spontaneous retrieval, consistent with an automatic mechanism that supports episodic specificity in spontaneous thoughts and with the absence or minimal of event construction in spontaneous retrieval.

Phenomenological Characteristics

Regarding phenomenological characteristics, we found no age-related differences in self-reported detail, emotional arousal and valence. Thus, we did not replicate previous age-related differences in emotional arousal and valence (Berntsen et al., 2015), including an age-related positivity effect in spontaneous thought (Schlagman et al., 2009). However, this result is difficult to interpret due to smaller sample sizes. The analysis of temporality in all sTUTs revealed there were more past than present-oriented thoughts. Present sTUTs were, in turn, more frequent for older adults, but the Bayesian analysis did not support this effect. When comparing only past and future-oriented sTUTs, the former were more frequent across age-group and type of induction. These results are in line with similar studies that report more past than present (Vannucci, Pelagatti, & Marchetti, 2017) and future-oriented sTUTs (Plimpton, Patel, & Kvavilashvili, 2015). Finally, younger but not older adults showed more visual than verbal imagery, consistent with an age-related decrease in visual imagery ability (Palermo, Piccardi, Nori, Giusberti, & Guariglia, 2016).[11]

Limitations and Future Directions

We did not analyze episodic specificity based on internal and external details using the AI procedure (Levine et al., 2002), because the spontaneous thoughts examined contained more implicit information and were shorter descriptions. Although we distinguished between specific events without versus with episodic detail, it was not possible to quantify how much more detail there was, which reduced the precision of the analyses. To capture more explicit aspects of spontaneous thoughts, one alternative would be to include a post-recall deliberate elaboration after both spontaneous and deliberate retrieval[12]. If spontaneous retrieval supports the automatic access to episodic detail then it should also facilitate subsequent deliberate elaboration of these same events and attenuate age-related differences compared to deliberate retrieval.

In the future, it will be important to directly compare spontaneous with deliberate thoughts using the same experimental paradigm (e.g., Barzykowski, Niedźwieńska, &

[11]Visual imagery is closely related with episodic specificity (e.g., Sheldon, Amaral, & Levine, 2017). Therefore, how can we explain that there are age-related differences in visual imagery but not in episodic specificity? This may be due to younger adults more frequently reporting visual images without any episodic context or event associated (e.g., “When I saw the word “rotten”, I saw a rotten apple in my mind. There was not a specific context or time”).

[12] We thank Dr. Nadia Brashier for this suggestion.

Mazzoni, 2019). Given the consistency of age-related decrease in episodic specificity in a variety of tasks (e.g., Devitt et al., 2017; Levine et al., 2002; Piolino et al., 2006; Piolino et al., 2002; Ros et al., 2009; Schlagman et al., 2009; St. Jacques & Levine, 2007), it is likely that we would have found a similar effect here if we had asked older adults to generate deliberate thoughts. However, a direct comparison between deliberate and spontaneous conditions will provide conclusive evidence.

In our analyses there was an unequal number of sTUTs *per* participant, due to the unexpected nature of sTUTs and the consistent individual differences in sTUTs (e.g., Vannucci & Chiorri, 2018). This contrasts with previous ESI studies on deliberate memory and future thinking (Madore et al., 2014), and may have played a role in the absence of the ESI effect. Additionally, it excludes participants that do not report sTUTs in both sessions from the analyses on phenomenological characteristics. To equate sTUTs between subjects, future studies may use experience-sampling methods that probe participants until a certain number of sTUTs are recorded. Similar methods have been successful in studying spontaneous thoughts with both younger and older adults (Warden, Plimpton, & Kvavilashvili, 2019).

Conclusions

We found that age-related differences in episodic specificity are attenuated in spontaneous retrieval. Additionally, training participants to recall episodic detail did not increase episodic specificity in subsequent spontaneous thought. These findings are consistent with the view that episodic specificity in spontaneous thought is supported by automatic cue-related mechanisms that bypass event construction. Several questions remain to be further explored in paradigms that include comparisons with deliberate and directly retrieved thoughts and that allow participants to elaborate their spontaneous thoughts. Nonetheless, the present evidence shows that activating spontaneous retrieval is a promising strategy to support episodic specificity in old age.

References

Addis, D. R., Musicaro, R., Pan, L., & Schacter, D. L. (2010). Episodic simulation of past and future events in older adults: Evidence from an experimental recombination task. *Psychology and Aging, 25*(2), 369–376. doi:10.1037/a0017280

Addis, D. R., Wong, A. T., & Schacter, D. L. (2008). Age-related changes in the episodic simulation of future events. *Psychological Science*, *19*(1), 33–41. doi:10.1111/j.1467-9280.2008.02043.x

Anderson, S. J., Cohen, G., & Taylor, S. (2000). Rewriting the past: Some factors affecting the variability of personal memories. *Applied Cognitive Psychology*, *14*(5), 435–454. doi:10.1002/1099-0720(200009)14:5<435::AID-ACP662>3.0.CO;2-B

Barzykowski, K., Niedźwieńska, A., & Mazzoni, G. (2019). How intention to retrieve a memory and expectation that a memory will come to mind influence the retrieval of autobiographical memories. *Consciousness and Cognition*, *72*, 31–48. doi:10.1016/j.concog.2019.03.011

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). Manual for the Beck Depression Inventory-II. *San Antonio, TX: Psychological Corporation*, *1*, 82.

Berntsen, D. (2009). *Involuntary autobiographical memories: An introduction to the unbidden past*. Cambridge: Cambridge University Press.

Berntsen, D. (2010). The unbidden past: Involuntary autobiographical memories as a basic mode of remembering. *Current Directions in Psychological Science*, *19*(3), 138–142. doi:10.1177/0963721410370301

Berntsen, D., & Rubin, D. C. (2008). The reappearance hypothesis revisited: Recurrent involuntary memories after traumatic events and in everyday life. *Memory and Cognition*, *36*(2), 449–460. doi:10.3758/mc.36.2.449

Berntsen, D., Rubin, D. C., & Salgado, S. (2015). The frequency of involuntary autobiographical memories and future thoughts in relation to daydreaming, emotional distress, and age. *Consciousness and Cognition*, *36*, 352–372. doi:10.1016/j.concog.2015.07.007

Brewer, W. F. (1996). What is recollective memory? In D. C. Rubin (Ed.), *Remembering our past: Studies in autobiographical memory* (pp. 19–66). Cambridge: Cambridge University Press.

Cabeza, R., & St Jacques, P. (2007). Functional neuroimaging of autobiographical memory. *Trends in Cognitive Sciences*, *11*(5), 219–227. doi:10.1016/j.tics.2007.02.005

Christoff, K., Irving, Z. C., Fox, K. C. R., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: A dynamic framework. *Nature Reviews Neuroscience*, *17*(11), 718–731. doi:10.1038/nrn.2016.113

Cole, S. N., & Kvavilashvili, L. (2019). Spontaneous future cognition: The past, present and future of an emerging topic. *Psychological Research*, *83*(4), 631–650. doi:10.1007/s00426-019-01193-3

Cole, S. N., Morrison, C. M., & Conway, M. A. (2013). Episodic future thinking: Linking neuropsychological performance with episodic detail in young and old adults. *Quarterly Journal of Experimental Psychology*, *66*(9), 1687–1706. doi:10.1080/17470218.2012.758157

Conway, M. A. (2001). Sensory-perceptual episodic memory and its context: Autobiographical memory. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *356*(1413), 1375–1384. doi:10.1098/rstb.2001.0940

Conway, M. A. (2005). Memory and the self. *Journal of Memory and Language*, *53*(4), 594–628. doi:10.1016/j.jml.2005.08.005

Craik, F. I. M. (1986). A functional account of age differences in memory. In F. Klix & H. Hagendorf (Eds.), *Human memory and cognitive capabilities: Mechanisms and performances* (pp. 409–422). Amsterdam, North-Holland: Elsevier Science Publishing Company.

Craik, F. I. M. (2020). Remembering: An activity of mind and brain. *Annual Review of Psychology, 71*, 1-24. doi:10.1146/annurev-psych-010419-051027

Cuddy, L. L., Sikka, R., & Vanstone, A. (2015). Preservation of musical memory and engagement in healthy aging and Alzheimer’s disease. *Annals of the New York Academy of Sciences*, *1337*(1), 223–231. doi:10.1111/nyas.12617

De Beni, R., Borella, E., Carretti, B., Zavagnin, M., Lazzarini, L., & Milojevi, G. (2013). Remembering the past and imagining the future: Age-related differences between young, young-old and old-old. *Aging Clinical and Experimental Research*, *25*(1), 89–97. doi:10.1007/s40520-013-0003-3

Devitt, A. L., Addis, D. R., & Schacter, D. L. (2017). Episodic and semantic content of memory and imagination: A multilevel analysis. *Memory and Cognition*, *45*(7), 1078–1094. doi:10.3758/s13421-017-0716-1

Fisher, R. P., & Geiselman, R. E. (1992). *Memory-enhancing techniques for investigative interviewing: The cognitive interview.* Springfield, IL: Charles C. Thomas Books

Ford, J. H., Rubin, D. C., & Giovanello, K. S. (2014). Effects of task instruction on autobiographical memory specificity in young and older adults. *Memory*, *22*(6), 722–736. doi:10.1080/09658211.2013.820325

Gallo, D. A., Korthauer, L. E., McDonough, I. M., Teshale, S., & Johnson, E. L. (2011). Age-related positivity effects and autobiographical memory detail: Evidence from a past/future source memory task. *Memory*, *19*(6), 641–652. doi:10.1080/09658211.2011.595723

Harris, C. B., O'Connor, A. R., & Sutton, J. (2015). Cue generation and memory construction in direct and generative autobiographical memory retrieval. *Consciousness and Cognition*, *33*, 204–216. doi:10.1016/j.concog.2014.12.012

JASP Team. (2019). *JASP (Version 0.10.1) [Computer software]*.

Jeunehomme, O., & D'Argembeau, A. (2016). Prevalence and determinants of direct and generative modes of production of episodic future thoughts in the word cueing paradigm. *The Quarterly Journal of Experimental Psychology*, *69*(2), 254–272. doi:10.1080/17470218.2014.993663

Jing, H. G., Madore, K. P., & Schacter, D. L. (2016). Worrying about the future: An episodic specificity induction impacts problem solving, reappraisal, and well-being. *Journal of Experimental Psychology: General*, *145*(4), 402–418. doi:10.1037/xge0000142

Jordão, M., Ferreira-Santos, F., Pinho, M. S., & St. Jacques, P. L. (2019). Meta-analysis of aging effects in mind wandering: Methodological and sociodemographic factors. *Psychology and Aging*, *34*(4), 531–544. doi:10.1037/pag0000356

Jordão, M., Pinho, M. S., & St. Jacques, P. L. (2019). Inducing spontaneous future thoughts in younger and older adults by priming future-oriented personal goals. *Psychological Research*, *83*(4), 710–726. doi:10.1007/s00426-019-01146-w

Kane, M. J., Gross, G. M., Chun, C. A., Smeekens, B. A., Meier, M. E., Silvia, P. J., & Kwapil, T. R. (2017). For whom the mind wanders, and when, varies across laboratory and daily-life settings. *Psychological Science*, *28*(9), 1271–1289. doi:10.1177/0956797617706086

Kensinger, E. A. (2009). *Emotional memory across the adult lifespan*. New York: Psychology Press.

