Simulate your Senses: Exploring the Impact of Sensory-Focused Episodic Future Simulation on Subsequent Memory in Younger and Older Adults

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Abstract

Episodic future simulation allows people to plan and prepare for the future. Previous research has shown that positive episodic future simulation can bias subsequent memory for positive details in overlapping narratives in younger adults, but not older adults. Therefore, questions remain regarding whether this simulation-related memory bias extends beyond emotional information to other core features of episodic events, such as sensory detail, and whether age-related reductions in this bias reflect a broader reduction in the influence of future simulation on later memory, or the emotional content used in previous studies. The present study examined whether sensory-focused episodic future simulation influences response bias for sensory details in later overlapping narratives, and whether this effect differs between younger and older adults. Younger and older adults imagined future events with a focus on sensory information, before later reading overlapping narratives describing how those events occurred. Recognition memory was then tested for sensory and emotion/thought narrative details. Sensory-focused simulation did not produce a more liberal response bias for sensory details in either younger or older adults. Instead, younger adults were more conservative overall, whereas older adults were more liberal overall, regardless of simulation condition or detail type. Our findings suggest that simulation-related memory bias may not generalise straightforwardly from emotional to sensory information. More broadly, the present study provides novel insight into the cognitive consequences of episodic future simulation by identifying a possible boundary condition on its influence over later memory, while also broadening understanding of how age-related changes in future simulation may interfere with the way imagined events shape later cognition.

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Chapter 1: Introduction

1.1 General Introduction

Our memories play a critical role in shaping our lives and defining who we are. Memory helps connect our past to the present, allowing us to learn from our past, understand the world around us, and maintain a sense of identity over time (Baddeley, 2013; Bisaz et al., 2014; Conway, 2005). Yet, despite its importance, memory is surprisingly fragile. We may forget details, feel certain about events that never happened, or mix up where information came from (Garry et al., 1996; Johnson et al., 1993; Loftus, 1997). One way that our memory can become fragile is when we imagine the future. Much of our daily lives involves planning and preparing for what lies ahead; we often think about upcoming meetings, holidays, or tasks before they happen (D'Argembeau et al., 2011; Schacter et al., 2017). However, while helpful, imagining the future might blur the line between what was imagined and what was truly experienced (Devitt & Schacter, 2018). In the context of aging, memory and future thinking differs across younger and older adulthood (Devitt & Schacter, 2020). Therefore, this thesis aims to further elucidate how imagining the future can influence later memory, and how these effects change with age.

1.2 Episodic Memory

Human memory is a complex and a multifaceted construct, encompassing various systems responsible for processing, storing and retrieving different types of information (Squire, 2004; Sridhar et al., 2023). Given its complexity, memory can be usefully separated into *declarative memory*, or consciously accessible experiences and facts, and *non-declarative memory*, which pertains to skills and habits that require no conscious awareness to learn or retrieve (Davachi & Dobbins, 2008; Squire, 1992, 2004; Squire & Dede, 2015). Declarative memory itself can be further distinguished as either *episodic* or *semantic* (Davachi & Dobbins, 2008). Episodic memory was initially proposed by Endel Tulving (1972), which he defined as memory for personal experiences linked to a specific spatial and temporal context. In contrast, semantic memory involves decontextualised facts and encyclopaedic knowledge about the world (Tulving, 1972, 1985a, 1993). Tulving (1985) later suggested that episodic memories are uniquely characterised by a rich recollective experience called *autonoetic consciousness*, which involves engaging in 'mental time travel', whereby people project themselves to a past event, and 'mentally relive' it as if it were occurring again (Tulving, 1985b; Zaman et al., 2024; Zaman & Russell, 2022).

