I remember it like it was yesterday: Age-related differences in the subjective experience of remembering

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Abstract

It has been frequently described that older adults subjectively report the vividness of their memories as being as high, or even higher, than young adults, despite poorer objective memory performance. Here, we review studies that examined age-related differences in the subjective experience of memory vividness. **By examining vividness calibration and resolution, studies using different types of approaches converge to suggest** that older adults overestimate the intensity of their vividness ratings relative to young adults, and that they rely on retrieved memory details to a lesser extent to judge vividness. We discuss potential mechanisms underlying these observations. Inflation of memory vividness with regard to the richness of memory content may stem from age-differences in vividness criterion or scale interpretation and psycho-social factors. **The reduced reliance on episodic memory details in older adults may stem from age-related differences in how they monitor these details to make their vividness ratings. Considered together, these findings emphasize the importance of examining age-differences in memory vividness using different analytical methods and they provide valuable evidence that the subjective experience of remembering is more than the reactivation of memory content. In this vein, we recommend that future studies explore the links between memory vividness and other subjective memory scales (e.g., ratings of details or memory confidence) in healthy aging and/or other populations**, as it could be used as a window to better characterize the cognitive processes that underpin the subjective assessment of the quality of recollected events.

Introduction

The subjective experience of remembering refers to the phenomenological experience accompanying the retrieval of a past event in episodic memory (Tulving, 1972, 2002). Mentions of the phenomenological experience accompanying the reminiscence of the past can already be found in the philosophical literature of the last century. Philosophers such as Russell, Malcolm, and Smith notably mentioned that, relative to perception, the mental images constituting one's recollection of the past are dim, unclear, sketchy and simplified (see Brewer, 1999, for a summary). The phenomenology of memory retrieval can be operationalized with various measures concerning several dimensions of the reminiscence: clarity of visual details, colors, sounds, order of events, the spatial location of people and objects, and the thoughts and feelings experienced during encoding (Johnson et al., 1988; Johnson et al., 1993). Yet, in episodic memory studies, participants are usually asked to introspectively rate the sharpness of their mental representations by means of memory vividness ratings. Vividness can be defined as the quality of being clear, brightly colored and detailed in one's mind (Cambridge University Press, n.d.). Vividness correlates with visual details, the clarity of a representation or its intensity (Tooming & Miyazono, 2020). This implies that the level of vividness of mental representations can strongly vary from one memory to another, with some recollected events being rich and intense while others are vague or blurry.

Although progress in the understanding of the cognitive underpinnings of memory vividness has been made during the last decades (Simons et al., 2020, 2021), much is still to be discovered. Notably, it remains unclear to what extent the intensity of the subjective experience of vividness maps onto the memory content on which it is based, so that it can

be considered as a reliable index of the richness of the retrieved episode. This question has notably arisen following the striking observation that older adults sometimes claim that they experience a vivid and intense sense of recollection when remembering previous episodes while, at the same time, the content of what they recollect is objectively impoverished (Folville, D'Argembeau, et al., 2020; Folville, Jeunehomme, et al., 2020; Hashtroudi et al., 1990; McDonough et al., 2014; St-Laurent et al., 2014). **In the cognitive aging literature, previous studies have examined age-differences in vividness using various approaches (e.g., laboratory stimuli, autobiographical memory, future thinking). Despite their methodological differences, these studies are usually lumped together, thus leading to the conclusion that older adults inflate their vividness ratings, but a careful comparison of their outcomes is currently lacking. Here, we review recent research that has investigated the subjective experience of memory vividness in normal aging, in an attempt to summarize the current state of knowledge.**

If their memories are objectively less detailed than those of young adults, what kind of information/source do older adults take into account to make their subjective memory vividness ratings? **Different theoretical perspectives have tried to address this question, mainly by invoking age-related changes in cognitive or memory abilities (Folville, Bahri, et al., 2020; Folville, D'Argembeau, et al., 2020; Johnson et al., 2015; Mitchell & Hill, 2019). However, these explanations have never been considered together, so that it is currently unclear whether they can fully account for the observed age-differences in memory vividness. In the present review, we discuss the strengths and weaknesses of various theories that may explain age-differences in memory vividness, and we identify gaps that future work should fill.**

The observation that older adults report strong vividness ratings in the face of poor objective memory performance has also questioned the taken-for-granted assumption that vividness just corresponds to the amount of information available in memory (Renoult & Rugg, 2020). In fact, the discrepancy between memory vividness and memory details in aging raises the possibility that the subjective experience of memory vividness is supported to some extent by other cognitive mechanisms than memory retrieval processes. We therefore assume that studies examining age-differences in memory vividness could be used as a window to identify the cognitive mechanisms that underpin memory vividness, thus providing critical inputs to feed theoretical accounts of episodic memory functioning.

In the following sections, we will first consider evidence relating to the cognitive basis of the subjective experience of memory vividness in young adults. Then, age-related differences in cognition and episodic memory functions will be described before reviewing studies that examined age-related differences in subjective memory vividness. Next, the cognitive and environmental factors that influence how older adults make their vividness ratings will be described. To further characterize how older adults make their ratings, age-differences in other subjective memory scales than vividness will be briefly described. Finally, the implications of this research for the study of the subjective experience of vividness will be outlined and some avenues for future investigation will be proposed.

The cognitive bases of memory vividness

Vividness has been widely studied within psychology and philosophy, but the experiential qualities on which a sense of vividness might be based are still a matter of debate (Langkau, 2021). According to recent philosophical accounts, vividness corresponds to the amount of

sensory or perceptive information contained in one's mental image (Langkau, 2021; Tooming & Miyazono, 2020). In psychology, it often relates to the clarity and salience of a mental image (D'Angiulli et al., 2013; Fazekas et al., 2020). When asked to define the characteristics of vividness, people mention the presence of colors, rich details, and well-defined shapes (Cornoldil et al., 1991). Consistent with these accounts are results from fMRI investigations showing that the intensity of vividness is related to neural (re)activation in primary and high-level visual areas both when imagining and remembering stimuli (Bone et al., 2020; Cui et al., 2007; Dijkstra et al., 2017; St-Laurent et al., 2015). Regardless of whether it pertains to mental imagery or episodic memory, the intensity of the subjective sense of vividness might thus be determined by the amount of sensory or perceptual information available in mind. To make a vividness rating, the visual appearance of the mental image may be compared with the clarity of an experience of actual perception (D'Angiulli et al., 2013). Mental imagery is thus a critical component of vividness (Marks, 1973). Consistently, it has been shown that vividness is associated with brain activity in the angular gyrus (Tibon et al., 2019) and precuneus (Richter et al., 2016), brain regions respectively involved in the online maintenance of sensory features (Humphreys et al., 2020; Yazar et al., 2012), and in mental imagery processes (Cavanna & Trimble, 2006; Fulford et al., 2018).

But how does one judge that a mental image is vivid and intense, or on the contrary, vague and blurry? It is considered that such decisions are determined by metacognitive mechanisms. Metacognition refers to one's knowledge about one's internal thoughts and cognitive functioning (Flavell, 1979; Fleming, 2010; Fleming & Dolan, 2012). Metacognitive judgements typically require participants to monitor the accuracy of their decisions, and they are influenced by participants' knowledge, expectancies, and prior experience (Dobromir Rahnev et al., 2015; Sherman et al., 2015; Sherman et al., 2016). In the literature,

metacognitive judgements have often been studied using memory confidence measures. Memory vividness and memory confidence are both metacognitive judgements that are expressed by means of Likert (usually from 0/1 to 5 or 7) or visual analog (from 0/1 to 100) scales during memory retrieval. **Like memory vividness, memory confidence is thought to be based on the quality of the recollected memory trace (Wong et al., 2012). It is therefore not surprising** that these concepts are usually found to correlate in episodic memory tasks (Robinson et al., 2000; Sharot et al., 2007) and that they seem to be supported to some extent by similar brain regions (Simons et al., 2010; Tibon et al., 2019; Yazar et al., 2014). In the metacognition domain, more attention has been given to memory confidence than vividness, however. Therefore, although memory vividness is the topic of interest of the current review, measures of metacognitive confidence judgements will be first described in this section.

Accuracy of metacognitive confidence is usually assessed using two measures: calibration and resolution. *Confidence calibration* quantifies the extent to which the intensity of confidence ratings matches the probability of memory accuracy and it provides insights as to how participants anchor their judgements on the response scale (i.e., metacognitive bias; Fleming & Lau, 2014), thus revealing under- or over-confidence in participants' answers (Luna & Martín-Luengo, 2012; Olsson, 2000; Olsson & Juslin, 2002). *Confidence resolution* is modeled by correlating trial-by-trial memory recognition accuracy to the intensity of the confidence rating within each participant before comparing correlation values to zero or between different groups or conditions (i.e., gamma correlations; Goodman & Kruskal, 1959). This measure indexes how the intensity of memory confidence tracks memory accuracy across task trials (i.e., metacognitive sensitivity; Fleming & Lau, 2014). **Existing evidence suggests that young individuals have insight as to how to adjust the intensity of**

their metacognitive confidence ratings with respect to the accuracy of their memory responses, as indexed both by calibration and resolution measures (Brewer et al., 2005; Brewer & Sampaio, 2006; Wong et al., 2012).