Klinger, E., Koster, E. H. W., & Marchetti, I. (2018). Spontaneous thought and goal pursuit from functions such as planning to dysfunctions such as rumination. In K. Christoff & K. C. R. Fox (Eds.), *The Oxford handbook of spontaneous thought: Mind-wandering, creativity, and dreaming*. Retrieved from https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780190464745.001.0001/oxfordhb-9780190464745-e-24

Levine, B., Svoboda, E., Hay, J. F., Winocur, G., & Moscovitch, M. (2002). Aging and autobiographical memory: Dissociating episodic from semantic retrieval. *Psychology and Aging*, *17*(4), 677–689. doi:10.1037/0882-7974.17.4.677

Mace, J. H. (2007). Involuntary memory: Concept and theory. In J. H. Mace (Ed.), *Involuntary Memory* (1–19). New York: Blackwell.

Madore, K. P., Gaesser, B., & Schacter, D. L. (2014). Constructive episodic simulation: Dissociable effects of a specificity induction on remembering, imagining, and describing in young and older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *40*(3), 609–622. doi:10.1037/a0034885

Madore, K. P., Jing, H. G., & Schacter, D. L. (2016). Divergent creative thinking in young and older adults: Extending the effects of an episodic specificity induction. *Memory and Cognition*, *44*(6), 974–988. doi:10.3758/s13421-016-0605-z

Madore, K. P., Jing, H. G., & Schacter, D. L. (2019). Selective effects of specificity inductions on episodic details: Evidence for an event construction account. *Memory*, *27*(2), 250–260. doi:10.1080/09658211.2018.1502322

Madore, K. P., & Schacter, D. L. (2014). An episodic specificity induction enhances means-end problem solving in young and older adults. *Psychology and Aging*, *29*(4), 913–924. doi:10.1037/a0038209

Maillet, D., & D. L. Schacter. (2016). From mind wandering to involuntary retrieval: Age-related differences in spontaneous cognitive processes. *Neuropsychologia*, *80*, 142–156. doi:10.1016/j.neuropsychologia.2015.11.017

Maillet, D., Seli, P., & Schacter, D. L. (2017). Mind-wandering and task stimuli: Stimulus-dependent thoughts influence performance on memory tasks and are more often past- versus future-oriented. *Consciousness and Cognition*, *52*, 55–67. doi:10.1016/j.concog.2017.04.014

Michaelian, K. (2011). Generative memory. *Philosophical Psychology*, *24*(3), 323–342. doi:10.1080/09515089.2011.559623

Moscovitch, M. (1995). Recovered consciousness: A hypothesis concerning modularity and episodic memory. *Journal of Clinical and Experimental Neuropsychology*, *17*(2), 276–290. doi:10.1080/01688639508405123

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., … Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, *53*(4), 695–699. doi:10.1111/j.1532-5415.2005.53221.x

Oliveira-Brochado, F., Simões, M. R., & Paúl, C. (2014). Inventário de Depressão de Beck-II (BDI-II). In L. S. Almeida, M. R. Simões, & M. M. Gonçalves (Eds.), *Instrumentos e contextos de avaliação psicológica* (Vol. 2, pp. 187–209). Coimbra: Edições Almedina.

Palermo, L., Piccardi, L., Nori, R., Giusberti, F., & Guariglia, C. (2016). The impact of ageing and gender on visual mental imagery processes: A study of performance on tasks from the Complete Visual Mental Imagery Battery (CVMIB). *Journal of Clinical and Experimental Neuropsychology*, *38*(7), 752–763. doi:10.1080/13803395.2016.1161735

Piolino, P., Coste, C., Martinelli, P., Macé, A.-L., Quinette, P., Guillery-Girard, B., & Belleville, S. (2010). Reduced specificity of autobiographical memory and aging: Do the executive and feature binding functions of working memory have a role? *Neuropsychologia*, *48*(2), 429–440. doi:10.1016/j.neuropsychologia.2009.09.035

Piolino, P., Desgranges, B., Benali, K., & Eustache, F. (2002). Episodic and semantic remote autobiographical memory in ageing. *Memory*, *10*(4), 239–257. doi:10.1080/09658210143000353

Piolino, P., Desgranges, B., Clarys, D., Guillery-Girard, B., Taconnat, L., Isingrini, M., & Eustache, F. (2006). Autobiographical memory, autonoetic consciousness, and self-perspective in aging. *Psychology and Aging*, *21*(3), 510–525. doi:10.1037/0882-7974.21.3.510

Plimpton, B., Patel, P., & Kvavilashvili, L. (2015). Role of triggers and dysphoria in mind-wandering about past, present and future: A laboratory study. *Consciousness and Cognition*, *33*, 261–276. doi:10.1016/j.concog.2015.01.014

Rasmussen, A. S., & Berntsen, D. (2009). The possible functions of involuntary autobiographical memories. *Applied Cognitive Psychology*, *23*(8), 1137–1152. doi:doi:10.1002/acp.1615

Rasmussen, A. S., Ramsgaard, S. B., & Berntsen, D. (2015). Frequency and functions of involuntary and voluntary autobiographical memories across the day. *Psychology of Consciousness: Theory, Research, and Practice*, *2*(2), 185–205. doi:10.1037/cns0000042

Ros, L., Latorre, J. M., & Serrano, J. P. (2009). Working memory capacity and overgeneral autobiographical memory in young and older adults. *Aging, Neuropsychology, and Cognition*, *17*(1), 89–107. doi:10.1080/13825580903042650

Rubin, D. C. (1995). *Memory in oral traditions: The cognitive psychology of epic, ballads, and counting-out rhymes*. New York: Oxford University Press.

Rubin, D. C., & Berntsen, D. (2009). The frequency of voluntary and involuntary autobiographical memories across the life span. *Memory & Cognition*, *37*(5), 679–688. doi:10.3758/37.5.679

Rubin, D. C., & Umanath, S. (2015). Event memory: A theory of memory for laboratory, autobiographical, and fictional events. *Psychological Review, 122*(1), 1–23. doi:10.1037/a0037907

Schacter, D. L., Addis, D. R., Hassabis, D., Martin, V. C., Spreng, R. N., & Szpunar, K. K. (2012). The future of memory: Remembering, imagining, and the brain. *Neuron*, *76*(4), 677–694. doi:10.1016/j.neuron.2012.11.001

Schacter, D. L., & Madore, K. P. (2016). Remembering the past and imagining the future: Identifying and enhancing the contribution of episodic memory. *Memory Studies*, *9*(3), 245–255. doi:10.1177/1750698016645230

Schlagman, S., Kliegel, M., Schulz, J., & Kvavilashvili, L. (2009). Differential effects of age on involuntary and voluntary autobiographical memory. *Psychology and Aging*, *24*(2), 397–411. doi:10.1037/a0015785

Schlagman, S., & Kvavilashvili, L. (2008). Involuntary autobiographical memories in and outside the laboratory: How different are they from voluntary autobiographical memories? *Memory and Cognition*, *36*(5), 920–932. doi:10.3758/mc.36.5.920

Schlagman, S., Kvavilashvili, L., & Schulz, J. (2007). Effects of age on involuntary autobiographical memories. In J. H. Mace (Ed.), *Involuntary Memory* (pp. 87–112). New York: Blackwell.

Seli, P., Carriere, J., & Smilek, D. (2015). Not all mind wandering is created equal: Dissociating deliberate from spontaneous mind wandering. *Psychological Research*, *79*(5), 750–758. doi:10.1007/s00426-014-0617-x

Seli, P., Maillet, D., Smilek, D., Oakman, J. M., & Schacter, D. L. (2017). Cognitive aging and the distinction between intentional and unintentional mind wandering. *Psychology and Aging*, *32*(4), 315–324. doi:10.1037/pag0000172

Sheldon, S., Amaral, R., & Levine, B. (2017). Individual differences in visual imagery determine how event information is remembered. *Memory*, *25*(3), 360–369. doi:10.1080/09658211.2016.1178777

Simões, M. R., Freitas, S., Santana, I., Firmino, H., Martins, C., Nasreddine, Z. S., & Vilar, M. (2008). *Montreal Cognitive Assessment (MoCA): Versão portuguesa*. Serviço de Avaliação Psicológica da Faculdade de Psicologia e de Ciências da Educação da Universidade de Coimbra, Coimbra.

Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin*, *132*(6), 946–958. doi:10.1037/0033-2909.132.6.946

St. Jacques, P. L., & Levine, B. (2007). Ageing and autobiographical memory for emotional and neutral events. *Memory*, *15*(2), 129–144. doi:10.1080/09658210601119762

St. Jacques, P. L., Rubin, D. C., & Cabeza, R. (2012). Age-related effects on the neural correlates of autobiographical memory retrieval. *Neurobiology of Aging*, *33*(7), 1298–1310. doi:10.1016/j.neurobiolaging.2010.11.007

Stawarczyk, D., Majerus, S., Maj, M., Van der Linden, M., & D'Argembeau, A. (2011). Mind-wandering: Phenomenology and function as assessed with a novel experience sampling method. *Acta Psychologica*, *136*(3), 370–381. doi:10.1016/j.actpsy.2011.01.002

Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology*, *53*(1), 1–25. doi:10.1146/annurev.psych.53.100901.135114

Unsworth, N., & McMillan, B. D. (2014). Similarities and differences between mind-wandering and external distraction: A latent variable analysis of lapses of attention and their relation to cognitive abilities. *Acta Psychologica*, *150*, 14–25. doi:10.1016/j.actpsy.2014.04.001

Uzer, T., Lee, P. J., & Brown, N. R. (2012). On the prevalence of directly retrieved autobiographical memories. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*(5), 1296–1308. doi:10.1037/a0028142

van Doorn, J., van den Bergh, D., Boehm, U., Dablander, F., Derks, K., Draws, T., … Wagenmakers, E.-J. (2019). *The JASP Guidelines for Conducting and Reporting a Bayesian Analysis*. Retrieved from doi:10.31234/osf.io/yqxfr

Vannucci, M., Batool, I., Pelagatti, C., & Mazzoni, G. (2014). Modifying the frequency and characteristics of involuntary autobiographical memories. *PloS One*, *9*(4), e89582. doi:10.1371/journal.pone.0089582

Vannucci, M., & Chiorri, C. (2018). Individual differences in self-consciousness and mind wandering: Further evidence for a dissociation between spontaneous and deliberate mind wandering. *Personality and Individual Differences*, *121*, 57–61. doi:10.1016/j.paid.2017.09.022

Vannucci, M., Pelagatti, C., & Marchetti, I. (2017). Manipulating cues in mind wandering: Verbal cues affect the frequency and the temporal focus of mind wandering. *Consciousness and Cognition*, *53*, 61–69. doi:10.1016/j.concog.2017.06.004

Warden, E. A., Plimpton, B., & Kvavilashvili, L. (2019). Absence of age effects on spontaneous past and future thinking in daily life. *Psychological Research*, *83*(4), 727–746. doi:10.1007/s00426-018-1103-7

Wheeler, M. A., Stuss, D. T., & Tulving, E. (1997). Toward a theory of episodic memory: The frontal lobes and autonoetic consciousness. *Psychological Bulletin*, *121*(3), 331–354. doi:10.1037/0033-2909.121.3.331

Williams, J. M. G., Barnhofer, T., Crane, C., Herman, D., Raes, F., Watkins, E., & Dalgleish, T. (2007). Autobiographical memory specificity and emotional disorder. *Psychological Bulletin*, *133*(1), 122–148. doi:10.1037/0033-2909.133.1.122

Williamson, V. J., Liikkanen, L. A., Jakubowski, K., & Stewart, L. (2014). Sticky tunes: How do people react to involuntary musical imagery? *PloS One*, *9*(1), e86170. doi:10.1371/journal.pone.0086170

Zavagnin, M., De Beni, R., Borella, E., & Carretti, B. (2016). Episodic future thinking: The role of working memory and inhibition on age-related differences. *Aging Clinical and Experimental Research*, *28*(1), 109–119. doi:10.1007/s40520-015-0368-6

General Discussion

Summary of the Main Findings

The present dissertation explored age-related changes in the frequency and episodic specificity of spontaneous thoughts. This type of thoughts are characterized by reduced effort and intentionality and thus provided an opportunity to test theories of aging that predict minimal age-related differences when less self-initiated processing is required (Craik, 2020). We also explored the mechanisms involved in spontaneous thought, namely the role of priming and event construction.