Retrieving an episodic memory involves a fundamentally reconstructive, rather than reproductive process (Schacter, 2012; Schacter et al., 2017). When we recall an episodic memory, we piece back together the individual details comprising the event to form a coherent mental representation (Neisser, 1986; Schacter et al., 1998). These *episodic details* provide contextual information about an event, including who was there, what happened, where it occurred, and where it took place (Tulving, 1983, 1985, 1993). Episodic details can also include sensory information (e.g., sight, sound, touch, taste, smell), emotions experienced during the event, conceptual elements such as actions and meanings, and visuo-spatial features relating to scenes, layouts, and object properties (Conway, 2009; Levine et al., 2002). These episodic details are processed and stored in separate brain regions (Addis, 2018; Fuster, 1997; Mitchell & Johnson, 2009; Rugg & Vilberg, 2013). As such, 'no single [brain] location contains a complete record of the trace or engram of a specific experience' (Schacter et al., 1998, p. 291).

During episodic recall, we reactivate the distributed brain regions storing the episodic details through a process called pattern completion (McClelland et al., 1995; Rolls, 2013; Schacter & Addis, 2007). In this process, a subset of the details comprising an experience are reactivated, and neural activation 'spreads' to the remaining details of the experience (McClelland et al., 1995). The activated details are then combined to form a coherent representation of the event (Addis et al., 2009; Schacter, 2012; Schacter & Addis, 2020).

A reconstructive memory system is considered to serve a variety of adaptive benefits (Schacter, 2012a; Schacter et al., 2011). One benefit is that existing memory representations can be flexibly updated to accommodate newly acquired information, which helps them maintain relevance in guiding future behaviour (Lee, 2009; Schacter et al., 2011; Schlichting & Preston, 2016; Wahlheim & Zacks, 2025; Ye et al., 2020). Another benefit is that we can form 'links' between related memories, which supports generalisation across events through the extraction of their broader meaning or 'gist' (McClelland, 1995; Schacter, 2012a, 2012b; Schacter et al., 2011; Schlichting & Preston, 2016). The constructive nature of episodic memory might also assist in our ability to imagine events that have not happened to us, allowing us to plan and prepare for the future (Schacter et al., 2007; Schacter, 2012; Schacter et al., 2017; Schacter & Addis, 2020).

1.3 Episodic Future Simulation

According to the *constructive episodic simulation hypothesis*, episodic details are extracted from various episodic memories, and are flexibly recombined to construct mental representations of novel future scenarios (Schacter & Addis, 2007). The process of imagining future experiences—termed *episodic future simulation*—involves imagining oneself in a specific future situation and simulating how it might unfold (Schacter et al., 2008). In doing so, people can mentally "try out" possible actions, decisions, responses, and outcomes without expending the necessary resources to engage in actual behaviours (Addis, 2018; Schacter et al., 2013, 2017; Schacter & Addis, 2007). In this way, episodic memory allows people to mentally travel backward in time to re-experience past events, and forward in time to pre-experience events that have not yet occurred (Boyer, 2008; Michaelian, 2024; Tulving, 1985b).

Several lines of research support the constructive episodic simulation hypothesis. For instance, the types of details comprising episodic memories and episodic future simulations are overwhelmingly similar (Addis, 2018). A spatiotemporal context is a defining feature of an episodic representation (Tulving, 1972), and as argued by Hassabis & Maguire, (2007), the spatial scene is crucial for representations of both past and future events. Moreover, both types of events contain various sensory and conceptual details about the objects and other people featuring in the event, about the self as the subject and/or the observer of the experience itself, as well as an unfolding sequence of actions, consequences, dialogue, thoughts, and emotions (Addis, 2018; D'Argembeau & Van der Linden, 2012; Levine et al., 2002; McLelland et al., 2015; Rubin & Umanath, 2015).

Further support comes from research examining how healthy aging affects remembering the past and imagining the future. If both processes rely on a common episodic memory system, then age-related changes observed in one domain should also appear in the other. Consistent with this prediction, age-related reductions typically observed in remembering past events (e.g., Levine et al., 2002) also extend to imagining the future (Addis et al., 2008; Gaesser et al., 2011; Schacter et al., 2013). In a series of studies, Addis et al., (2008, 2010) examined episodic (sensory, spatial, emotional, and temporal information), and non-episodic (factual information, as well as information irrelevant to the event and metacognitive statements) content of past and future events. Compared to younger adults, older adults produced fewer episodic details and more non-episodic (specifically semantic) details for *both* remembered past events and imagined future events (Addis et al., 2008, 2010). These decreases/increases were of similar magnitude for past and future events, and the number of episodic details comprising past and future events were significantly correlated both within and across the age groups (Addis et al., 2008, 2010).