Less attention has been paid to the relationship between the subjective vividness of a memory and other objective measures of the quality of the memory, such as how precisely it is remembered or the number of details that are recalled. There is evidence that individuals can accurately monitor the level of vividness of non-episodic mental images using Likert scales. For instance, when participants judge the vividness of imagined visual patterns (e.g., imagining a pattern of green vertical grating), vividness intensity of the imagined pattern predicts the subsequent perceptual bias (i.e., whether the participant will preferentially orient his/her attention toward a visually presented green vertical gratings) in a visual task (Pearson et al., 2011; see also Cochrane, 2021). Likewise, when participants judge the vividness of mental images corresponding to words, vividness intensity predicts the likelihood that these words will be subsequently recalled in a surprise memory task (D'Angiulli et al., 2013). A few studies have examined *vividness calibration*, that is, the extent to which levels of memory vividness match with memory performance (e.g., the mean number of remembered episodic details in a free-recall task). Young participants can calibrate the intensity of their vividness ratings with regard to the richness of their memories, as revealed by studies showing that mean memory accuracy/precision increases with levels of memory vividness (Cooper et al., 2019; Richter et al., 2016; Thakral et al., 2019; Xie & Zhang, 2017). More recent studies have examined *vividness resolution*, that is the extent to which the intensity of vividness tracks memory content across task trials. One study used linear regressions conducted within each participant to examine whether the intensity of vividness ratings concerning the reminiscence of pictures was predicted by how

participants remembered the visual appearance of these pictures (Cooper et al., 2019). Results revealed that regression values significantly differed from zero, thus suggesting that the intensity of memory vividness was determined by how low-level visual features were reinstated (Cooper et al., 2019). Other recent studies have used mixed-effects models to examine the relationship between the intensity of memory vividness and the associated number of retrieved details (Folville, D'Argembeau et Bastin, 2020b, 2020a). While both linear regressions conducted within each participant and mixed-effects analyses consider the dependent and independent variables at the trial level, mixed-effects models offer the advantage of considering both trials and participants as random effects (Baayen et al., 2008). Using these measures, it was shown that the intensity of memory vividness was significantly predicted both by spatial source memory accuracy (Folville, D'Argembeau, et al., 2020b) and the number of retrieved memory details (Folville et al., 2021; Folville, D'Argembeau, et al., 2020b, 2020a). Interestingly, the positive relation between vividness and memory content extends to memory studies conducted outside the laboratory, with young participants' vividness ratings being related to the amount of recollected units of experience from real-life events (Folville, Jeunehomme et al., 2020).

In summary, these studies indicate that young individuals have a good metacognitive understanding of how they should subjectively judge the quality of their memories. Memory vividness indexes the amount of sensory information available to mind and participants seem to adequately monitor this source of information to make vividness judgements. What happens when the access to the information used to make vividness ratings, that is, the amount of sensory features, is compromised? Such diminution in the access of precise memory details is evident in healthy aging, for which an episodic memory decline has been widely documented over the past decades (for review, see Nilsson, 2003; Park & Gutchess,

2005). Age-related differences in episodic memory mechanisms will be thus described in the following section before considering the impact of these age-related episodic memory differences on vividness ratings.

Age-related differences in cognition and memory

Several theories have been proposed to account for the age-related decline in memory encoding and retrieval. Concerning memory encoding, recent work has revealed that aging diminishes the representational quality of encoded stimuli, with older adults encoding traces in a less precise and distinct fashion than young adults (Trelle et al., 2017, 2019). Aging also diminishes the ability to memorize the relations between encoded elements, so that older adults experience difficulties in forming cohesive episodic memory traces (Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2007). It has also been suggested that young and older participants may differentially attend to stimuli features during memory encoding. For instance, it has been proposed that older adults, due to their reduced inhibitory abilities, have difficulties in ignoring non-relevant information (Hasher & Zacks, 1988). **Other evidence has pointed that older participants focus their attention on visual features to a lesser extent than young adults during memory encoding (Carstensen & Turk-Charles, 1994; Fredrickson & Carstensen, 1990; Labouvie-vief & Blanchard-fields, 1982)**. This differential focus of attention during encoding may hinder older adults' memory performance at retrieval, especially in cases in which perceptive aspects of encoded stimuli are assessed (Hashtroudi et al., 1994; Rahhal et al., 2002). Interestingly, when young and older adults' attention is focused on the same features during memory encoding (i.e., when they are specifically asked to focus their attention on the visual appearance and content of the pictures to be encoded), it does not alleviate the age-related decline in source memory

performance at retrieval (Mitchell & Hill, 2019). Somewhat similar results have been put forward by McDonough & Gallo (2013), who have shown that increased elaboration during the generation of past events (i.e., asking participants to provide more perceptual details about the event), did not benefit to the source memory performance of older participants (i.e., determining whether additional perceptual details were given for each event or not). Enhancing the availability of memory details at retrieval, either by constraining the focus of attention at encoding or by increasing the degree of elaboration during event generation, thus does not seem to narrow age-related differences in source memory performance. Together, these results thus provide evidence that older adults' poorer objective memory performance may not be entirely due to an age-related reduction in the encoding of memory features but may also be attributed to how older adults reinstate and make use of these features in their memory decisions during retrieval (McDonough & Gallo, 2013; Mitchell & Hill, 2019; Trelle et al., 2017, 2019).

With respect to episodic memory retrieval, healthy aging negatively impacts recollection- the capacity to remember previously encoded items with their associated encoding context (Yonelinas, 2002) – while typically having less effect on the sense of familiarity of prior exposure (Koen & Yonelinas, 2014, 2016). Also congruent with this account are studies showing that the capacity to reinstate the precise and specific details of past experience declines with advancing age, but that older adults are still efficient at remembering the general meaning, namely the gist, of previously encoded information (Flores et al., 2017; Gallo et al., 2019). Other authors assume that the age-related decline in episodic memory retrieval may stem from difficulties for older adults to identify the source of past episodes (Cansino, 2009; Mitchell & Johnson, 2009). **Older adults would also experience difficulties in reinstating contextual representations from retrieved items and then to strategically use**

them to guide the retrieval of other information in memory (Healey & Kahana, 2016; Wahlheim et al., 2017).

To compensate for the reduction in the efficiency of episodic memory retrieval processes, older adults may be more likely than young adults to rely on their – relatively preserved – semantic knowledge when remembering (Umanath & Marsh, 2014). Yet, overreliance on semantic or schematic knowledge might be a double-edge sword for older adults. While it might positively guide memory reconstruction processes while remembering, it might also mislead episodic memory by enhancing the likelihood of committing false alarms due to an enhanced gist/familiarity-based recognition (Devitt & Schacter, 2016; Koutstaal & Schacter, 1997; Umanath & Marsh, 2014). Particularly relevant to study false alarms is the Deese-Roediger-McDermott (DRM) paradigm, in which participants study related words (e.g., nail, screwdriver, wrench…) before remembering these words along with a critical related lure (e.g., hammer) (Gallo, 2006). Some, but not all, studies examining age-effects in the DRM paradigms found an age-related related increase in false recognition rates of critical lures (Balota et al., 1999; Devitt & Schacter, 2016; Gallo, 2006; Norman & Schacter, 1997).

When faced with a challenging memory decision, memory monitoring processes may help in differentiating old from new items (Gallo et al., 2006; Johnson et al., 1993; Johnson, 2006). Although spared memory monitoring in aging has been reported on a few occasions (see for instance Gallo et al., 2007), there is mounting evidence that episodic memory monitoring processes become less efficient with advancing age and that it hinders memory discrimination accuracy (Devitt & Schacter, 2016; Gallo et al., 2006; Mitchell & Johnson, 2009; Trelle et al., 2017). Relevant to illustrate this is a study from Dehon and Brédart (2004) showing that young and older participants think about critical lures at the same rate during

the memory retrieval phase of the DRM paradigm but that older adults, due to difficulties to monitor the accuracy of their answers, endorse these lures as old more often than young adults do.