As an initial step, we conducted the first meta-analysis on aging and mind wandering to understand how methodological and socio-demographical factors contributed to previous results. We identified a large age-related decrease in MW frequency and confirmed that this effect was not due to publication bias. Importantly, the meta-analysis revealed for the first time that the age-related decrease in MW significantly depended on key methodological variables including, difficulty of the task, the response options provided to participants, and age-related differences in motivation. Practically, this meta-analysis provided specific guidelines for future studies on aging and spontaneous thought, indicating that (1) the use of open-ended and probe-caught methods are more adequate to prevent response bias and (2) less demanding tasks increase the number of spontaneous thoughts in older adults, facilitating further analysis.

In the second study, we incorporated our previous findings on methodological moderators in a task adapted to avoid age-related confounds. The task included a small number of targets in order to decrease task difficulty, and participants described their mental experiences freely when randomly probed to do so. Thus, we avoided age-related biases associated with retrospection and the interpretation of response options. As expected, no age-related differences were found in the frequency of spontaneous thoughts. In this study, we also developed a priming procedure to induce future spontaneous thoughts. This was important to explore the mechanisms by which spontaneous thoughts emerge. More specifically, this priming methodology allowed us to investigate whether the link between personal goals and future thinking, previously shown for younger adults (Stawarczyk, Majerus, Maj, Van der Linden, & D'Argembeau, 2011), was also preserved in healthy aging. We found an increase in future spontaneous thought after priming personal future-oriented goals in both age groups, but not when comparing priming with a control task in a group of younger adults. This finding indicates that spontaneous future thoughts are influenced by active personal goals across age groups. Additionally, the lack of age-related effects is consistent with theories suggesting that age-related differences are minimal in tasks that involve less self-initiated processing.

In the third study, we used the previous task adapted to avoid age-related confounds with additional improvements and analyzed age-related differences in episodic specificity. For the first time, we examined the content of spontaneous thoughts in aging using objective coding of participants' descriptions. Additionally, we tested the involvement of episodic construction in spontaneous retrieval by using an episodic specificity induction that targets these processes. We replicated the results of study 2 by finding no age-related differences in spontaneous thought frequency. We also found no age-related differences in episodic specificity and there was moderate to extreme evidence that these were null effects. This latter finding suggests that episodic specificity is not affected by aging in spontaneous retrieval as in deliberate retrieval. Thus, activating spontaneous retrieval processes is a promising strategy to support episodic specificity and its benefits in aging. The episodic specificity induction did not impact spontaneous thoughts in either age group, as shown by moderate to extreme evidence for null effects. This finding indicates that spontaneous thought is more independent from episodic construction processes than deliberate thought, and alternatively may be based on the spontaneous activation of pre-stored event representations.

In the next sections, we further discuss the contribution of this dissertation to understanding spontaneous thought in general, focusing on the mechanisms that influence their occurrence, the similarities and differences between past and future spontaneous thoughts, and the episodic vs. semantic distinction.

Spontaneous Thought Mechanisms

The present dissertation supports the view that spontaneous thoughts emerge as a result of an interaction between external cues and activated self-related contents such as personal goals. This interaction is automatic and provides access to event representations that are pre-made, that is, are constituted by episodic details that are already bound when the event is accessed.

We found that spontaneous thoughts were more likely to be triggered by an external stimulus, in both study 2 and 3. These results are consistent with previous research on IAM that emphasizes the role of external cues in automatically activating associative memory retrieval, similar to processes that may contribute to spontaneous thoughts (Berntsen, 2010). The predominance of externally cued spontaneous thoughts was observed for both younger and older adults, which indicates that automatic retrieval processes triggered by an external cue are robust to age-related deficits. According to the view that the absence of age-related deficits reduces self-initiated processing and frontal lobe involvement, the current findings would support the automatic nature of externally cued spontaneous thoughts. This is also in line with recent conceptualizations of the neural mechanisms underlying MW which demonstrate that frontal regions are involved in the initiation of spontaneous thoughts when they are self-generated but not when they are externally cued (Ciaramelli & Treves, 2019)[13]. Based on this theory, we would not expect an impact of the age-related decline in frontal function (Cabeza & Dennis, 2013) in externally cued spontaneous thought, and no age-related differences in their frequency and episodic specificity, which is in fact what we found in the present work.

The role of external cues on triggering spontaneous thoughts does not mean, however, that spontaneous thoughts are completely controlled by the stimuli we happen to encounter. Spontaneous thoughts are also modulated by self-related contents such as personal goals, as shown by study 2. Thus, we found support for the idea that spontaneous thought, like IAMs, are the result of an interaction between self-related factors and environmental cues (Berntsen, 2009), as well as for the induction principle, which states that thoughts are induced based on the combination between a current concern and a related cue (Klinger, 1978).

Additionally, we found that an episodic induction procedure that targets construction processes (Schacter & Madore, 2016) does not influence spontaneous thought (study 3). These findings indicate that the mechanisms underlying spontaneous thought favor the activation of representations that are less dependent on event construction, that is, pre-stored event representations in which episodic details are, to some extent, already assembled or bound together. Thus, our results call for a greater focus on pre-stored event representations, in addition to the constructive aspects of memory that have been a major area of interest in recent memory research (e.g., Schacter, 2012). This is in line with previous research on directly retrieved memories (Uzer, Lee, & Brown, 2012), mentioned in our study 3, and recent research on spontaneous future thoughts (Cole & Kvavilashvili, 2019a; Jeunehomme & D'Argembeau, 2016).

Past and Future Spontaneous Thought

We found no age-related differences in past and future-oriented spontaneous thoughts in frequency and episodic specificity, which extends previous evidence showing that past spontaneous retrieval is resistant to age-related deficits (Schlagman, Kliegel,

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[13]It should be noted, however, that as pointed out in study 1, cognitive effort may play a different role in the occurrence vs. maintenance of spontaneous thoughts, and such evolving process is still to be explored experimentally, particularly in cognitive aging.

Schulz, & Kvavilashvili, 2009; Schlagman, Kvavilashvili, & Schulz, 2007) to future spontaneous retrieval. Comparing past and future thoughts, independently of age group, revealed a more complex picture that raises a number of questions for future research, as exemplified below.

In study 2, but not study 3, we found spontaneous future thoughts to be less frequent than past-oriented ones. However, study 3 included more opportunities to report spontaneous thoughts than study 2 (24 vs. 5 probes, before the priming procedure), suggesting study 3 provides a more reliable measurement. The absence of differences in past and future thoughts frequency is in line with recent naturalistic studies (Warden, Plimpton, & Kvavilashvili, 2019) and contrary to the predominance of future-oriented MW in some lab tasks (Jackson, Weinstein, & Balota, 2013). Warden et al. (2019) found that not distinguishing clearly between spontaneous and deliberate thought produced a prospective bias and suggested that this might explain the prospective bias in previous MW studies. In our study, the absence of differences between past and future, while distinguishing spontaneous thoughts clearly, supports this idea.

Past spontaneous thoughts show greater episodic specificity than future spontaneous thoughts in study 3, which is in line with some previous results (Anderson & Dewhurst, 2009) but not with others (Cole, Staugaard, & Berntsen, 2016). Mixed findings have also been shown regarding the specificity of past and future events during deliberate retrieval, with some studies finding differences between past and future thoughts (Addis, Musicaro, Pan, & Schacter, 2010; Addis, Sacchetti, Ally, Budson, & Schacter, 2009) and others not (Addis, Wong, & Schacter, 2008; Madore, Gaesser, & Schacter, 2014). In the context of these inconsistent findings, our result is difficult to interpret. Previous research has suggested that the increased specificity in deliberate retrieval of the past compared to future thoughts is a result of the increased need for constructive processes in the latter (e.g., Addis et al., 2010), but we found evidence for the reduced involvement of constructive processes in spontaneous thought overall (study 3). Thus, this rational does not seem to apply to the current findings. From a different perspective, our results are consistent with the idea that future thoughts are memories of a future thought which was previously constructed (Jeunehomme & D'Argembeau, 2016), and thus the level of specificity may depend on the original construction process, which would be less detailed for the future than the past. But if that is the case, why does the impact of the original construction processes not result in age-related differences? This may be due to the fact that age-related differences are mainly related with the elaboration phase during deliberate retrieval (St. Jacques, Rubin, & Cabeza, 2012). If, as proposed by Mace (2007), pre-stored representations stem from the episodic buffer, where an event is first bound, the product of this process may be considered pre-elaborated and would thus be similar in younger and older adults. At any rate, these suggestions are speculative and more research is needed, in the first place, to confirm or not the differences between past and future thoughts, and clarify the mixed pattern of results in the area.

Episodic and Semantic Elements of Spontaneous Thought

The analysis of free descriptions of spontaneous thoughts, in studies 2 and 3, provides a window into how episodic and semantic elements intertwine when participants are not constrained by instructions to focus on either of them (a common practice in previous research, e.g., Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002). Participants reported thoughts across all the categories of specificity, from general knowledge, to repeated events, and specific events with more or less detail. Thus, in spontaneous thought, we found examples of a mix between semantic and episodic and elements, that has also been identified in deliberate retrieval and conceptualized as personal semantics (Renoult, Davidson, Palombo, Moscovitch, & Levine, 2012). This is consistent with the view that spontaneous thought, despite being based on different retrieval processes, relies on the same episodic and semantic memory systems that support deliberate past and future thinking (O'Callaghan & Irish, 2018; Mildner & Tamir, 2019).

More research is needed to understand how spontaneous thought mechanisms influence the interplay between semantic and episodic elements. While is known that the cue-item discriminability mechanisms favor specific thoughts (Berntsen, 2009), we showed in study 3 that general knowledge thoughts are just as frequent. How can we explain the frequent occurrence of general spontaneous thoughts? These thoughts are unlikely to result from cue-item discriminability that favors episodic specificity. Alternatively, they may be due to very long-term priming, as has previously been suggested for involuntary semantic memories, but the evidence in this area is still scarce (Kvavilashvili & Mandler, 2004). Another possibility is that spontaneous thoughts are evolving over time (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016) and that by interrupting participants at random times we are assessing different points of that process. It is reasonable to think that episodic specificity may vary as the thought develops in time and thus, by interrupting the process with a probe, we are capturing thoughts that are not fully developed and might be more general.

Overall, our research emphasizes the relevance of freely described spontaneous thought to better understand the distinction and interaction between semantic and episodic systems, a topic increasingly relevant for cognitive science as a whole (Renoult, Irish, Moscovitch, & Rugg, 2019).

Contributions to Cognitive Aging

This dissertation presents two main contributions to the understanding of how spontaneous thoughts change with aging. First, it shows that the way we measure spontaneous thoughts with older adults in the laboratory may introduce confounds and needs to be carefully considered in order to avoid misleading results. Second, spontaneous thoughts do not show age-related effects comparable to those consistently observed in deliberate thought, confirming the role of self-initiated processing in age-related differences, and the potential of automatic mechanisms to prompt spontaneous retrieval and support cognition in aging.