Similar parallel reductions in past and future event generation have been reported in other populations, including people with depression, (Addis et al., 2016), post-traumatic stress disorder (Brown et al., 2014), Alzheimer's disease (El Haj et al., 2015) and long-term opiate users (Mercuri et al., 2016). Taken together, these results suggest a common role of episodic memory in both processes, supporting the constructive episodic simulation hypothesis (Addis et al., 2008; Schacter, 2012; Schacter et al., 2013; Schacter & Addis, 2007; van Genugten & Schacter, 2021).

Other evidence comes from neuropsychological and neuroscientific research examining the brain systems that support both remembering the past and imagining the future. For instance, individuals with amnesia following hippocampal or broader medial temporal lobe damage often show profound impairments in recalling personal past experiences and imagining personal future events (e.g., Hassabis et al., 2007; Race et al., 2011; Tulving, 1985b). Moreover, functional neuroimaging studies reveal substantial overlap in the neural regions engaged during remembering the past and imagining the future (Benoit & Schacter, 2015). Specifically, both processes recruit a “core network” of brain regions, which includes prefrontal regions, the medial temporal lobe, posterior areas, and the hippocampal region (Addis et al., 2009; Benoit & Schacter, 2015; Miloyan et al., 2019; Thakral et al., 2017).

Although there are many similarities, past and future thinking do exhibit differences. Relative to simulated future events, remembered past events have more sensory detail (Addis et al., 2009; D’Argembeau & Van der Linden, 2004) and contextual clarity (e.g., who, what, where, when information); (D’Argembeau & Van der Linden, 2004). In contrast, imagined events are more schematic, meaning they rely on generalised knowledge structures that capture how an event typically unfolds in a specific context (Fenerci et al., 2024; Johnson & Raye, 1981). Additionally, the clarity and sensory detail of memories for imagined events declines more rapidly over time compared to memories of real events (Suengas & Johnson, 1988). Another key difference between remembering and imagining emerges when the event is initially being constructed. Because imagining involves binding new episodic details together rather than reactivating existing links, imagined future events possess elements of generation, recombination, and construction which are more intensive than remembered past events (Addis, 2018; Arnold et al., 2011; Hassabis, Kumaran, & Maguire, 2007; McDonough & Gallo, 2010).

1.4 Benefits and Costs of Episodic Future Simulation

Our ability to draw on memory to think about the future offers several benefits (Schacter et al., 2017). One benefit lies in decision-making. In studies of intertemporal choice, people decide between receiving a smaller but immediate reward, or a larger but delayed reward (Boyer, 2008; Schacter, 2012). Future rewards are typically devalued based on the length of delay, resulting in shortsighted choices of the immediate option (Schacter et al., 2017). However, when people simulate a future episode of receiving the larger reward, they become more patient and shift their preference to the farsighted option (Benoit et al., 2011; O'Donnell et al., 2017; Peters & Büchel, 2010). Future thinking can also facilitate prosocial intentions toward people in need (Campbell et al., 2022; Schacter et al., 2017). After simulating themselves helping others, people become more willing to actually help these people (Gaesser & Schacter, 2014) and devote more time and money to them (Gaesser et al., 2018, 2020). Various studies have also shown that episodic future simulation boosts prospective memory—the ability to carry out an intended action in the future (Schacter, 2012a; Schacter et al., 2017; Spreng et al., 2018). For instance, imagining a future event whereby one performs an intention increases the probability that the intention will be later carried out (Altgassen et al., 2015; Chasteen et al., 2001; Neroni et al., 2014).