Age-related differences in episodic memory functions have also been examined in light of autobiographical memory accounts. When remembering past events from their lives, older adults report a lower number of – internal - episodic memory features while they produce more – external – semantic statements than young adults (Gaesser et al., 2011; Levine et al., 2002; Madore et al., 2014). Increased reporting of semantic/external details may be a means for older participants to compensate for the lack of episodic richness of their remembrance (Devitt, Addis, et al., 2017), which is in line with the idea that older adults' remembering experience is influenced by their preserved semantic knowledge (Umanath & Marsh, 2014). An age-related decline in the level of specificity of retrieved autobiographical event has also been documented, with older participants reporting memories that are more general and generic than those of young adults (Levine et al., 2002; Piolino et al., 2002, 2010). Remembering the past and imagining the future involve many similar cognitive and neural mechanisms (D'argembeau, 2020; Schacter & Addis, 2007). Therefore, and similarly to what have been observed in studies examining age-related differences in memory for past events, older adults report a lower amount of details when they imagine possible future events (Addis et al., 2010, 2016; Gaesser et al., 2011; Madore et al., 2014) or atemporal events/scenes (Rendell et al., 2012; Romero & Moscovitch, 2012).

It is worth mentioning that a few authors have proposed that age-differences in broader cognitive mechanisms could account for the episodic memory decline, above and beyond age-differences in memory encoding and retrieval processes. For instance, age-related

decreases in the efficiency of sensory functioning (Baltes & Lindenberger, 1997), speed of processing (Salthouse, 1996) and working memory (Park et al., 1996) have been invoked to account for older adults' reduced ability to encode and retrieve information in episodic memory. A recent study further found that episodic memory precision correlated with perceptual and working memory abilities in older participants (Korkki et al., 2020). Besides, previous evidence revealed that the level of specificity of older adults' autobiographical memories was strongly predicted by their executive functioning, consistent with the notion that age-differences in episodic memory for past events might be mediated by age-differences in non-episodic executive functions (Piolino et al., 2010). It has been further shown that older adults spontaneously reported fewer details even when episodic memory retrieval processes were not necessary to perform the task at hand (i.e., to describe pictures), thus suggesting that age-differences in narrative style could account, at least to some degree, for the episodic memory decline (Gaesser et al., 2011; Madore et al., 2014). Non-episodic memory mechanisms could thus hinder older adults' memory performance and then inflate age-differences in episodic memory retrieval.

Collectively, the studies described in the present section converge to suggest that age-related episodic memory decline may be attributed to differences in memory encoding, memory retrieval, post-retrieval monitoring processes and non-episodic mechanisms. What is the influence of these changes on older adults' memory vividness ratings? Do older adults accurately judge the quality of their impoverished memories? In the next section, studies examining age-differences in memory vividness will be reviewed.

Age-differences in the subjective experience of memory vividness

In the cognitive aging literature, age-related differences in episodic memory vividness have been studied using various approaches: laboratory stimuli, recent controlled real-life events, remote autobiographical memories, and imagined future or atemporal events. Therefore, age-differences in memory vividness will be described separately for these different types of approaches (see Table 1). Included in the present section will be studies that comprised: 1) young and older participants; 2) a memory task that involved the retrieval of emotionally neutral stimuli or events; 3) an assessment of memory vividness and an objective measure of the richness of episodic memory (e.g., a free-recall or source memory task).

Laboratory stimuli

It has been previously reported that older adults produced vividness ratings that were as high or even higher in intensity than those of young adults, despite clear evidence for age-related reductions in source memory performance (Folville, D'Argembeau, et al., 2020b), in the number of remembered stimuli details (Folville et al., 2020, 2021; Folville, D'Argembeau, et al., 2020b; St-Laurent et al., 2014), and in the precision with which stimuli were remembered (Korkki et al., 2020). **It appears from these studies that older participants less precisely adjust their vividness ratings than young participants (i.e., vividness calibration), as the intensity of their vividness ratings does not match the actual level of precision of their recollection (see Table 1).** Congruent with this view are fMRI studies showing increased vividness in the older age-group accompanied by an age-related reduction in neural (re)activation in brain regions responsible for the visual processing of pictures (Folville et al., 2020) or videos (St-Laurent et al., 2014) during memory retrieval. Collectively, these studies provide evidence that older adults overestimate/**miscalibrate** the intensity of their

subjective memory vividness ratings with regard to the richness of their memories measured objectively. However, one exception deserves mention. In one experiment of Henkel and colleagues, young and older participants viewed and imagined pictures of common objects (Henkel et al., 1998). Two days later, participants were tested for source memory (imagined vs. perceived) and subjective memory vividness. Results revealed that source memory performance and vividness ratings were lower in older than in young adults (Henkel et al., 1998). This study is, to the best of our knowledge, the only one showing agreement between objective and subjective measures of memory in aging, thus suggesting that older participants calibrated their vividness ratings as precisely as young adults did. Yet, the reasons for the difference between that study and above-mentioned works are not at all clear.

A few studies have examined whether the intensity of memory vividness for pictures closely followed objective memory performance to a similar extent in young and in older adults (i.e., vividness resolution). For instance, it was found that the intensity of memory vividness was predicted by spatial source memory accuracy both in young and in older adults (Folville, D'Argembeau, et al., 2020b). In other words, the trial-by-trial intensity of memory vividness for pictures was related to whether young and older participants remembered if the picture was presented on the right or on the left of the screen. Other studies have examined the relationship between memory vividness and the corresponding amount of retrieved episodic details and they showed that the amount of retrieved memory details predicted the intensity of memory vividness to a greater extent in young than older adults (Folville et al., 2021; Folville, D'Argembeau, et al., 2020b). These findings thus suggest that older adults may not use retrieved memory features in a similar way as young adults to frame their sense of memory vividness (Folville, D'Argembeau, et al., 2020b). Similar conclusions were put

forward by Johnson and colleagues who showed that older adults' trial-by-trial vividness ratings were less related to neural representations in parietal brain regions (in which memory features are represented (Kuhl & Chun, 2014)) than those of young adults (Johnson et al., 2015).

Drawing on the idea that older adults may not necessarily use retrieved episodic memory features to inform their subjective memory vividness ratings, we have recently examined whether the intensity of memory vividness would be similar across older participants remembering the same pictures (Folville et al., 2021). Considering that memory vividness is based on visual features and that older adults presumably use these features to a lesser extent to make their vividness ratings, we hypothesized that the intensity of memory vividness would be less similar across older than young participants. Consistent with our hypothesis, we found that the intensity of memory vividness was similar across young participants remembering the same pictures but that the similarity of vividness measured across older participants was reduced. Critically, we also found that the same quantity of details was remembered across participants remembering the same items, and that it was the case to a similar extent in young and older age-groups. In other words, older adults remembering the same pictures recollected similar quantities of pictures details but made vividness ratings that greatly differed in intensity across participants (Folville et al., 2021).

Collectively, studies using laboratory stimuli to examine age-related differences in memory vividness suggest that older adults overestimate the intensity of their subjective ratings with regard to the richness of memory content **(i.e., reduced calibration)**, and show a reduced trial-by-trial relation between vividness and memory details relative to young adults **(i.e., reduced resolution)**.

Controlled real-life events

Older adults produced vividness ratings that were higher than those of young adults when remembering objects in a real-life setting, despite lower performance in remembering the spatio-temporal context of memory encoding (Mazurek et al., 2015). Also, older adults were found to report vividness ratings that were higher than those of young adults when remembering recent real-life activities (e.g., buying a beverage) while memory performance regarding the unfolding of the activity did not differ between age-groups (Folville, Jeunehomme et al., 2020). Results of that study further revealed that the intensity of memory vividness was predicted by the number of retrieved moments of experience when accomplishing the activity in young but not in older participants (Folville, Jeunehomme et al., 2020). **Taken together, these findings provide evidence that older adults show reduced calibration and lower resolution than young adults when judging the vividness of retrieved recent real-life events (Table 1).**

Remote autobiographical events

Age-differences in subjective memory vividness have been extensively examined in light of autobiographical memory retrieval. Older participants were found to produce vividness ratings that were equivalent to, or higher than, those of young participants, while, at the same time, they reported a lower number of episodic details than their younger counterparts (De Beni et al., 2013; De Brigard et al., 2017; Devitt, Tippett, et al., 2017; Fastame & Penna, 2012; Peters et al., 2019; Robin & Moscovitch, 2017; St-Jacques et al., 2012; Zavagnin et al., 2016). A somewhat similar pattern has been observed in studies showing that older adults produced vividness ratings that were as high or higher than young

adults while objective coding of memory content indicated that their memories were less specific and more general (Holland et al., 2012; Kapsetaki et al., 2021). **These studies thus converge to suggest that older participants show poorer vividness calibration than young adults when remembering autobiographical events; to our knowledge, age-differences in vividness resolution have not been examined yet in the context of remote autobiographical events (Table 1).**

Imagined future/atemporal events or scenes

As mentioned earlier, remembering the past and imagining the future involve many common cognitive processes (D'Argembeau, 2020; Schacter et al., 2012; Schacter & Addis, 2007), so that the age-related deficit in remembering past events usually extends to situations that require the imagination of future plausible scenarios (Addis et al., 2010). Consistently with studies on memory, older adults experienced their imagination of future scenarios with a comparable or stronger sense of vividness than young adults even when the content of their imagined event was less detailed (Cole et al., 2013; De Beni et al., 2013; De Brigard et al., 2017; Devitt et al., 2020; Lapp & Spaniol, 2017; Robin & Moscovitch, 2017; Zavagnin et al., 2016; Table 1). Interestingly, this pattern of findings extended to situations in which participants imagined atemporal scenes (e.g., a familiar place in town), with older participants displaying a discrepancy between the intensity of their vividness ratings and the level of detail of their imagined scene (Robin & Moscovitch, 2017; Sawczak et al., 2019). **Relative to young adults, older adults thus seem to overestimate the intensity of their memory vividness ratings (i.e., vividness calibration), but it remains unknown whether the**

intensity of memory vividness tracks memory richness to a similar extent as in young adults (i.e., vividness resolution).