An interesting possibility raised by the present results is that older adults may be able to maintain cognitive function in their daily life because of the involvement of spontaneous retrieval processes, which we found to be more resistant to age effects. Namely, in study 3, past and future spontaneous thoughts that are triggered by external cues do not show an age-related decrease in episodic specificity. This suggests that, in a real-life context, the presence of meaningful cues in an older person's home may spontaneously prompt specific memories or be reminders of future tasks. In contrast, when these highly personal cues are absent, such as when older people transition to a nursing home setting, spontaneous memories and future thoughts may be hindered. This example shows the overreaching consequences of considering spontaneous thoughts processes in aging, in this case, for the design of nursing home settings. In the next sections we further develop future directions for the present work.

Future Directions

Neural and Neuropsychological Studies

The present work focused primarily on behavioral effects, but provides an opportunity to establish connections with research on the neural mechanisms of spontaneous thought. We believe these connections prompt future avenues of research, specifically, with respect to distinguishing the initiation vs. maintenance of spontaneous thought and episodic specificity.

In study 1, we emphasize the distinction between processes supporting the initiation vs. maintenance of MW, and take this distinction into account to interpret the age-related decrease in MW frequency. More importantly, in study 2 and 3, we collect and analyze information about the triggers that initiate spontaneous thoughts, and show similar patterns in the frequency with which these triggers are present for both age groups. Thus, the present lab task allows to identify the initiation of the thought by analyzing what triggered it, which is frequently associated with the cue-words included in the task. This focus on dissociating spontaneous thought with and without a trigger is supported by recent research that looks into the role of the hippocampus and the ventromedial prefrontal cortex (vmPFC) in spontaneous thought (Ciaramelli & Treves, 2019). Neuropsychological evidence with patients that show selective damage on these structures suggests a dissociation between the ability to initiate a spontaneous thought and the type of contents generated, the former affected only in vmPFC patients and the latter only with hippocampal patients (McCormick, Ciaramelli, De Luca, & Maguire, 2018). Future studies with older participants would benefit from bringing together the behavioral analysis of frequency and types of triggers, included in the present work, and their neural correlates. The dissociation between spontaneous thought initiation and maintenance would benefit, in particular, from electroencephalography (EEG) techniques that allow for a more precise record of the temporal profile of spontaneous thought. Importantly, while there are studies comparing spontaneous thought in older and younger adults using high spatial resolution techniques such as functional magnetic resonance (fMRI) (e.g., Maillet & Rajah, 2016), we find no published studies focusing on temporal resolution by using EEG. Using EEG along with a vigilance task similar to the tasks used in studies 2 and 3 of this dissertation would allow to identify the temporal evolution of an externally triggered spontaneous thought in the brain. Specifically, the initiation of the thought is frequently associated with the cues included in the task and its time of presentation can be precisely determined by the experimenter, so that event-related potentials (ERPs) can be analyzed. Age-related differences in this type of neural correlates would challenge the idea that there are no age-related changes processes less reliant on self-initiated processing (Craik, 2020). The analysis of frontal activity, that we approach in the present dissertation only indirectly, would be particularly important to support or challenge the theory.

EEG would also be a useful tool to look into the neural correlates of spontaneous thoughts with different levels of specificity. In the present work, we found similar patterns of episodic specificity in younger and older groups, based on participants' verbal descriptions. The absence of age-related differences, also in the neural correlates, would confirm this result and show that the lack of age-related differences cannot be explained by narrative style, or other factors related with how participants reported their thoughts in our study. EEG techniques seem preferable here because different levels of episodic specificity, including general facts, personal semantics and unique episodic events have been found to have a distinguishable EEG profile in deliberate thought (Renoult et al., 2016). It would be interesting to test if this profile extends to spontaneous thought and across age groups and thereby, support or challenge the present interpretation that age-related differences in these processes should be minimal, both at the behavioral and the neural level.

The new elicitation task resulting from this dissertation may be particularly important for future studies dealing with pathological aging. Pathological aging is a promising source of evidence to understand the neural basis of spontaneous thought, and will rely on adapting tasks to patient populations (for a review see, O'Callaghan & Irish, 2018). The present task controls methodological features that have been shown to introduce confounds in age-related comparisons. This type of task adaptation has also been suggested to be key when studying pathological aging, in face of contradictory evidence that shows a decrease in MW frequency for Alzheimer's disease patients compared to healthy controls in a more cognitive demanding task (Gyurkovics, Balota, & Jackson, 2018) but not in an easy task designed for populations with cognitive decline (O'Callaghan, Shine, Hodges, Andrews-Hanna, & Irish, 2019). Thus, we believe it would be worthwhile to apply the present task in studies of pathological aging.

Overall, it is noteworthy that the study of neural correlates in aging poses particular challenges, for example, to avoid confound associated with how study characteristics are processed by different age groups, and with different performance levels (Rugg & Morcom, 2005). When looking into spontaneous thought, further challenges emerge, related with both conceptual definitions and methodology, as explored in the next section.

Conceptual and Methodological Challenges

"Empirical investigations in other sciences are often stimulated by the availability of novel techniques. In psychology, they are often triggered by the investigation of novel procedures, a phenomenon that Tulving and Madigan (1970) called the functional autonomy of methods. Such procedures become fashionable when widely thought to provide answers to important theoretical questions. Ten years and a flood of papers later, the apparently simple original experimental finding is found to be very complex indeed, and its theoretical value is much less clear. So a pessimist could view the history of normal human experimental psychology as a succession of mirages. The end result consists of islands of detailed empirical knowledge surrounded by a sea of ignorance, whose size we conceal from ourselves by vague theorizing."

(Shallice, 1988, pp. 5–6)

In this section we exemplify how conceptual and methodological issues are linked in the study of spontaneous thought and pose challenges for future research. While there is no reason to hold to the pessimistic view that the field is condemned to be an "island of detailed empirical knowledge" amidst a "sea of ignorance", there is a recognized lack of clarity in the way spontaneous thought is conceptualized (e.g., Seli et al., 2018), despite the emergence of influential novel procedures (e.g., O'Callaghan, Shine, Lewis, Andrews-Hanna, & Irish, 2015; Wang et al., 2018). We explore the challenges this poses for future research with older adults and for spontaneous thought in general.

Older Adults in the Laboratory: Confounds and Paradoxes

In the history of cognitive aging research there are numerous examples of how age-related differences are misunderstood due to methodological issues (Schwarz, Park, Knauper, & Sudman, 1998). A pivotal example is prospective memory, defined as the ability to remember intended actions in a particular time in the future (e.g., McDaniel & Einstein, 2000). Older adults show performance decreases in prospective memory in the lab but increases in naturalistic settings (for a review, see Peter & Kliegel, 2018), a paradox that has been attributed to a variety of methodological factors such as task demand (Kvavilashvili, Cockburn, & Kornbrot, 2013)[14]. In light of the present dissertation, spontaneous thought appears as another area in which methodology modulates age-related differences and may, if not taken into account, lead to mixed results that are seemingly irreconcilable. In fact, recent studies that focus on naturalistic settings (Warden et al., 2019) or use a less demanding task (Maillet et al., 2019) find no differences in spontaneous thought or MW frequency, as in this dissertation. However, another study with an undemanding task still found age-related decreases in the frequency of MW (Irish, Goldberg, Alaeddin, O'Callaghan, & Andrews-Hanna, 2019). Finally, an age-related increase in past and future thoughts has also been reported (Martinon et al., 2019). In these four recent studies only (Irish et al., 2019; Maillet et al., 2019; Martinon et al., 2019; Warden et al., 2019), we find several terms, "mind wandering", "spontaneous task-unrelated thoughts", "self-generated thought", "off-task thought", apparently targeting the same concept but not always measuring it in the same way. This inconsistency in terminology and methods hinders our ability to bring together the results from different studies. The lack of a common framework is a problematic issue in spontaneous thought research as a whole and the need for well-defined concepts is ongoing. We develop this theoretical discussion in the next section.

[14]It is noteworthy that prospective memory is not only an example of methodological issues in cognitive aging, but one particularly close to spontaneous thought, having a recognized key role in spontaneous future thought (Cole & Kvavilashvili, 2019b).

Spontaneous Thought: Searching for a Concept

Currently, there is no shortage of research interest and theoretical proposals about spontaneous thought and related concepts. In the last couple of years, we count the publication of an handbook covering spontaneous thought, from theory to clinical practice (Christoff & Fox, 2018), and several papers suggesting alternative theoretical frameworks to understand the phenomena (Ciaramelli & Treves, 2019; Cole & Kvavilashvili, 2019a; Mildner & Tamir, 2019). Some authors believe it is important to distinguish different varieties of MW and spontaneous thought but, for the time being, find no grounds as to why some types of thoughts should be focused on over others, admitting the concept is inherently varied (Seli, Kane, Metzinger, et al., 2018; Seli, Kane, Smallwood, et al., 2018). An alternative perspective is that, as a starting point, we should formulate a definition for spontaneous thought and focus only on the thoughts that conform to that definition (Christoff et al., 2016, 2018). While there seems to be no convergence yet with respect to these definition proposals, it is clear that to make sense of the results in the field it is important for studies to be comparable. This will depend on clearly identifying the nature of the thoughts in dimensions such as spontaneity and the relationship with external cues and with the task (Seli et al., 2017), as in the present dissertation. This will be particularly important to further advance the study of behavioral correlates of spontaneous thought obtained using new techniques such as pupillometry (Pelagatti, Binda, & Vannucci, 2018) and eye gaze (Faber, Bixler, & D'Mello, 2018). These techniques allow us to identify the onset of a spontaneous thought objectively, which is particularly important to study spontaneous thoughts with populations with less ability to introspect such as people with dementia. However, the identification of these correlates is only possible if the method allows to distinguish between the different varieties of MW experience and clearly isolates spontaneous thoughts (Seli, Kane, Smallwood, et al., 2018). A detailed characterization of spontaneous thoughts is thus an essential step not only to clarify present results, but to maximize the future usefulness of new techniques.

From the Laboratory to Everyday Life

"The results of a hundred years of psychological study of memory are somewhat discouraging. We have established firm empirical generalizations, but most of them are so obvious that every ten-year-old knows them anyway. We have made discoveries, but they are only marginally about memory; in many cases we don't know what to do with them, and wear them out with endless experimental variations. We have an intellectually impressive group of theories, but history offers little confidence that they will provide any meaningful insight into natural behavior."

(Neisser, 1981, pp. 11–12)

The practical relevance of spontaneous thoughts and episodic specificity is regularly emphasized (e.g., Jing, Madore, & Schacter, 2016; Klinger, Koster, & Marchetti, 2018), but the amount of studies that take a naturalistic approach to investigate spontaneous thoughts in everyday life, particularly with older adults, are still a minority (Maillet et al., 2018; Warden et al., 2019). Studies 2 and 3, presented here, were developed in a lab environment but aimed to recreate the low demand conditions in which people often describe spontaneous thoughts in daily life. Furthermore, we asked participants to freely describe their thoughts, thereby avoiding a less naturalistic choice between response options pre-determined by the experimenter. As a whole, the focus on methodological confound in the present thesis is an attempt to create laboratory tasks that are closer to naturalistic conditions. We find support for the success of our lab task in the fact that recent studies conducted in a naturalistic setting found no age-related differences in spontaneous thought frequency (Warden et al., 2019), as in our studies 2 and 3. Thus, our dissertation limits the artificiality introduced by the lab and highlights the relevance of future naturalistic and intervention studies, that along with lab experiments can “provide meaningful insight in natural behavior”, as described by Neisser.