However, future thinking also comes with costs. Given that we use the same memory system to remember actual past experiences and imagine novel future situations, we may at times find it difficult to distinguish actual memories from imagined mental representations (Mahr & Schacter, 2022; McDonough & Gallo, 2013). People usually evaluate the origin and authenticity of their mental representations by s*ource monitoring* (Johnson et al., 1993), which relies on the notion that mental representations of different origins have different characteristics (Johnson, 1997; Johnson et al., 1993; Mitchell & Johnson, 2009). For instance, mental representations of authentic experiences typically contain many perceptual features (e.g., what one saw, heard, etc), contextual information (spatial and temporal) and the sense of 'reliving' the event (D'Argembeau & Van der Linden, 2004; McDonough & Gallo, 2010, 2013; Szpunar & McDermott, 2008). In contrast, imagined future events contain more details about the cognitive operations involved during their generation (e.g., thoughts and reasoning), and feelings of emotion and importance (D'Argembeau & Van der Linden, 2004; Hassabis, Kumaran, & Maguire, 2007; Johnson et al., 1988; McDonough & Gallo, 2010; McGinnis & Roberts, 1996; Mitchell & Johnson, 2009).

Although useful, monitoring the source of a mental experience can fail; we might accidentally identify an imagined future event as having actually occurred in the past (Mahr & Schacter, 2022; McDonough & Gallo, 2013). As mentioned above, memories of authentic experiences and imagined events tend to differ in characteristics, benefiting the source monitoring process (Johnson et al., 1988; Johnson & Raye, 1981; Justice et al., 2013). However, the imagination process can actually enhance the phenomenological characteristics of a simulated event (Heaps & Nash, 2001; Lampinen et al., 2003), causing an increased overlap and resemblance with the source cues people use to identify authentic memories (Devitt & Addis, 2016). Therefore, it becomes more difficult to distinguish between authentic and imagined future events (Mahr & Schacter, 2022; McDonough & Gallo, 2013). Consistent with this idea, imagination inflation research shows that imagining events can increase later belief or confidence that those events actually occurred, suggesting that the act of simulation itself can blur the lines between imagined and experienced events (Garry et al., 1996; Polaschek, 2000).

1.5 Episodic Memory, Future Simulation, and Aging

Episodic memory is generally considered the most age sensitive out of the human long-term memory systems (Nyberg, 1996, 2017; Squire, 2004). Cross-sectional research proposes that a decline in episodic memory begins as early as the age of 30 (e.g., Park et al., 2002) while longitudinal studies implicate a later onset between ages 65 and 70 years (e.g., Rönnlund et al., 2005). Impairment in episodic memory is recognised as one of the earliest manifestations of Alzheimer's Disease, and part of the symptomology for a range of neuropsychological disorders, such as schizophrenia and traumatic brain injury (Hulme et al., 1993; Liampas et al., 2023; van Oostrom et al., 2003; Vanderploeg et al., 2001). However, even in the absence of disease-related impairments, healthy aging is typically associated with a decline in episodic memory performance (Schacter et al., 2013). Given that future thinking relies on the episodic memory system, these age-related changes have direct implications for episodic future simulation (Addis et al., 2007, 2008; Schacter et al., 2013).

Age related changes in episodic memory are not "all or none", such that older adults simply cannot remember personal past events and imagine future ones (Levine et al., 2002). Rather, healthy aging is marked by a reduced *quality* in both processes (Korkki et al., 2020). For instance, as previously mentioned, healthy older adults typically produce fewer episodic details and rely more on semantic details relative to younger adults when remembering the past and imagining the future (Addis et al., 2008, 2010; Lalla et al., 2022; Levine et al., 2002; Schacter et al., 2018).