Summary

Taken together, findings from these studies converge to suggest that older adults do not calibrate their vividness ratings to a similar extent as young adults and that they may inflate the intensity of their subjective memory vividness ratings with regard to the actual precision and richness of their memory retrieval experiences. **What is particularly worth mentioning is that this pattern has been systematically observed in many studies (with only one exception), regardless of the type of memories/representations being investigated (e.g., laboratory vs. autobiographical vs. future thinking).** In the second part of the present review, we will try to identify the factors that may explain why older adults inflate their subjective memory ratings.

Previous studies also revealed that the trial-by-trial intensity of the vividness ratings followed the corresponding amount of retrieved details to a lesser extent in older than in young adults (Folville et al., 2021; Folville, D'Argembeau, et al., 2020b). From these findings, it appears that aging reduces memory vividness resolution and it is reasonable to suggest that older adults may not necessarily use memory details to inform their subjective memory judgements. **The present review has also emphasized that while vividness calibration has received great attention in the literature, vividness resolution has been scarcely studied.** Why, and under which conditions, older adults are less likely to use event memory details to make their subjective memory ratings is a question that will be discussed in the next part of the present review.

Why do older adults inflate their ratings when judging the strength of memory vividness?

Several hypotheses have been invoked to explain why older participants inflate the intensity of their vividness judgements and thus show poorer **vividness calibration** than young adults. Unless specified, we assume that these hypotheses might apply to all studies showing an inflation of memory vividness (see Table 1), regardless of the approach used.

A first possibility that has been mentioned in our previous studies (Folville et al., 2020; Folville, D'Argembeau et al., 2020b), and elsewhere (St-laurent et al., 2011a), is that older adults lower their memory vividness criterion during memory retrieval. In fact, it is likely that each person sets vividness thresholds to determine how many memory details should be retrieved to assign a "low" or "high" vividness judgement (St-laurent et al., 2011). Figure 1 illustrates this hypothesis and presents the mean number of recalled details for each vividness rating in young and older adults in our previous study (Folville, D'Argembeau et al., 2020b). While young adults on average remembered 7 or 8 details to assign vividness ratings of 2 or 3 out of 5, respectively, older adults only retrieved 5 or 6 details for the same vividness ratings (Figure 1). In other words, members of the two age-groups assigned subjective ratings of comparable intensity but older adults remembered on average two episodic details fewer than young adults. Older adults are, most of the time, aware of their cognitive decline (Hultsch et al., 1988). Therefore, it could be speculated that, with increasing age, participants reduce their expectations regarding their performance in memory tasks, so that older adults may be satisfied with the retrieval of 6 episodic details and that this may be sufficient for them to assign a subjective vividness rating of 3 on a task trial.

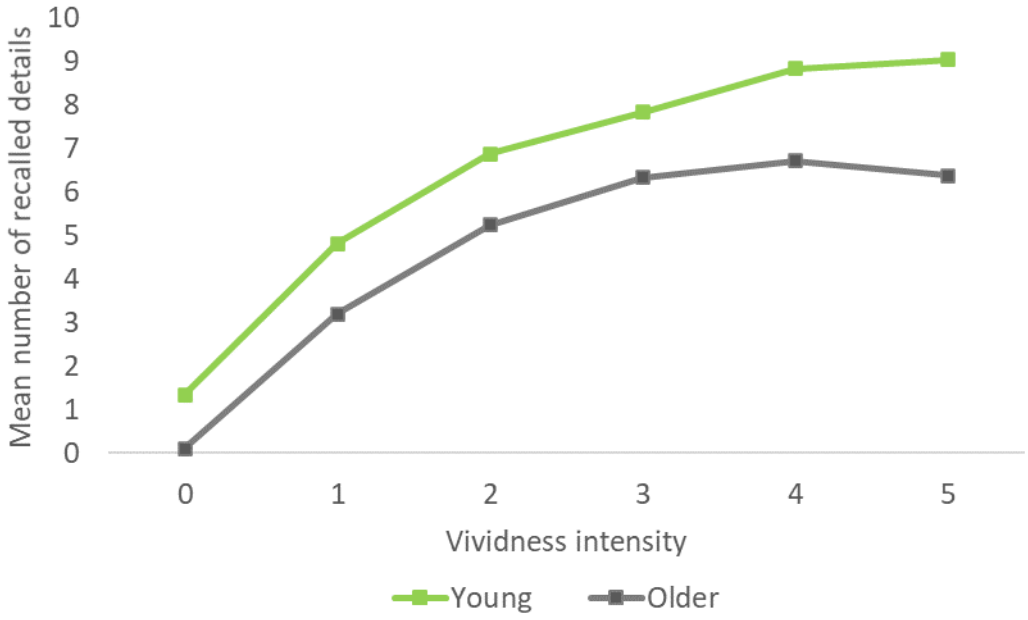

Figure 1. Mean number of recalled episodic details as a function of the intensity of memory vividness in young and older adults (data from Folville, D'Argembeau et al., 2020b).

Yet, how participants set the vividness threshold is also strongly related to how they understand and interpret the memory rating scale. Members of different groups often do not interpret the response scale in the same way, so that comparing subjective judgements between them is tricky (Bartoshuk et al., 2005). It could be that older adults interpret the response scale in a different way than young adults so that they anchor their vividness judgements higher. This possibility has been examined in an unpublished study (Bloise, 2008, cited by Mitchell & Hill, (2019)) in which young and older participants made subjective memory ratings about pictures using either a classic Likert scale or a General Label Magnitude scale (gLM). The latter type of scale relies on the assumption that it is possible to reduce group differences in scale interpretation by asking participants to anchor their judgements of interest with respect to a standard (Bartoshuk et al., 2002; Bartoshuk et al.,

2005). For instance, participants make their subjective judgements while imagining the intensity of a sensation of reference (e.g., looking at the sun as the maximal sensation) that they take as a "standard" (Bartoshuk et al., 2005). The subjective judgment of interest (e.g., vividness) is supposed to be made with respect to this anchored sensation that should be interpreted similarly by different groups, thus making group comparisons more valid (Bartoshuk et al., 2005). Results of the study of Bloise (2008) suggest that older adults still assign high memory vividness ratings when using such a gLM scale, thus questioning an interpretation of the vividness inflation in terms of differential understanding of the Likert scale between age-groups. However, an important issue related to the use of this scale with older participants is that it remains unknown whether they imagine the sensation of reference (e.g., looking at the sun) in the same way as young adults (especially when considering age-related declines in visual perception (Roberts & Allen, 2016) and mental imagery mechanisms (Palladino & De Beni, 2003)), thus questioning its use as a standard. Thus, future studies should further examine whether potential age-differences in scale interpretation could explain the age-related reduction in **vividness calibration** (Mitchell & Hill, 2019).

Older adults' **reduced calibration** of their subjective vividness ratings could also be explained by psycho-social mechanisms. In our society, older people are often seen as less competent than their younger counterparts in many cognitive domains such as memory (Cuddy et al., 2005), and, as we mentioned earlier, older adults may also consider their own memory abilities to be declining (Hultsch et al., 1988). Consequently, older people might sometimes try to present themselves in a favorable way, to avoid fulfilling age-related negative stereotypes. For instance, it has been shown that older adults have higher scores of social desirability (i.e., the tendency to present oneself in a favorable way in social interactions)

than young adults (Dijkstra et al., 2001), and that older adults with high social desirability scores misestimate the quality of their metacognitive efficiency (Fastame & Penna, 2012). It could thus be that older participants assign high subjective memory vividness judgements to present themselves in a favorable way to the experimenter **during memory retrieval** (Folville et al., 2020). In other words, saying that they remember the event in a highly vivid fashion would be a means for older adults to demonstrate that they still have good memory capacities.