One way to study spontaneous thoughts in everyday life would be to expand on the studies that successfully used experiential sampling to measure spontaneous thought (Maillet et al., 2018; Warden et al., 2019). It would be interesting to combine priming manipulations with subsequent experiential sampling, and test if there are reliable priming effects in a naturalistic context. In study 2, we found an increase in future spontaneous thoughts after a goal-related priming. Would the effect extend to naturalistic settings, in which participants are in contact with uncontrolled stimulus and tasks that may initiate competing priming processes? There is no present research that allow us to answer this question, which is important to assess the usefulness of the priming procedure developed in study 2 in real life scenarios.

If the priming is effective in a naturalistic context, it may useful, for example, to support the emergence of future spontaneous thoughts (e.g., to support the recall of future tasks). Given the relationship between depressive mood and past-oriented MW (Hoffmann, Banzhaf, Kanske, Bermpohl, & Singer, 2016; Poerio, Totterdell, & Miles, 2013; Smallwood & O’Connor, 2011), a future-oriented priming could also be a useful strategy to improve mood. Versions of a card-sorting task based on personal goals, as the one used in study 2, could be converted in a virtual card-sorting task to be assessed as a game in an app, for example. Although this would hardly constitute an intervention on its own, and would need to be carefully monitored (to avoid promoting dysfunctional future thinking, Madore, Jing, & Schacter, 2016) it may provide an additional tool in wider interventions.

Another way to study spontaneous retrieval in daily life is to make use of its automatic nature to support interventions in pathological aging or neuropsychological impairment. In studies 2 and 3, we found that spontaneous thoughts are predominantly elicited by cues with reduced effort. These spontaneous thoughts revealed no age-related differences in episodic specificity in study 3, providing evidence that cued spontaneous thoughts are resistant to the effect of aging on episodic specificity. This is in line with previous research showing that the use of specific cues facilitates the retrieval of past events in neuropsychological impairment, and suggests it can be expanded for future-oriented thoughts. For example, Loveday and Conway (2011) successfully used visual cues of the first person experience of an amnesic patient to elicit detailed everyday memories, inaccessible otherwise. In a recent systematic review, similar procedures have been shown to be helpful in remediating memory deficits in a variety of neuropsychological conditions (Allé et al., 2017).

In addition to the cognitive benefits, idiosyncratic cues in the first-person perspective have also proved to improve well-being in patients with Alzheimer's disease (Silva et al., 2017). The same spontaneous cue-related mechanisms have been used in a different way with Alzheimer's patients, with whom autobiographical memory was improved by objects from the patients' youth in an experimental study (Kirk & Berntsen, 2018) and in a immersive environment five-weeks intervention (Kirk, Rasmussen, Overgaard, & Berntsen, 2019). These studies echo the proposal for "environments for successful aging" (Lindenberger & Mayr, 2014), based on the view that age-related deficits are minimal or absent when the environment supports cognitive process that would otherwise be self-initiated (Craik, 2020). An interesting addition to the literature would be to test the impact of an intervention using specific cues embedded in a customized virtual reality environment, instead of real-life recreations. Virtual reality has been successfully used in the past in normal and pathological aging to remediate episodic memory (for a review, see La Corte, Sperduti, Abichou, & Piolino, 2019). Previous studies vary in how ecological the tasks are, but do not usually include idiosyncratic cues for each person. Ideally, environments that are specific to each person could be created based, for example, on photographs, descriptions from the person or family members. This would allow more flexibility than what is possible in real-life (e.g., recreate a factory where the person used to work and that no longer exists) to support the use of cues tailored to the participants, and thereby promote detailed retrieval and well-being.

Conclusion

Understanding how spontaneous thought change with aging is essential to understand cognitive aging in daily life, in which spontaneous thoughts are frequent. In this dissertation we conducted three studies focused on aging and spontaneous thoughts, exploring its frequency and episodic specificity. We found reduced age-related differences, in line with the role of self-initiated processing in cognitive aging and the automatic nature of spontaneous thought. We also provided further evidence for the cue-related and priming mechanisms underlying spontaneous thoughts and discuss their role for past vs. future and episodic vs. semantic thoughts.

In sum, we provide several novel contributions to understand spontaneous thoughts and aging. Namely, we showed that an age-related decline in spontaneous thought frequency is influenced by methodological factors, based on the first meta-analysis in this area, and on the absence of an age-related decline when methodological factors are controlled in our lab tasks. For the first time, we analyzed age-related differences in the episodic specificity of spontaneous thoughts based on an objective assessment of participants' descriptions. This analysis showed no age-related decline, opening new avenues of research that focus on mobilizing spontaneous processes to promote episodic specificity in aging. We finished by highlighting the relevance of moving from lab tasks to more naturalistic approaches and provide suggestions for future research outside the lab.

References

Addis, D. R., Musicaro, R., Pan, L., & Schacter, D. L. (2010). Episodic simulation of past and future events in older adults: Evidence from an experimental recombination task. *Psychology and Aging, 25*(2), 369–376. doi:10.1037/a0017280

Addis, D. R., Wong, A. T., & Schacter, D. L. (2008). Age-related changes in the episodic simulation of future events. *Psychological Science*, *19*(1), 33–41. doi:10.1111/j.1467-9280.2008.02043.x

Allé, M. C., Manning, L., Potheegadoo, J., Coutelle, R., Danion, J.-M., & Berna, F. (2017). Wearable cameras are useful tools to investigate and remediate autobiographical memory impairment: A systematic PRISMA review. *Neuropsychology Review*, *27*(1), 81–99. doi:10.1007/s11065-016-9337-x

Anderson, R. J., & Dewhurst, S. A. (2009). Remembering the past and imagining the future: Differences in event specificity of spontaneously generated thought. *Memory*, *17*(4), 367–373. doi:10.1080/09658210902751669

Berntsen, D. (2009). *Involuntary Autobiographical Memories: An Introduction to the Unbidden Past*. Cambridge: Cambridge University Press.

Berntsen, D. (2010). The unbidden past: Involuntary autobiographical memories as a basic mode of remembering. *Current Directions in Psychological Science*, *19*(3), 138–142. doi:10.1177/0963721410370301

Cabeza, R., & Dennis, N. A. (2013). Frontal lobes and aging deterioration and compensation. In D. T. Stuss & R. T. Knight (Eds.), *Principles of frontal lobe function*. Retrieved from https://oxfordmedicine.com/view/10.1093/med/9780199837755.001.0001/med-9780199837755-chapter-44

Christoff, K., & Fox, K. C. R. (2018). *The Oxford handbook of spontaneous thought: Mind-wandering, creativity, and dreaming*. New York: Oxford University Press.

Christoff, K., Irving, Z. C., Fox, K. C. R., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: A dynamic framework. *Nature Reviews Neuroscience*, *17*(11), 718–731. doi:10.1038/nrn.2016.113

Christoff, K., Mills, C., Andrews-Hanna, J. R., Irving, Z. C., Thompson, E., Fox, K. C. R., & Kam, J. W. Y. (2018). Mind-wandering as a scientific concept: Cutting through the definitional haze. *Trends in Cognitive Sciences*, *22*(11), 957–959. doi:10.1016/j.tics.2018.07.004

Ciaramelli, E., & Treves, A. (2019). A mind free to wander: Neural and computational constraints on spontaneous thought. *Frontiers in Psychology*, *10*(39). doi:10.3389/fpsyg.2019.00039

Cole, S. N., & Kvavilashvili, L. (2019a). Spontaneous and deliberate future thinking: A dual process account. *Psychological Research*. Advance online publication. doi:10.1007/s00426-019-01262-7

Cole, S. N., & Kvavilashvili, L. (2019b). Spontaneous future cognition: The past, present and future of an emerging topic. *Psychological Research*, *83*(4), 631–650. doi:10.1007/s00426-019-01193-3

Cole, S. N., Staugaard, S. R., & Berntsen, D. (2016). Inducing involuntary and voluntary mental time travel using a laboratory paradigm. *Memory and Cognition*, *44*(3), 376–389. doi:10.3758/s13421-015-0564-9

Craik, F. I. M. (2020). Remembering: An activity of mind and brain. *Annual Review of Psychology*, *71*, 1-24. doi:10.1146/annurev-psych-010419-051027

Faber, M., Bixler, R., & D’Mello, S. K. (2018). An automated behavioral measure of mind wandering during computerized reading. *Behavior Research Methods*, *50*(1), 134–150. doi:10.3758/s13428-017-0857-y

Gyurkovics, M., Balota, D. A., & Jackson, J. D. (2018). Mind-wandering in healthy aging and early stage Alzheimer’s disease. *Neuropsychology*, *32*(1), 89–101. doi:10.1037/neu0000385

Hoffmann, F., Banzhaf, C., Kanske, P., Bermpohl, F., & Singer, T. (2016). Where the depressed mind wanders: Self-generated thought patterns as assessed through experience sampling as a state marker of depression. *Journal of Affective Disorders*, *198*, 127–134. doi:10.1016/j.jad.2016.03.005

Irish, M., Goldberg, Z., Alaeddin, S., O’Callaghan, C., & Andrews-Hanna, J. R. (2019). Age-related changes in the temporal focus and self-referential content of spontaneous cognition during periods of low cognitive demand. *Psychological Research*, *83*(4), 747–760. doi:10.1007/s00426-018-1102-8

Jackson, J. D., Weinstein, Y., & Balota, D. A. (2013). Can mind-wandering be timeless? Atemporal focus and aging in mind-wandering paradigms. *Frontiers in Psychology*, *4*(742), 1-16. doi:10.3389/fpsyg.2013.00742

Jeunehomme, O., & D’Argembeau, A. (2016). Prevalence and determinants of direct and generative modes of production of episodic future thoughts in the word cueing paradigm. *The Quarterly Journal of Experimental Psychology*, *69*(2), 254–272. doi:10.1080/17470218.2014.993663

Jing, H. G., Madore, K. P., & Schacter, D. L. (2016). Worrying about the future: An episodic specificity induction impacts problem solving, reappraisal, and well-being. *Journal of Experimental Psychology: General*, *145*(4), 402–418. doi:10.1037/xge0000142

Kirk, M., & Berntsen, D. (2018). A short cut to the past: Cueing via concrete objects improves autobiographical memory retrieval in Alzheimer’s disease patients. *Special Issue: Autobiographical Memory, 110*, 113–122. doi:10.1016/j.neuropsychologia.2017.06.034

Kirk, M., Rasmussen, K. W., Overgaard, S. B., & Berntsen, D. (2019). Five weeks of immersive reminiscence therapy improves autobiographical memory in

Alzheimer's disease. *Memory*, *27*(4), 441–454. doi:10.1080/09658211.2018.1515960

Klinger, E. (1978). Modes of normal conscious flow. In K. S. Pope & J. L. Singer (Eds.), *The stream of consciousness: Scientific investigations into the flow of human experience* (pp. 225–258). New York: Plenum Press.