A related possibility could be that older participants are more sensitive to task trials for which they cannot correctly remember the target event **at retrieval**. In that view, older participants would make subjective vividness ratings of high intensity to remembered events to compensate for retrieval failures in other trials. Assigning high ratings to trials for which they remember the event could make them feel comfortable with regard to their memory capacities (e.g., "*I do not remember everything but what I remember, I recollect it in a highly detailed fashion because my memory is still quite good*") (Folville, D'Argembeau et al., 2020b). A somewhat different, yet related, account that has been proposed by an anonymous reviewer is that older adults could produce subjective vividness ratings that are higher because of a contrast effect. According to this view, retrieved events would appear more clear and vivid than they actually are because they would contrast with the lack of details of forgotten events **at retrieval**. One way to test these accounts would be to experimentally manipulate the number of retrieval failures occurring before successful memory retrieval (e.g., by adding new items in a memory task in which all items are supposed to be old, for instance). In that particular case, the intensity of older adults' subjective vividness ratings would inflate as the number of retrieval failures increases.

Drawing on the observation that older adults produced vividness ratings that were higher than those of young adults across different types of memory material (e.g., laboratory, autobiographical memory), we postulate that the above-mentioned hypotheses might apply to all these domains. There are, however, hypotheses that are specific to autobiographical memory retrieval during which retrieved events have been encoded in episodic memory several years or decades ago. To explain why older adults sometimes assign higher ratings than young adults, some authors examining age-differences in subjective memory vividness ratings for autobiographical events have proposed that older adults may have the opportunity to select memory episodes that would be of great importance for them (Luchetti & Sutin, 2018). Indeed, throughout their life, older adults would have more time to integrate meaningful events and to relate them to their identity than young adults. Because of their importance, the selected memories would be re-experienced with a strong sense of recollection, which would yield higher subjective memory ratings in older than in young adults (Luchetti & Sutin, 2018). **An alternative possibility could be that older adults remember more events that are stored in their autobiographical memory system as semantic information or facts from their lives (Conway & Pleydell-Pearce, 2000; Levine et al., 2002). Those retrieved events would appear as very vivid and intense in older adults' mind but would lack of episodic richness during episodic memory recall.** Last, a hypothesis that has been mentioned on a few occasions is that older adults could have had the opportunity to rehearse memory events more frequently than young adults (De Brigard et al., 2016; Luchetti & Sutin, 2018), which could increase the ease with which events are retrieved and then inflate the associated subjective memory ratings.

Finally, it should be noted that these accounts are not mutually exclusive and there may be multiple reasons why older adults sometimes assign ratings of greater intensity than young

adults and show poorer **vividness calibration**. It is likely that different factors act in conjunction and their respective contribution might also depend on the circumstances in which the episodic reminiscence occurs.

Do older adults use episodic details in a similar way as young adults to frame their subjective sense of memory vividness?

As described above, older participants show a deficit in monitoring resolution as their vividness ratings are less closely tied to the corresponding amount of remembered details than those of young adults. This finding raises the possibility that older adults use retrieved episodic memory details in a different way than young adults. If this is the case, what information would older adults use/rely on to determine the subjective vividness of their memories?

A first possibility is that older adults rely more than young adults on incorrect memory details when making their subjective judgements. **Because older participants have difficulties in binding details into a cohesive memory during encoding (Naveh-Benjamin, 2000), and naturally tend to rely to a greater extent on schematic knowledge about remembered events at retrieval (Umanath & Marsh, 2014),** they would infer the presence of some details that were actually not encoded in memory. In a previous study, we found that older adults were more likely than young adults to mention incorrect details (e.g., mentioning the presence of a bed in a room in which there was no bed) when remembering scene pictures (Folville, D'Argembeau, et al., 2020b). Recent evidence further revealed that older participants were more likely than young adults to recall lures that were semantically related to targets in a virtual reality paradigm (Abichou et al., 2021). In contradiction to these findings, other studies have shown that older adults were as likely as young adults to

endorse lure objects as old when remembering scenes (e.g., a bathroom) containing both schematic (e.g., a sink) and non-schematic (e.g., a vase of flowers) old and new objects (Webb & Dennis, 2019, 2020). Regardless of whether older adults have similar or higher rates of false recognition than young adults, it could be that older adults are just more likely than their younger counterparts to use these false details to inform their subjective vividness ratings, perhaps because of age-related differences in monitoring processes. Part of this assumption comes from fMRI data that revealed that older adult's vividness ratings correlated more than those of young adults with neural representations in prefrontal brain regions (Johnson et al., 2015). Given the role of prefrontal regions in the processing of the conceptual and schematic aspects of experience (Gilboa & Marlatte, 2017; Wagner et al., 1997), the authors interpreted this finding as evidence that older adults relied to a greater extent than young adults on inferences drawn from their conceptual knowledge when making vividness ratings (Johnson et al., 2015). To directly examine this hypothesis, we added incorrect details to the total amount of correct details to test whether it would narrow age-differences in vividness resolution in our previous study (Folville, D'Argembeau et al., 2020b). We did not find evidence that incorporating incorrect details in the number of retrieved features reduced the age-differences in vividness resolution, so that future studies should examine in further details whether older adults indeed rely to a greater extent on conceptual and/or schematic information than young adults when making memory vividness ratings.

In episodic memory tasks, stimuli such as pictures are not all remembered equally and some are more distinctive than others, probably because some aspects of the picture such as the presence of people or an unusual object make it memorable (Bainbridge, 2020; Bylinskii et al., 2015; Isola et al., 2011). One hypothesis to explain age-differences in

vividness resolution could be that older adults may give more weight to some of the retrieved event details than young adults when making their vividness judgements (Johnson et al., 2015). This differential use of retrieved details in older adults may be explained both by age-related differences in memory encoding and/or retrieval. On the one hand, it could be that older adults focus their attention on some specific information during memory encoding, which might restrict attentional resources devoted to the processing of other visual features and details. On the other hand, it could be that older adults focus on the same features as young adults during memory encoding but that they give more weight to some details during memory retrieval. A picture detail (e.g., a young boy walking alone in a street) could thus be promptly remembered and could inflate older adults' vividness ratings because of its distinctiveness (which would not be captured with a free-recall task in which the absolute number of remembered details is measured), thus reducing the extent of the relation between the intensity of vividness and the corresponding amount of retrieved episodic details.

An alternative possibility to explain age-differences in vividness resolution is that older adults would be more likely than young adults to rely on the richness of thoughts or personal memories experienced during memory encoding when judging the subjective vividness of memories at retrieval (Bloise 2008; Mitchell & Hill, 2019; Mitchell & Johnson, 2009). When viewing the picture with the young boy in the street, older adults might be engaged in internal thoughts (*"why is this child alone in the street?"*) or self-referential processing ("*he looks like my grandson*") on which they could base their subjective vividness ratings subsequently (Mitchell & Johnson, 2009). Relatedly, it could be that older adults recollect personal autobiographical memories while presented with pictures at encoding ("*it reminds me when I went shopping yesterday*") and that they use this remembrance to base their

vividness rating regarding the picture (Mitchell & Hill, 2019; Mitchell & Johnson, 2009). fMRI data showing that brain activity in self-referential (i.e., posterior cingulate cortex) or autobiographical memory retrieval (right inferior frontal gyrus) brain regions during encoding is associated with subsequent subjective memory ratings in older adults may be interpreted as compatible with this possibility (Mitchell & Johnson, 2009). Importantly, we do not assume that older adults produce and/or retrieve personal memories/thoughts more often than young adults during memory encoding **(actually, studies show that older adults experience involuntary memory retrieval or mind-wandering less frequently than young adults, see Maillet & Schacter, 2017 for a review)**; we rather propose that older adults use these internal states more often that young adults do to inform their subjective vividness judgements **during memory retrieval**. It can be speculated that this use of internal thoughts/memories over picture memory content may be attributed to age-related differences in memory monitoring processes. The instances in which older adults may favor personal information over perceptual details to make their vividness ratings are still to be determined (Mitchell & Johnson, 2009). Notably, it could be that older adults experience difficulties at attending to the appropriate reactivated memory information across remembering trials (Mitchell et al., 2013), which may impact what is used to make metamemory ratings such as vividness. Also, older adults could rely on personal information to inform their vividness ratings when retrieved perceptual details are lacking of richness, so that relying on thoughts or memories may be an adaptative way to compensate for reduced recollection abilities.