Klinger, E., Koster, E. H. W., & Marchetti, I. (2018). Spontaneous thought and goal pursuit from functions such as planning to dysfunctions such as rumination. In K. Christoff & K. C. R. Fox (Eds.), *The Oxford handbook of spontaneous thought: Mind-wandering, creativity, and dreaming*. Retrieved from https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780190464745.001.0001/oxfordhb-9780190464745-e-24

Kvavilashvili, L., Cockburn, J., & Kornbrot, D. E. (2013). Prospective memory and ageing paradox with event-based tasks: A study of young, young-old, and old-old participants. *Quarterly Journal of Experimental Psychology*, *66*(5), 864–875. doi:10.1080/17470218.2012.721379

Kvavilashvili, L., & Mandler, G. (2004). Out of one's mind: A study of involuntary semantic memories. *Cognitive Psychology*, *48*(1), 47–94. doi:10.1016/S0010-0285(03)00115-4

La Corte, V., Sperduti, M., Abichou, K., & Piolino, P. (2019). Episodic memory assessment and remediation in normal and pathological aging using virtual reality: A mini review. *Frontiers in Psychology*, *10*, 173. doi:10.3389/fpsyg.2019.00173

Levine, B., Svoboda, E., Hay, J. F., Winocur, G., & Moscovitch, M. (2002). Aging and autobiographical memory: Dissociating episodic from semantic retrieval. *Psychology and Aging*, *17*(4), 677–689. doi:10.1037/0882-7974.17.4.677

Lindenberger, U., & Mayr, U. (2014). Cognitive aging: Is there a dark side to environmental support? *Trends in Cognitive Sciences*, *18*(1), 7–15. doi:10.1016/j.tics.2013.10.006

Loveday, C., & Conway, M. A. (2011). Using SenseCam with an amnesic patient: Accessing inaccessible everyday memories. *Memory*, *19*(7), 697–704. doi:10.1080/09658211.2011.610803

Mace, J. H. (2007). Involuntary memory: Concept and theory. In J. H. Mace (Ed.), *Involuntary Memory*. Retrieved from https://doi.org/10.1002/9780470774069.ch1

Madore, K. P., Gaesser, B., & Schacter, D. L. (2014). Constructive episodic simulation: Dissociable effects of a specificity induction on remembering, imagining, and describing in young and older adults. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *40*(3), 609–622. doi:10.1037/a0034885

Madore, K. P., Jing, H. G., & Schacter, D. L. (2016). Divergent creative thinking in young and older adults: Extending the effects of an episodic specificity induction. *Memory and Cognition*, *44*(6), 974–988. doi:10.3758/s13421-016-0605-z

Maillet, D., Beaty, R. E., Adnan, A., Fox, K. C. R., Turner, G. R., & Spreng, R. N. (2019). Aging and the wandering brain: Age-related differences in the neural correlates of stimulus-independent thoughts. *PLOS ONE*, *14*(10), e0223981. doi:10.1371/journal.pone.0223981

Maillet, D., Beaty, R. E., Jordano, M. L., Touron, D. R., Adnan, A., Silvia, P. J., … Kane, M. J. (2018). Age-related differences in mind-wandering in daily life. *Psychology and Aging*, *33*(4), 643–653. doi:10.1037/pag0000260

Maillet, D., & Rajah, M. N. (2016). Assessing the neural correlates of task-unrelated thoughts during episodic encoding and their association with subsequent memory in young and older adults. *Journal of Cognitive Neuroscience*, *28*(6), 826–841. doi:10.1162/jocn_a_00935

Martinon, L. M., Riby, L. M., Poerio, G., Wang, H.-T., Jefferies, E., & Smallwood, J. (2019). Patterns of on-task thought in older age are associated with changes in functional connectivity between temporal and prefrontal regions. *Brain and Cognition*, *132*, 118–128. doi:10.1016/j.bandc.2019.04.002

McCormick, C., Ciaramelli, E., De Luca, F., & Maguire, E. A. (2018). Comparing and contrasting the cognitive effects of hippocampal and ventromedial prefrontal cortex damage: A review of human lesion studies. *Neuroscience*, *374*, 295–318. doi:10.1016/j.neuroscience.2017.07.066

McDaniel, M. A., & Einstein, G. O. (2000). Strategic and automatic processes in prospective memory retrieval: A multiprocess framework. *Applied Cognitive Psychology*, *14*(7), S127–S144. doi:10.1002/acp.775

Mildner, J. N., & Tamir, D. I. (2019). Spontaneous thought as an unconstrained memory process. *Trends in Neurosciences*, *42*(11), 763–777. doi:10.1016/j.tins.2019.09.001

Neisser, U. (1981). *Memory observed: Remembering in natural contexts*. San Francisco: Freeman.

O'Callaghan, C., & Irish, M. (2018). Candidate mechanisms of spontaneous cognition as revealed by dementia syndromes. In K. Christoff & K. C. R. Fox (Eds.), *The Oxford* *handbook of spontaneous thought: Mind-wandering, creativity, dreaming, and clinical disorders* (pp. 493-508). New York: Oxford University Press.

O'Callaghan, C., Shine, J. M., Hodges, J. R., Andrews-Hanna, J. R., & Irish, M. (2019). Hippocampal atrophy and intrinsic brain network dysfunction relate to alterations in mind wandering in neurodegeneration. *Proceedings of the National Academy of Sciences*, *116*(8), 3316-3321. doi:10.1073/pnas.1818523116

O'Callaghan, C., Shine, J. M., Lewis, S. J. G., Andrews-Hanna, J. R., & Irish, M. (2015). Shaped by our thoughts – A new task to assess spontaneous cognition and its associated neural correlates in the default network. *Brain and Cognition*, *93*, 1–10. doi:10.1016/j.bandc.2014.11.001

Pelagatti, C., Binda, P., & Vannucci, M. (2018). Tracking the dynamics of mind wandering: Insights from pupillometry. *Journal of Cognition*, *1*(1), 1–12. doi:10.5334/joc.41

Peter, J., & Kliegel, M. (2018). The age-prospective memory paradox: Is it about motivation? *Clinical and Translational Neuroscience*, *2*(2), 2514183X18807103. doi:10.1177/2514183X18807103

Poerio, G. L., Totterdell, P., & Miles, E. (2013). Mind-wandering and negative mood: Does one thing really lead to another? *Consciousness and Cognition*, *22*(4), 1412–1421. doi:10.1016/j.concog.2013.09.012

Renoult, L., Davidson, P. S. R., Palombo, D. J., Moscovitch, M., & Levine, B. (2012). Personal semantics: At the crossroads of semantic and episodic memory. *Trends in Cognitive Sciences*, *16*(11), 550–558. doi:10.1016/j.tics.2012.09.003

Renoult, L., Irish, M., Moscovitch, M., & Rugg, M. D. (2019). From knowing to remembering: The semantic–episodic distinction. *Trends in Cognitive Sciences, 23*(12), 1041-1057. doi:10.1016/j.tics.2019.09.008

Renoult, L., Tanguay, A., Beaudry, M., Tavakoli, P., Rabipour, S., Campbell, K., … Davidson, P. S. R. (2016). Personal semantics: Is it distinct from episodic and semantic memory? An electrophysiological study of memory for autobiographical facts and repeated events in honor of Shlomo Bentin. *Special Issue: Functional Selectivity in Perceptual and Cognitive Systems - A Tribute to Shlomo Bentin (1946-2012)*, *83*, 242–256. doi:10.1016/j.neuropsychologia.2015.08.013

Rugg, M. D., & Morcom, A. M. (2005). The relationship between brain activity, cognitive performance, and aging: The case of memory. In R. Cabeza, L. Nyberg, & D. Park (Eds.), *Cognitive neuroscience of aging: Linking cognitive and cerebral aging* (pp. 132–154). Oxford: Oxford University Press.

Schacter, D. L., & Madore, K. P. (2016). Remembering the past and imagining the future: Identifying and enhancing the contribution of episodic memory. *Memory Studies*, *9*(3), 245–255. doi:10.1177/1750698016645230

Schlagman, S., Kliegel, M., Schulz, J., & Kvavilashvili, L. (2009). Differential effects of age on involuntary and voluntary autobiographical memory. *Psychology and Aging*, *24*(2), 397–411. doi:10.1037/a005785

Schlagman, S., Kvavilashvili, L., & Schulz, J. (2007). Effects of age on involuntary autobiographical memories. In J. H. Mace (Ed.), *Involuntary Memory* (pp. 87–112). New York: Blackwell.

Schwarz, N., Park, D., Knauper, B., & Sudman, S. (1998). *Cognition, aging and self-reports*. Psychology Press.

Seli, P., Kane, M. J., Metzinger, T., Smallwood, J., Schacter, D. L., Maillet, D., … Smilek, D. (2018). The family-resemblances framework for mind-wandering remains well clad. *Trends in Cognitive Sciences*, *22*(11), 959–961. doi:10.1016/j.tics.2018.07.007

Seli, P., Kane, M. J., Smallwood, J., Schacter, D. L., Maillet, D., Schooler, J. W., & Smilek, D. (2018). Mind-wandering as a natural kind: A family-resemblances view. *Trends in Cognitive Sciences*, *22*(6), 479–490. doi:10.1016/j.tics.2018.03.010

Seli, P., Maillet, D., Schacter, D. L., Kane, M. J., Smallwood, J., Schooler, J. W., & Smilek, D. (2017). *What does (and should) "mind wandering" mean?* doi:10.31234/osf.io/q7s8u

Shallice, T. (1988). *From Neuropsychology to mental structure*. Cambridge: Cambridge University Press.

Silva, A. R., Pinho, M. S., Macedo, L., Moulin, C., Caldeira, S., & Firmino, H. (2017). It is not only memory: Effects of SenseCam on improving well-being in patients with mild Alzheimer's disease. *International Psychogeriatrics*, *29*(5), 741–754. doi:10.1017/S104161021600243X

Smallwood, J., & O'Connor, R. C. (2011). Imprisoned by the past: Unhappy moods lead to a retrospective bias to mind wandering. *Cognition and Emotion*, *25*(8), 1481–1490. doi:10.1080/02699931.2010.545263

St. Jacques, P. L., Rubin, D. C., & Cabeza, R. (2012). Age-related effects on the neural correlates of autobiographical memory retrieval. *Neurobiology of Aging*, *33*(7), 1298–1310. doi:10.1016/j.neurobiolaging.2010.11.007

Stawarczyk, D., Majerus, S., Maj, M., Van der Linden, M., & D’Argembeau, A. (2011). Mind-wandering: Phenomenology and function as assessed with a novel experience sampling method. *Acta Psychologica*, *136*(3), 370–381. doi:10.1016/j.actpsy.2011.01.002

Uzer, T., Lee, P. J., & Brown, N. R. (2012). On the prevalence of directly retrieved autobiographical memories. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*(5), 1296–1308. doi:10.1037/a0028142

Wang, H.-T., Poerio, G., Murphy, C., Bzdok, D., Jefferies, E., & Smallwood, J. (2018). Dimensions of experience: Exploring the heterogeneity of the wandering mind. *Psychological Science*, *29*(1), 56–71. doi:10.1177/0956797617728727

Warden, E. A., Plimpton, B., & Kvavilashvili, L. (2019). Absence of age effects on spontaneous past and future thinking in daily life. *Psychological Research*, *83*(4), 727–746. doi:10.1007/s00426-018-1103-7

Supplementary material 1

Sample and methodological characteristics of the studies included in the meta-analysis

Reference ID	Study	Sample size		Mean age		Mean education		Gender proportion		Type of task
		Older	Younger	Older	Younger	Older	Younger	Older	Younger	
Berntsen et al. (2015)	4	42	306	64.5	24.96			0.55	0.40	Inventory
Frank et al. (2015)	1	40	36	69	19.5	15.7	13.19			Reading comprehension
Giambra (1989) A I	1	32	28					0.06	0.18	Vigilance
Giambra (1989) A II	1	25	28					0.12	0.18	Vigilance
Giambra (1989) B	2	35	20					0.37	0.5	Vigilance
Giambra (1989) C	2	25	23					0.40	0.48	Vigilance
Giambra (1989) D	3	30	43					0.47	0.44	Vigilance
Giambra (1989) E	3	39	40					0.33	0.33	Vigilance
Giambra (1989) F	4	13	29					0.23	0.41	Vigilance

Reference ID	Study	Sample size		Mean age		Mean education		Gender proportion		Type of task
		Older	Younger	Older	Younger	Older	Younger	Older	Younger	
Giambra (1989) G	5	5	10					0.60	0.50	Vigilance
Giambra (2000a) A	1	316	1155					0.45	0.59	Inventory
Giambra (2000a) B	1	247	460					0.33	0.60	Inventory
Giambra & Grodsky (1992) I	1	27	30			14.9	13.8	0.48	0.50	Reading comprehension
Giambra & Grodsky (1992) II	1	27	31			14.9	14.7	0.48	0.48	Reading comprehension
Jackson & Balota (2012) A	1	62	54	77.3	19	15	13	0.65	0.54	SART
Jackson & Balota (2012) B I	2	38	29	75.8	19.4	14.7	13.4	0.82	0.62	SART
Jackson & Balota (2012) C	3	49	31	76.3	20.9	15.8	14.9	0.59	0.52	SART
Jackson & Balota (2012) B II	4	38	29	75.8	19.4	14.7	13.4	0.82	0.62	Reading comprehension
Jackson & Balota (2012) B III	4	38	29	75.80	19.40	14.70	13.40	0.82	0.62	Reading comprehension
Jackson et al. (2013) A	1	57	89	57.24	24.59					SART

Reference ID	Study	Sample size		Mean age		Mean education		Gender proportion		Type of task
		Older	Younger	Older	Younger	Older	Younger	Older	Younger	
Jackson et al. (2013) B	2	74	82	56.56	25.15	15.43	15.39	0.65	0.50	SART
Jordano & Touron (2017) I	1	30	30	66.52	19.20	16.67	12.80			Working Memory task
Jordano & Touron (2017) II	1	30	30	66.52	19.20	16.67	12.80			Working Memory task
Krawietz et al. (2012) A	1	23	76	75.10	19.05			0.61	0.63	Reading comprehension
Krawietz et al. (2012) B	2	23	63	71.70	19.03			0.91	0.57	Reading comprehension
Maillet et al. (2018)	1	20	31	70.70	21.53			0.50	0.61	Experience sampling in daily life
Maillet & Rajah (2013)	1	25	29	64.30	22.60	14.90	15.19	0.58	0.71	Memory task
Maillet & Rajah (2016)	1	16	20	67.00	23.40	16.38	16.35	0.69	0.60	Memory task
Maillet & Schacter (2016b)	1	30	30	71.10	23.00	16.23	15.93	0.53	0.53	Memory task
McVay et al. (2013) A	1	49	55			15.22	12.85			SART
McVay et al. (2013) B	1	50	53			15.62	12.98			SART

Reference ID	Study	Sample size		Mean age		Mean education		Gender proportion		Type of task
		Older	Younger	Older	Younger	Older	Younger	Older	Younger	
McVay et al. (2013) C	2	43	54			15.58	12.41			1-back task
McVay et al. (2013) D	2	42	58			15.00	12.70			Working Memory task
Mevel et al. (2013) I	1	19	14							Inventory
Mevel et al. (2013) II	1	20	26							Rest
Parks et al. (1988−89)	1	42	42	70.00	19.80	16.00	14.00	0.50	0.50	Inventory
Seli et al. (2017)	2	27	29	73.48	21.93					SART
Shake et al. (2016)	1	34	34	67.12	19.53	16.26	13.41	0.50	0.53	Reading comprehension
Staub et al. (2014a)	1	30	30	65.20	24.80	14.30	15.20	0.53	0.70	SART
Staub et al. (2014b)	1	25	22	64.80	23.20	13.70	14.30	0.48	0.68	Go/No-Go inhibition task
Zavagnin et al. (2014) I	1	19	20	80.00	24.15	11.68	13.10			SART
Zavagnin et al. (2014) II	1	19	20	80.00	24.15	11.68	13.10			SART
Zavagnin et al. (2014) III	1	20	20	69.05	24.15	10.95	13.10			SART

Zavagnin et al. (2014) IV	1	20	20	69.05	24.15	10.95	13.10			SART

Reference ID	Study	Reporting mode	Task demand	Stimulus time	ISI time	Pace	Target proportion	Probe rate	Stimulus meaningfulness	Measure type
Berntsen et al. (2015)	4									Retrospective
Frank et al. (2015)	1	Probe-caught	High						With meaning	Online
Giambra (1989) A I	1	Self-caught	Low	500	500	60	0.006		No meaning	Online
Giambra (1989) A II	1	Self-caught	Low	500	500	60	0.006		No meaning	Online
Giambra (1989) B	2	Probe-caught	Low	500		60	0.006	25	No meaning	Online
Giambra (1989) C	2	Probe-caught	Low	500		60	0.006	25	No meaning	Online
Giambra (1989) D	3	Self-caught	Low	2000					No meaning	Online
Giambra (1989) E	3	Self-caught	Low	2000					No meaning	Online
Giambra (1989) F	4	Probe-caught	Low	2000				25	No meaning	Online

Reference ID	Study	Reporting mode	Task demand	Stimulus time	ISI time	Pace	Target proportion	Probe rate	Stimulus meaningfulness	Measure type
Giambra (1989) G	5	Probe-caught	Low	1000				29	No meaning	Online
Giambra (2000a) A	1									Retrospective
Giambra (2000a) B	1									Retrospective
Giambra & Grodsky (1992) I	1	Self-caught	High						With meaning	Online
Giambra & Grodsky (1992) II	1	Self-caught	High						With meaning	Online
Jackson & Balota (2012) A	1	Probe-caught	High	200	900	54	0.111		No meaning	Online
Jackson & Balota (2012) B I	2	Probe-caught	High	200	900	54	0.111		No meaning	Online
Jackson & Balota (2012) C	3	Probe-caught	High	1250	1250	22.5	0.111		No meaning	Online
Jackson & Balota (2012) B II	4	Probe-caught	High						With meaning	Online
Jackson & Balota (2012) B III	4	Self-caught	High						With meaning	Online
Jackson et al. (2013) A	1	Self-caught	High	1250	1250	24			No meaning	Online
Jackson et al. (2013) B	2	Probe-caught	High	1250	1250	24			No meaning	Online

Reference ID	Study	Reporting mode	Task demand	Stimulus time	ISI time	Pace	Target proportion	Probe rate	Stimulus meaningfulness	Measure type
Jordano & Touron (2017) I	1	Probe-caught	High						No meaning	Online
Jordano & Touron (2017) II	1		High						No meaning	Retrospective
Krawietz et al. (2012) A	1	Probe-caught	High						With meaning	Online
Krawietz et al. (2012) B	2	Probe-caught	High						With meaning	Online
Maillet et al. (2018)	1	Probe-caught							With meaning	Online
Maillet & Rajah (2013)	1			1500		13.6			With meaning	Retrospective
Maillet & Rajah (2016)	1	Probe-caught				6.7			With meaning	Online
Maillet & Schacter (2016b)	1	Probe-caught		4000	4000	7.5			With meaning	Online
McVay et al. (2013) A	1	Probe-caught	High	350	900	48	0.11	20	With meaning	Online
McVay et al. (2013) B	1	Probe-caught	High	350	900	48	0.11	20	With meaning	Online
McVay et al. (2013) C	2	Probe-caught	Low	500	2500	20	0.25	50	With meaning	Online
McVay et al. (2013) D	2	Probe-caught	High	500	2500	20	0.25	50	With meaning	Online

Reference ID	Study	Reporting mode	Task demand	Stimulus time	ISI time	Pace	Target proportion	Probe rate	Stimulus meaningfulness	Measure type
Mevel et al. (2013) I	1									Retrospective
Mevel et al. (2013) II	1		Low							Retrospective
Parks et al. (1988−89)	1									Retrospective
Seli et al. (2017)	2	Probe-caught	High	350	1650	30	0.111		No meaning	Online
Shake et al. (2016)	1	Probe-caught	High						With meaning	Online
Staub et al. (2014a)	1		High	150		27	0.111		No meaning	Retrospective
Staub et al. (2014b)	1		High	600	1500	28	0.108		With meaning	Retrospective
Zavagnin et al. (2014) I	1	Probe-caught	High	2000	2000	15	0.163		No meaning	Online
Zavagnin et al. (2014) II	1	Probe-caught	High	2000	2000	15	0.163		With meaning	Online
Zavagnin et al. (2014) III	1	Probe-caught	High	2000	2000	15	0.163		No meaning	Online
Zavagnin et al. (2014) IV	1	Probe-caught	High	2000	2000	15	0.163		With meaning	Online

Note: In Reference ID, capital letters represent independent effect sizes and roman numerals indicate dependent effect sizes. In type of task, SART stands for Sustained Attention to Response Task. Pace was defined as the number of stimuli presented per minute, calculated by dividing the total number of stimuli presented by the duration of the task (in minutes). Target proportion was calculated by dividing the total number of targets by the total number of stimuli. Probe rate consisted of the time between each probe, calculated by dividing the total time of the task (in seconds) by the number of probes. Gender proportion differences were based on subtracting younger from older group gender proportions, which were calculated by dividing the number of women by the total number of participants in each group. Some spaces were intentionally left blank to represent missing values.

Supplementary material 2

Words presented in the first and second part of the vigilance task by order of presentation and descriptive summary of words' valence, arousal and frequency

Vigilance task	**Order of presentation**	**European Portuguese**	**English**
Part 1	1	varíola	smallpox
Part 1	2	motim	riot
Part 1	3	inundação	flood
Part 1	4	excitação	thrill
Part 1	5	acre	needle
Part 1	6	tanque	pungent
Part 1	7	beco	alley
Part 1	8	estrume	manure
Part 1	9	veículo	vehicle
Part 1	10	pesar	bereavement
Part 1	11	adega	cellar
Part 1	12	gozo	enjoyment
Part 1	13	cego	blind
Part 1	14	peçonha	poison
Part 1	15	vespa	wasp
Part 1	16	piolho	louse
Part 1	17	comédia	comedy
Part 1	18	lixeira	dump

Part 1	19	térmite	termite
Part 1	20	ciúme	jealousy
Part 1	21	pontapé	kick
Part 1	22	heroína	heroin
Part 1	23	disparate	nonsense
Part 1	24	optimismo	optimism
Part 1	25	sepultura	tomb
Part 1	26	salvador	savior
Part 1	27	amado	loved
Part 1	28	débil	feeble
Part 1	29	êxtase	ecstasy
Part 1	30	luxúria	lust
Part 1	31	jóia	jewel
Part 1	32	lucro	profit
Part 1	33	talento	talent
Part 1	34	elevador	elevator
Part 1	35	rainha	queen
Part 1	36	vulcão	vulcano
Part 1	37	barril	barrel
Part 1	38	tigela	bowl
Part 1	39	tortura	torture
Part 1	40	troféu	trophy
Part 1	41	licenciado	graduate