We have emphasized earlier that normal aging decreases the capacity to recollect the specific details of past experience while not affecting memory for the general meaning of previously encoded information (Flores et al., 2017; Gallo et al., 2019). A limitation of the

free-recall approach that we have used in our previous studies linking vividness and episodic details is that it does not provide any insight about the capacity of participants to reinstate the gist of the memory trace (Folville, D'Argembeau et al., 2020a). One may thus wonder whether older adults could rely more than young adults on the gist of the memory trace to judge its vividness **during retrieval**, hence reducing vividness resolution, that is, the intensity of the relationship between vividness and the amount of recalled specific details. A few previous studies have used narrative coding procedures that code details as either pertaining to the gist or to peripheral information of the remembered event (Berntsen, 2002; Sekeres et al., 2016). Using this coding procedure, it was shown that the number of remembered central/gist details was not related to the associated vividness ratings in young participants (Berntsen, 2002), but one may wonder whether it would be the case in older adults. Interestingly, one study using the same coding protocol has revealed that older adults recalled less peripheral details than young adults while memory for the gist did not differ between age-groups (Sacripante et al., 2019). In other words, older adults seem to remember the general frame of the retrieved event to a similar extent as young adults. Future research should therefore use this type of coding procedure to examine whether the number of gist details predicts the intensity of memory vividness in older adults.

It is worth mentioning that the intensity of metamemory ratings is not only determined by the content of the retrieved memory representation but can also be biased by external sources of information. **Evidence supporting this assumption comes from the metamemory confidence literature showing that** the intensity of confidence ratings is influenced by external sources of information such as a perceptual change between study and test (i.e., the luminosity of studied stimuli being enhanced at test; Busey et al., 2000). Likewise, it has been shown that the ease of retrieval of a semantic trace partly determines the confidence

associated to the response (Kelley & Lindsay, 1993). **Somewhat similar findings have been put forward in the memory vividness literature**, with evidence revealing that memories that are easily retrieved during an autobiographical interview are usually assigned higher vividness ratings than those that are difficult to recollect (Echterhoff & Hirst, 2006; Winkielman et al., 1998). One way to explain these findings is that the ease of retrieval creates a feeling of fluency that participants transpose into the intensity of their vividness judgements (Benjamin et al., 1998; Echterhoff & Hirst, 2006). Thus, the fluency with which a memory is retrieved would influence subsequent memory vividness ratings. In recognition paradigms, the fluency with which an item is processed can guide recognition memory (Yonelinas, 2002), by being interpreted as evidence that this item has been seen previously and leading to a feeling of familiarity. As described earlier, familiarity, compared with recollection, remains relatively preserved during aging (Koen & Yonelinas, 2014, 2016), and older adults tend to over-rely on it, which can bias their memory decisions (Devitt & Schacter, 2016). Cognitive aging studies have also revealed that older adults are as sensitive as young adults to retrieval fluency when making their memory decisions in recognition paradigms (Parks & Totii, 2006; Thapar & Westerman, 2009).

Drawing on these observations, it could be hypothesized that older adults rely to a greater extent on the ease – the fluency – of memory retrieval to guide their vividness ratings. More broadly, it could be speculated that older adults, due to their deficit in recollection, in part base their vividness ratings on the feeling of familiarity experienced when presented with the label cuing the recollection of the associated picture or autobiographical memory. Of note, this interpretation could explain why memory vividness was predicted by spatial source memory accuracy to a similar extent in young and in older participants (Folville, D'Argembeau, et al., 2020b). Indeed, previous evidence has shown that young participants

could correctly remember the position of previously encoded pictures (left or right) on the basis of familiarity in a spatial source memory task (Mollison & Curran, 2012). In that precise case, older adults could have based their memory responses on familiarity, which might explain why they did not differ from young adults neither in spatial source memory performance nor in the magnitude of the relation between vividness and source memory accuracy (Folville, D'Argembeau, et al., 2020b). In contrast, because memory recall is thought to exclusively require recollection-based processes (Yonelinas, 2002), older adults' subsequent report of memory details would be severely diminished and the relation between vividness and recall would be weakened.

Last, it could be that age-differences in non-episodic mechanisms have, indirectly, reduced the magnitude of the vividness resolution in older adults. For instance, reduced executive functioning could decrease older adult's ability to update/flexibly change their vividness responses from one trial to another, which would undoubtedly decrease the extent of the vividness-details relation. Also, age-differences in narrative style could slightly decrease the amount of reported details in episodic memory tasks, which would reduce rates of free-recall and weaken the relation between recall and memory vividness (i.e., memory vividness would be based on retrieved details but only some of them would be verbally reported by the participant). A recent study suggests that age-differences in memory vividness resolution still remained significant when age-differences in narrative style or executive functioning were considered (Folville, D'Argembeau, et al., 2020b), but more studies should investigate how non-episodic mechanisms contribute to age-differences in the relation between memory vividness and event details.

Together, findings from studies examining vividness resolution and the aforementioned explanations converge to suggest that older adults may not necessarily use episodic memory details to make their vividness ratings. This pattern may be due to age-related differences in: memory encoding processes (i.e., the ability to properly focus on the perceptive details of experience); episodic recollection (i.e., the ability to properly reinstate precise and numerous details from past episodic memory traces); memory monitoring processes (i.e., the ability to efficiently use these details to make memory quality ratings); and non-episodic memory mechanisms (i.e., the ability to narrate retrieved memories in a specific fashion and the capacity to update vividness ratings across trials). Again, we do not assume that these possibilities are mutually exclusive, but rather that their influence on older adults' subjective experience of memory vividness might depend on a number of situational factors. In the following section, age-differences in other subjective scales than memory vividness will be briefly described, as we believe that they could provide valuable information as to how older individuals use retrieved features to make their subjective memory ratings.

Age-related differences in other subjective memory scales than vividness

As described earlier, the phenomenological experience accompanying episodic memory retrieval can refer to various other dimensions than memory vividness. As such, previous studies have examined age-related differences in subjective scales assessing the intensity of reliving, the visual details of the remembered event, the spatial location of objects in the recollected scene or the thoughts experienced during memory encoding (De Brigard et al., 2016; Hashtroudi et al., 1990). In the literature, particular emphasis has been given to scales

assessing the subjective quantity of retrieved details or the amount of sensory and perceptual information. Accordingly, existing studies have revealed that older participants produced subjective ratings assessing memory for event details that were as high or higher than young adults when remembering laboratory pictures (McDonough et al., 2014), recent real-life events (Folville, Jeunehomme et al., 2020; Shahin Hashtroudi et al., 1990), remote autobiographical memories (Brigard et al., 2016) or when imagining future and atemporal events and scenes (Robin & Moscovitch, 2017). Again, older adults reported strong subjective phenomenological ratings in the face of poorer source memory (Gallo et al., 2011; McDonough & Gallo, 2013) or free-recall performance (Robin & Moscovitch, 2017), thus supporting the assumption that they show reduced calibration and inflate the intensity of their subjective memory judgements.

One could argue that these findings largely echo those observed with subjective vividness ratings and that these types of subjective memory judgements might show similar patterns **with respect to age-differences in memory resolution**. One recent finding contradicts this assumption, however. As described earlier, when examining age-differences in memory vividness for recent real-life events, we found that older adults produced vividness ratings that were higher than young adults and that the vividness ratings of young, but not older adults, closely followed the corresponding amount of retrieved details (Folville, Jeunehomme et al., 2020). In that study, other dimensions than vividness were assessed. **Notably, we found that older adults produced ratings that were higher than young adults when they judged the amount of visual details of the remembered event (Figure 2). Interestingly, the examination of memory resolution between visual details ratings and the** amount of episodic details yielded an unexpected finding. While the trial-by-trial intensity of subjective ratings was predicted by the amount of episodic details in young but

not in older adults for the vividness dimension, young and older adults' subjective memory ratings followed the corresponding amount of retrieved details to a similar extent for the subjective scale assessing visual details (see Figure 2, Folville, Jeunehomme et al., 2020). In other words, the number of episodic details predicted the corresponding subjective memory ratings for some (i.e., visual details), but not all (i.e., vividness), phenomenological dimensions.

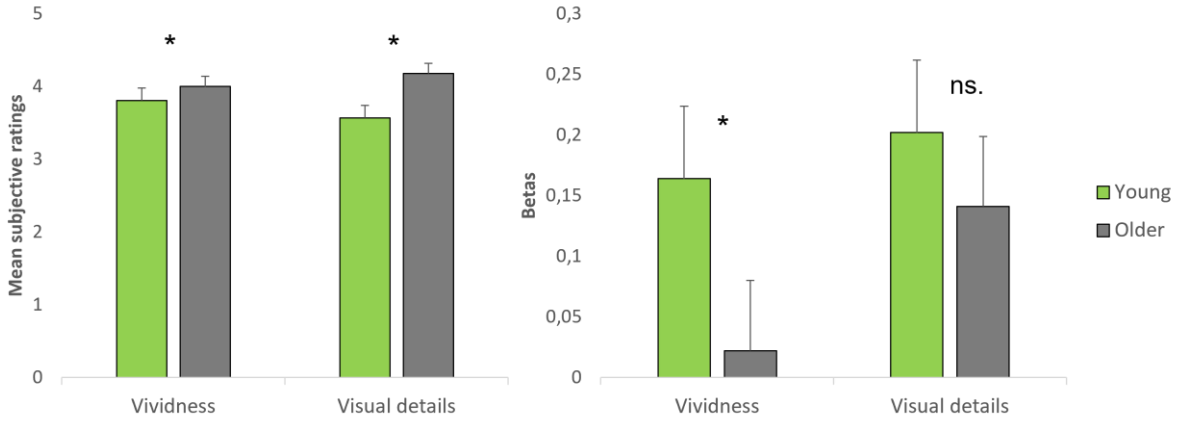

Figure 2. Pattern of findings for two subjective memory scales (i.e., vividness and visual details) using mean values of subjective ratings (i.e., to measure calibration) and the trial-by-trial relation of these ratings with event details (i.e., resolution) in young and older adults (data from Folville, Jeunehomme et al., 2020). Asterisks indicate significant differences at $p < .05$.