Part 1	42	vencedor	champion
Part 1	43	tesouro	treasure
Part 1	44	engenho	wit
Part 1	45	violino	violin
Part 1	46	sustento	alimony
Part 1	47	enterro	burial
Part 1	48	veleiro	sailboat
Part 2	1	muleta	crutch
Part 2	2	relâmpago	lightning
Part 2	3	desgosto	grief
Part 2	4	diversão	fun
Part 2	5	sebo	grime
Part 2	6	recado	errand
Part 2	7	tédio	ennui
Part 2	8	azedo	sour
Part 2	9	execução	execution
Part 2	10	solidão	loneliness
Part 2	11	céptico	skeptical
Part 2	12	circo	circus
Part 2	13	escândalo	scandal
Part 2	14	ligadura	bandage
Part 2	15	réptil	reptile
Part 2	16	enfermidade	sickness

Part 2	17	glória	glory
Part 2	18	grosseiro	coarse
Part 2	19	fuzil	gun
Part 2	20	cólera	rage
Part 2	21	alerta	alert
Part 2	22	bebida	beverage
Part 2	23	colete	vest
Part 2	24	místico	mystic
Part 2	25	diabo	devil
Part 2	26	ordenado	tidy
Part 2	27	deslumbramento	dazzle
Part 2	28	urina	urine
Part 2	29	lotaria	lottery
Part 2	30	beliscão	pinch
Part 2	31	bolo	cake
Part 2	32	triunfo	triumph
Part 2	33	bebé	baby
Part 2	34	assento	seat
Part 2	35	correio	mail
Part 2	36	anseio	desire
Part 2	37	mutação	mutation
Part 2	38	queixo	chin
Part 2	39	aflito	distressed

Part 2	40	namorado	sweetheart
Part 2	41	iate	yacht
Part 2	42	paixão	passion
Part 2	43	natal	christmas
Part 2	44	chocolate	chocolate
Part 2	45	relva	grass
Part 2	46	pântano	swamp
Part 2	47	insulto	insult
Part 2	48	privacidade	privacy

	Vigilance Task: Part 1 *N* = 48		Vigilance Task: Part 2 *N* = 48	
	M	*SD*	*M*	*SD*
Valence	4.93	1.83	5.00	1.83
Arousal	5.11	0.99	5.07	1.11
Frequency	14.92	14.35	15.15	14.83

Supplementary material 3.1

Words presented in the vigilance tasks and descriptive summary of words' valence, arousal (norms from Soares, Comesaña, Pinheiro, Simões, & Frade, 2012), and frequency, concreteness and imageability (norms from Soares, Costa, Machado, Comesaña, & Oliveira, 2017) by vigilance task

Vigilance task	European Portuguese	English
A	açúcar	sugar
A	alergia	allergy
A	ambulância	ambulance
A	áspero	harsh
A	assento	seat
A	autocarro	bus
A	avenida	avenue
A	bandeira	flag
A	bar	pub
A	beco	alley
A	beijo	kiss
A	brinquedo	toy
A	carruagem	wagon
A	casal	couple
A	casamento	wedding
A	casino	casino
A	centopeia	roach

A	chave	key
A	chuva	rain
A	coluna	column
A	comida	food
A	contente	glad
A	corredor	aisle
A	cozinheiro	cook
A	dentista	dentist
A	diabo	devil
A	diamante	diamond
A	diploma	diploma
A	doente	sick
A	escuro	dark
A	esposa	wife
A	faca	knife
A	famoso	famous
A	febre	fever
A	fogo	fire
A	forno	oven
A	germes	germs
A	gozo	enjoyment
A	igreja	church

A	infantário	nursery
A	jogo	game
A	lamacento	muddy
A	lâmpada	lightbulb
A	larva	maggot
A	leão	lion
A	lenço	handkerchief
A	ligadura	bandage
A	lixo	garbage
A	manteiga	butter
A	milionário	millionaire
A	mosquito	mosquito
A	motor	engine
A	mundo	world
A	nu	naked
A	nublado	overcast
A	peixe	fish
A	planta	plant
A	podre	rotten
A	pomba	dove
A	porco	pig
A	prenda	gift

A	provocador	defiant
A	quebrado	broken
A	relâmpago	lightning
A	salvamento	rescue
A	serpente	serpent
A	tecido	tissue
A	tesoura	scissors
A	torre	tower
A	trombeta	trumpet
A	urina	urine
A	vulcão	volcano
B	adulto	adult
B	agulha	needle
B	alerta	alert
B	aranha	spider
B	atleta	athlete
B	bebé	baby
B	bebida	drink
B	bengala	crutch
B	bolha	blister
B	bolor	mildew
B	brutal	brutal

B	cadeira	chair
B	calor	heat
B	cicatriz	scar
B	colete	vest
B	computador	computer
B	coração	heart
B	coroa	crown
B	criança	child
B	dinheiro	money
B	elevador	elevator
B	emprego	employment
B	escorpião	scorpion
B	escritório	office
B	falcão	hawk
B	feio	ugly
B	ferramenta	tool
B	ferro	iron
B	forte	strong
B	frio	cold
B	garrafa	bottle
B	homem	man
B	insecto	insect

B	irmão	brother
B	leite	milk
B	lesão	lesion
B	louco	mad
B	lucro	profit
B	máquina	machine
B	morgue	morgue
B	muco	mucus
B	muleta	crutch
B	musculado	muscular
B	namorado	sweetheart
B	natal	christmas
B	nó	knot
B	noiva	bride
B	obesidade	obesity
B	pântano	marsh
B	paralisia	paralysis
B	pecado	sin
B	petróleo	kerosene
B	porcaria	junk
B	rapaz	boy
B	relógio	clock

B	relvado	lawn
B	réptil	reptile
B	rocha	rock
B	rua	street
B	sarampo	measles
B	sujo	dirty
B	tabaco	tobacco
B	tanque	tank
B	táxi	taxi
B	termómetro	thermometer
B	troféu	trophy
B	tubarão	shark
B	veículo	vehicle
B	vermelho	red
B	vespa	wasp
B	vidro	glass
B	vinho	wine

	Vigilance Task A *N* = 72		Vigilance Task B *N* = 72	
	M	*SD*	*M*	*SD*
Valence	5.10	1.31	5.07	1.38

Arousal	4.80	.73	4.83	.65
Frequency	26.20	69.31	28.39	52.62
Concreteness	5.70	.94	5.75	.96
Imageability	5.59	.64	5.59	.71

Note: Valence, arousal, concreteness and imageability were measured in scale increasing scale from 1 to 9. Frequency was given by frequency per million of occurrences in the linguistic corpus. There were no significant differences between the words in vigilance task A and B (all $p > .721$).

References

Soares, A. P., Comesaña, M., Pinheiro, A. P., Simões, A., & Frade, C. S. (2012). The adaptation of the affective norms for english words (ANEW) for european portuguese. *Behavior Research Methods, 44*(1), 256-269. doi: 10.3758/s13428-011-0131-7

Soares, A. P., Costa, A. S., Machado, J., Comesaña, M., & Oliveira, H. M. (2017). The minho word pool: Norms for imageability, concreteness, and subjective frequency for 3,800 portuguese words. *Behavior Research Methods, 49*, 1065–1081. doi: 10.3758/s13428-016-076

Supplementary material 3.2

Coding instructions

a) If the content includes one of the following situations, please select:
    1. It is only a music (earworm);
    2. It is only noticing something in the environment without further elaboration (external distraction);
    3. It is only the repetition of the last word presented on the screen[15].

b) Is the **content** described by the participant related with the task? Please code:
    0. The content is related to the task.
    1. The content is not related with the task.

Examples of thoughts related with the task: “I was reminding myself to say yes when a yellow word appears”, “I was wondering if the words would repeat”, "The word *sour* brought up an aversion feeling", "I was thinking I was more concentrated now than at the beginning of the task".

c) For task-unrelated thoughts code episodic specificity from 0 to 4 within Piolino et al. (2006) guidelines.

Notes

- The time and place information may be explicit or implicit.
- General knowledge (facts about the world and public events) should be coded 0 even if they refer to facts that occur in certain time epoch and country. **However**, there may be cases in which general knowledge is represented in an image or scene with some detail, suggesting a higher level of episodic construction (e.g., “I saw many refugees in a small boat, struggling”, referring to knowledge about the refugee crisis) compared to simply stating general facts or images. These cases should be coded 1.

[15] These cases were flagged because it was not clear how they should be classified, given that the content is not about the task (as in e.g., “I was thinking the task is very slow”), but is only a repetition of an element presented in it, without any further elaboration. After discussion with a senior researcher, and given the absence of any task-unrelated information in these cases, we decided to classify them as task-related thoughts.

- When several events are mentioned by the participants and you are unsure which one is central, take into account what was the participant report about the predominant event (given in the temporality score). When the description includes general knowledge and/or personal semantics **and** an event, **the event should be the focus of coding**.
- The cognitive, perceptual and emotional details must refer to something experienced in the event described. This means that thoughts or emotion about recalling/imagining the event **now** are not considered (e.g. "This is silly, but I was remembering…).

Reference

Piolino, P., Desgranges, B., Clarys, D., Guillery-Girard, B., Taconnat, L., Isingrini, M., & Eustache, F. (2006). Autobiographical memory, autonoetic consciousness, and self-perspective in aging. *Psychology and Aging*, *21*(3), 510–525. doi:10.1037/0882-7974.21.3.510

Supplementary material 3.3

Descriptive statistics of spontaneous task-unrelated thoughts by trigger, temporality and verbal/visual form

Table 1. Mean frequency (standard deviation) of sTUTs in each trigger status (without, with trigger) by age group in the episodic specificity induction (ESI) and in the control induction.

	Without trigger		With trigger	
	Younger	Older	Younger	Older
ESI	0.63 (0.82)	0.63 (0.97)	3.96 (3.25)	3.67 (3.50)
Control	0.79 (0.88)	0.67 (1.09)	4.00 (3.09)	3.67 (3.36)
Total	0.71 (0.72)	0.65 (0.72)	3.98 (3.10)	3.67 (3.10)

Table 2. Mean frequency (standard deviation) of sTUTs in each temporality (past, present, future, atemporal) by age group in the episodic specificity induction (ESI) and in the control induction[16].

	Past		Present		Future		Atemporal	
	Younger	Older	Younger	Older	Younger	Older	Younger	Older
ESI	1.83 (1.97)	1.29 (1.68)	0.33 (0.56)	1.08 (1.18)	0.83 (1.09)	0.58 (1.25)	1.58 (2.55)	1.25 (1.92)
Control	1.50 (1.82)	1.63 (2.23)	0.17 (0.38)	1.17 (1.20)	1.29 (1.43)	0.46 (0.78)	1.83 (2.12)	0.83 (1.20)
Total	1.67 (1.67)	1.46 (1.67)	0.25 (0.74)	1.13 (0.74)	1.06 (1.00)	0.53 (1.00)	1.71 (1.77)	1.04 (1.77)

[16]There were some instances in which participants reported more than one temporal-orientation for the thought described (e.g., thinking about a past experience that is going to happen in the future, or an ongoing/present situation that is going to have a future resolution…). These mixed temporality cases were only 1.85% of thoughts collected, and were not included in the temporality analysis.

Table 3. *Mean frequency (standard deviation) of sTUTs in each form (verbal, visual) by age group in the episodic specificity induction (ESI) and in the control induction.*

	Verbal		Visual	
	Younger	Older	Younger	Older
ESI	1.29 (1.12)	2.21 (1.86)	3.29 (2.93)	2.04 (2.46)
Control	1.71 (1.40)	2.21 (2.04)	3.08 (2.55)	1.96 (2.18)
Total	1.50 (1.46)	2.21 (1.46)	3.19 (2.34)	2.00 (2.34)