These findings are particularly important for three main reasons. First, they suggest that **older adults show reduced subjective memory calibration**, regardless of the approach (i.e., laboratory stimuli or autobiographical/future events) or the type of scale (i.e., vividness, quantity of perceptive/visual details) used. Second, these results provide further evidence that calibration and resolution are two separate and dissociable metacognitive constructs. Indeed, we found that age-differences in mean subjective ratings were similar across the scales while age-differences in the extent of the trial-by-trial relation between these ratings

and event details differed between the two phenomenological dimensions. It is thus important to not only measure age-differences in mean memory vividness and recall but also to examine the trial-by-trial relation between the two measures. Third, **these vividness resolution results** might be taken as evidence that older adults, in some cases, adjust their subjective memory ratings with regard to the corresponding quantity of memory details to a similar extent as young participants. **It could be that assessing the richness of visual details in memory is less abstract than assessing memory vividness so that older participants would have insights as to the type of information (namely, visual details) that they should use to make their ratings (which might be less the case with "vividness"). Asking older adults what they understand by "vividness" or conducting a study in which half the older adults receive a detailed definition of memory vividness while the other half does not might help in answering this question.** With respect to theoretical hypotheses that aimed at explaining why there is an age-related reduction in vividness resolution, this finding questions an interpretation in terms of age-differences in non-episodic mechanisms (i.e., executive functioning and narrative style); otherwise, the same pattern of responses would be expected for all subjective memory scales. **This observation also argues against the possibility that older participants have more difficulties in encoding and binding episodic memory features than their younger counterparts. The finding that older adults are able to retrieve and use episodic details to make their subjective ratings regarding the visual details of their memories also questions an interpretation of the age-related deficit in vividness resolution in terms of age-related recollection decline (because older adults seem to be able to recollect episodic memory details and then to use them for their ratings). Rather, it suggests that older adults encode, retrieve, but do not necessarily use, episodic memory features for their subjective memory judgements (Johnson et al., 2015;**

Koutstaal, 2003). This finding thus supports the hypothesis that the reduced relation between vividness and event details in older adults can be partly explained by the fact that older adults may monitor retrieved details in a different way than young participants during memory retrieval. Of course, the other causes (i.e., age-related differences in memory encoding, memory recollection and non-episodic mechanisms) might also, to some extent, explain the age-related deficit in vividness resolution, but we believe that their contribution to the phenomenon might be less important than the age-related difference in memory monitoring processes. Of course, these findings need replication before strong conclusions are drawn, but they offer promise for future research.

Other previous studies have examined age-differences in the subjective experience of memory by means of memory confidence. These studies suggest that older adults less precisely calibrate their confidence ratings with regard to memory accuracy than young adults (Dodson et al., 2007; Wong et al., 2012). This assumption is further supported by existing evidence showing that older adults are more likely than their younger counterparts to assign confidence judgements of high intensity to incorrect/new items (Dodson et al., 2007; Fandakova et al., 2013; Jacoby & Rhodes, 2006; Kelley & Sahakyan, 2003; Shing et al., 2009). Findings regarding age-related differences in confidence resolution are less clear. Some previous studies have revealed an age-related decrement in the monitoring (i.e., resolution) of subjective memory judgements (Kelley & Sahakyan, 2003; Wong et al., 2012) while other studies did not report any age-group difference (Hertzog et al., 2021).

It is interesting to note that patterns of vividness and confidence show similarities across comparable memory tasks. As already mentioned, memory vividness and confidence judgments are correlated constructs in autobiographical memory tasks (Robinson et al.,

2000; Sharot et al., 2007). Besides, it has been shown that these two types of memory judgements were higher when the remembered episode was emotional rather than neutral (Talarico & Rubin, 2003; Xie & Zhang, 2017). Likewise, brain injured patients with parietal lesions were found to produce lower rates of vividness (Berryhill et al., 2007) and confidence (Simons et al., 2010) responses, thus suggesting that these judgements might be based, at least to some extent, on a common memory strength signal. Also relevant and somewhat similar to what has been concluded regarding age-differences in vividness resolution in the present review is that the age-related decline in confidence resolution has been in part attributed to age-related differences in memory monitoring processes (Wong et al., 2012).

Memory vividness and memory confidence are usually not examined together within the same task but one may wonder whether vividness and confidence might show the same pattern of responses with respect to an objective measure of the richness of memory retrieval. Do confidence resolution and vividness resolution correlate, and if so, are there instances in which these measures might diverge? Are older adults who display low confidence resolution also those who show a reduction in the extent of the vividness-episodic details relationship? Eventually, examining whether, and under which conditions, these types of subjective judgements correlate might help in understanding whether they track the same memory strength signal. Such investigation would also provide important insights about the cognitive mechanisms supporting metacognitive monitoring.

Finally, it is important to note that the subjective experience of remembering can be also operationalized by means of remember judgements in recognition memory paradigms. Remember judgements are typically used as a subjective assessment of episodic remembering. They index recognition based on the retrieval of contextual features (Gardiner

et al., 1998). A discrepancy between the rates of Remember responses and performance in objective measures of episodic memory has been reported on a few occasions. For instance, older participants are more likely than their younger counterparts to assign Remember responses to false details or unstudied items (McCabe & Balota, 2007) and it may be even more the case for naturalistic rather than laboratory events (Diamond et al., 2020). Similarly, a few studies have shown that older adults assigned as many Remember responses as young adults in recognition memory paradigms, in spite of lower source memory performance (Duarte et al., 2006, 2008; Mark & Rugg, 1998). The fact that older adults usually report lower amounts of Remember responses indexing memory recollection than young adults in traditional recognition memory tasks (Koen & Yonelinas, 2014) suggests that these studies are the exception rather than the rule. Critically, a recent study that directly contrasted Remember judgements and source memory performance within the same task concluded that the extent of age-differences in rates of Remember responses might depend on older participants' cognitive profile, the nature of the memory task, and how Remember responses are analyzed (Alghamdi & Rugg, 2020).

In the next section, practical and theoretical implications of the ideas discussed above for accounts of the subjective experience of memory vividness will be presented.

Implications and perspectives

In the current review, we assume that the subjective experience of memory vividness must be considered with respect to two dimensions: the mean values of the subjective ratings with regard to averaged objective memory measures (i.e., calibration) and the trial-by-trial adjustment of these ratings to the amount of retrieved memory details (i.e., resolution). We believe that comparing the mean intensity of subjective ratings can be informative in many

ways but that the trial-by-trial approach can reveal important insights about young and older adults' pattern of responses that may have otherwise remained unknown. Particularly relevant to illustrate this point is the aforementioned finding that older participants produced subjective ratings that were higher than young adults for both the vividness scale and the scale assessing the visual details of memory, while the amount of episodic details predicted the intensity of these ratings for the latter but not for the former dimension. In this context, it would be useful for future studies collecting subjective memory ratings like vividness and an objective measure of memory retrieval to systematically link the two dimensions with a trial-by-trial approach. Such an approach using different types of analyses is already widely used in studies investigating memory confidence, and there is no reason why it could not be systematically applied to subjective memory vividness ratings.

From a theoretical perspective, the studies described here have implications for accounts of the subjective experience of memory vividness. Indeed, the finding that older adults' vividness ratings are less closely tied to episodic details provide evidence that the subjective experience of memory vividness is more than just the retrieval of memory content. Rather, it suggests that the objective and subjective dimensions of episodic memory are in part supported by distinct cognitive mechanisms, which echoes recent evidence revealing that memory details and the associated sense of vividness recruit different brain regions (Richter et al., 2016; Ritchey & Cooper, 2020; Thakral et al., 2019). Some accounts have proposed that the way memory details are transposed into the subjective experience of episodic memory may be dependent on the study material (Phelps & Sharot, 2008) and task context (Bastin et al., 2019; Bodner & Lindsay, 2003). For instance, the quality of some memory features rather than the total amount of retrieved memory details might determine the subjective experience associated with the remembrance of emotional material (Phelps &

Sharot, 2008; Rimmele et al., 2011). The use of memory details to make subjective ratings might also be influenced by their relevance in the context in which the remembering experience takes place as it has been shown that young adults assigned confidence ratings that were higher when answering questions of medium difficulty that were presented after difficult rather than easy questions in a memory task (Pansky & Goldsmith, 2014; Portnoy & Pansky, 2016). There might thus be cognitive mechanisms, namely, attribution processes (i.e., memory monitoring or metacognitive heuristics) that determine how memory details and external sources of information (i.e., task context, expectations) are monitored when making subjective memory decisions (Bastin et al., 2019; Kafkas & Montaldi, 2018). **The finding of our previous study that the number of retrieved episodic details predicted the intensity of subjective memory ratings regarding the amount of visual details but not the vividness of older adults' recollection seems compatible with this account (Folville, Jeunehomme et al., 2020).**

Although some perspectives or avenues for future research have already been formulated earlier in the current review, we would like to detail two lines of future research that, in our opinion, would be of interest for a wide audience.

First, future studies should seek to replicate the vividness resolution findings described here. As shown in Table 1, age-differences in vividness resolution have been examined through the remembering of laboratory stimuli or recent life events, and the assumption that vividness resolution is poorer in older than in young adults is based on restricted evidence. Relatedly, the finding that the resolution of subjective memory ratings other than vividness can be spared in older adults is interesting but needs more empirical support. Moreover, future studies should further explore whether the disconnection between vividness and the

number of details in aging extends to other mental representations. **For instance, older adults produce subjective ratings regarding the sensory features of their memories that are as high (Hashtroudi et al., 1990; Shimizu et al., 2012) or higher (Luchetti & Sutin, 2018) than young adults, while they recall a low number of sensory details when remembering (Hashtroudi et al., 1990), thus suggesting that they also show reduced calibration when they judge non-visual memory representations. One may then wonder whether older adults also show poorer resolution when they make this kind of non-visual ratings, a question that is still to be answered.** As described earlier, older adults make vividness ratings that are higher than younger adults (De Brigard et al., 2016) but report lower amount of details (Addis et al., 2016; Gaesser et al., 2011; Madore et al., 2014; Madore & Schacter, 2016) when they imagine possible future events. It would therefore also be of interest to examine whether young and older adults' subjective memory vividness ratings follow the amount of imagined details to a similar extent. Older adults also produce vividness ratings that are as high as young adults when they imagine familiar places (Robin & Moscovitch, 2017). Critically, older adults report subjective vividness levels that are as high as young adults when they fill-in mental imagery questionnaires (Folville et al., 2020; Murray & Kensinger, 2013; Pierce & Storandt, 1987; Uittenhove et al., 2015). However, whether these judgements reflect the richness of the content of what older participants have in mind has been questioned (Pierce & Storandt, 1987), but not examined yet. Answering this question is important because imagery questionnaires are often used to compare or to match age-groups in terms of mental imagery capacities (Henkel et al., 1998). Besides, examining this question will help to determine whether the discrepancy between vividness and objective details is due to age-related differences in monitoring processes that are specifically involved in episodic memory mechanisms or whether it stems from differences in general attribution

processes engaged in the subjective assessment of various cognitive operations, including mental imagery.

Second, it would be worth investigating whether the apparent discrepancy between vividness and episodic memory content extends to other populations. In particular, Alzheimer's Disease (AD) is characterized by an impairment of the ability to remember past autobiographical events (see El Haj et al., 2015 for a review). **Studies examining the effect of AD on metacognitive subjective memory judgements have focused on memory confidence. Findings from the AD literature have yielded mixed findings regarding the effect of AD on the accuracy of metacognitive confidence memory judgements, some authors revealing a decline in memory confidence resolution (Dodson et al., 2011) while others did not (Gallo et al., 2012; Moulin et al., 2003). The effect of AD on the accuracy of subjective phenomenological memory ratings have received little attention in the literature.** To the best of our knowledge, only one study linked objective memory retrieval and subjective phenomenological memory ratings in AD (El Haj & Antoine, 2017). Results of this study revealed a weaker relation between subjective memory ratings and the specificity of remembered events in AD patients than in the control group. However, the authors of that study operationalized the relation between subjective and objective aspects of memory using a ratio between mean values of subjective ratings and memory specificity (El Haj & Antoine, 2017), so that it remains unknown whether AD patients' trial-by-trial subjective memory judgements follow the richness of the corresponding memory representation to a similar extent as in normal aging. Besides, the authors summed all subjective ratings for their analyses instead of considering each subjective dimension of memory retrieval separately. Examining whether such a discrepancy between objective and subjective memory retrieval is evident early in the progression of the disease (even at the prodromal stage, that is, Mild

Cognitive Impairment (MCI)) may help in better characterizing the cognitive impairments associated with AD. More broadly, examining the trial-by-trial relationship between the intensity of subjective memory vividness judgements and the corresponding memory content may be of great interest to enlighten our knowledge about the functioning of episodic memory in other disorders characterized by a diminution of the subjective sense of recollection such as autism (Cooper & Simons, 2019) or depression (Holmes et al., 2016).

Conclusion

Although older adults are usually found to assign vividness ratings that are as high or higher than young adults, we argue that this does not mean that the subjective experience of memory vividness remains unaffected in aging. **In fact, it appears from converging evidence using various approaches (i.e., laboratory stimuli, recent real-life events, autobiographical memory, future thinking or imagination) that older adults inflate the intensity of their vividness ratings but also rely on episodic details to a lesser extent than young adults to make their subjective vividness judgements. Memory vividness inflation in older adults seems to occur because of age-related differences in vividness criterion, scale interpretation or socio-psychological factors. The reduced relation between memory vividness and objective memory measures in the older age-group may be explained by the fact that retrieved memory details are used/weighted differently by young and older adults, perhaps because of age-related differences in memory attribution or monitoring processes.**

The present review further emphasized the need of considering both measures of calibration and resolution when studying memory vividness or other subjective memory

dimensions in the context of aging. The studies discussed here also provided evidence that the amount of available memory content is not literally transposed into a subjective sense of memory vividness but is rather weighted by attribution processes that may be sensitive to age. In this context, we recommend that future studies combine different analytic methods (i.e., calibration and resolution) and different subjective memory measures (e.g., vividness, ratings of details and confidence) to examine age-differences in the subjective experience of memory. These investigations would shed new light on age-differences in episodic memory functions and could in turn be used as a window to determine the nature and the extent of the contribution of cognitive processes that are responsible for the weighting and the transposition of retrieved episodic details into a subjective sense of remembering.

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	Vividness calibration	Overestimation?	Vividness resolution	Reduced relation with event details?
Laboratory stimuli	Henkel et al., (1988)	**No**	Folville, D'Argembeau et al., (2020)	**Yes**
	St-Laurent et al., (2014)	**Yes**	Folville et al., (2021)	**Yes**
	Korkki et al., (2020)	**Yes**		
	Folville, D'Argembeau et al., (2020)	**Yes**		
	Folville et al., (2020)	**Yes**		
	Folville et al., (2021)	**Yes**		
Controlled real-life events	Mazurek et al., (2015)	**Yes**	Folville, Jeunehomme et al., (2020)	**Yes**
	Folville, Jeunehomme et al., (2020)	**Yes**		
	Holland et al., (2012)	**Yes**		
	St-Jacques et al., (2012)	**Yes**		

Remote autobiographical events	De Beni et al., (2013)	**Yes**
	Zavagnin et al., (2016)	**Yes**
	Devitt et al., (2017)	**Yes**
	De Brigard et al., (2017)	**Yes**
	Robin & Moscovitch (2017)	**Yes**
	Peters et al., (2019)	**Yes**
	Kapsetaki et al., (2021)	**Yes**
Imagined future events	Cole et al., (2013)	**Yes**
	De Beni et al., (2013)	**Yes**
	Zavagnin et al., (2016)	**Yes**
	De Brigard et al., (2017)	**Yes**
	Lapp & Spaniol (2017)	**Yes**
	Robin & Moscovitch (2017)	**Yes**
	Devitt & Schacter (2020)	**Yes**

	Robin & Moscovitch (2017)	**Yes**		
Imagined scenes				
	Sawczak et al., (2019)	**Yes**		

Table 1. Studies examining episodic memory vividness and an objective memory measure in young and older adults. From left to the right: the first column indicates the type of approach used; the second column gives the first author and the year of publication of studies that examined the calibration of vividness ratings; The third column indicates if an overestimation of memory vividness was observed in the older age-group in these studies; The fourth column gives the first author and the year of publication of studies that examined the resolution of vividness ratings; the fifth column indicates whether the trial-by-trial relation between memory vividness and recall was reduced in the older age-group in these studies.

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