Supporting these behavioural findings, using functional magnetic resonance imaging, Addis et al., (2011) compared brain activity in younger and older adults while they remembered past events and imagined novel future events. Although both age groups recruited regions of the core network during past and future tasks, older adults showed reduced activation during the initial construction phase in regions associated with episodic detail retrieval, including the hippocampus, parahippocampal cortex, and precuneus (Addis et al., 2011). Moreover, when participants were elaborating on the contents of remembered or imagined events, older adults demonstrated increased activation in the left lateral temporal regions, which have been associated with semantic or conceptual autobiographical information (e.g., Graham et al., 2003). Overall, these observations align with the behavioural data mentioned above indicating that older adults produce fewer episodic and more semantic details relative to younger adults when remembering the past and imagining the future.

These parallel deficits in remembering the past and imagining the future are thought to reflect underlying changes in episodic brain regions as we age. The prefrontal cortex and medial temporal lobe (especially the hippocampus) are two brain regions crucial for episodic remembering and future simulation (Benoit & Schacter, 2015; Schacter et al., 2017). However, these brain regions are disproportionately impacted by age-related structural and functional decline (Buckner, 2004; Devitt & Schacter, 2016; Hedden & Gabrieli, 2004; Raz et al., 2005). In particular, decreased hippocampal volume (Driscoll et al., 2003; Persson et al., 2012; Tisserand et al., 2004) and reduced functional activation has been linked to a decline in episodic processes (Dennis et al., 2007, 2008; Giovanello et al., 2010; Persson et al., 2012; Viard et al., 2011). As a result, older adults have an increased reliance in preserved brain regions involved with semantic retrieval, such as the temporopolar cortices (St. Jacques et al., 2012).

Functional and structural declines in the prefrontal cortex and medial temporal lobe are associated with an enhanced susceptibility to false memories with age (Devitt & Schacter, 2016). One explanation for this vulnerability is the associative deficit hypothesis, which postulates that that age-related hippocampal decline results in a deficit in encoding and retrieving the relationship between items (Bender et al., 2010; Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000; Spencer & Raz, 1995), for instance, binding together various episodic details that constitute an episode into a coherent event representation (Overman & Becker, 2009). The hippocampus is crucial for binding these details together during encoding (Davachi et al., 2003; Giovanello et al., 2004; Jackson & Schacter, 2004; Kirwan & Stark, 2004) and this binding is critical for pattern completion, which involves reconstructing a memory back together (see section 1.1; (McClelland, 1995; Schacter & Addis, 2020).

A reduced capacity for feature binding has important implications for source monitoring. As previously discussed, source monitoring relies on the qualitative characteristics and differences between remembered and imagined events to distinguish between the two (Johnson, 1997; Johnson et al., 1993; Mitchell & Johnson, 2009). However, these characteristics are only useful for source monitoring if they were successfully bound to the event during encoding and can be retrieved alongside the corresponding memory trace – processes that decline with healthy aging (Devitt & Schacter, 2016). For example, Lyle et al., (2006) asked younger and older adults to perceive and imagine objects. Participants later made a judgement about the source and location for studied objects (e.g., magnifying glass) and perceptually similar objects (e.g., lollipop). Older adults were more likely than younger adults to falsely recognise perceptually similar objects, such as mistaking a lollipop as being previously seen (Lyle et al., 2006). However, older adults were also less likely to claim that the falsely recognised object was presented in the same location as the perceptually similar object; this pattern suggests that with age, perceptual and contextual features of stimuli may be less tightly bound together (Devitt & Schacter, 2016).

Another consequence of reduced associative binding is that different experiences are more similar in quality (Devitt & Schacter, 2016). Indeed, older adults rate memories for real events, imagined events, and false memories are subjectively more similar compared to younger adults (Gallo et al., 2011; Karpel et al., 2001). With age, the distinctive perceptual and contextual details associated with actual experiences, as well as information about the cognitive operations involved during imagination, may be less effectively bound to the original event representation. Therefore, imagined events become less distinguishable from perceived events upon retrieval, increasing the likelihood that they are confused as such (Devitt & Schacter, 2016). These age-related changes in memory and imagination might have particular implications when it comes to distinguishing between future thoughts and actual events.

1.6 Episodic Future Simulation and Subsequent Memory

Although a wealth of evidence indicates that memory influences how we think about the future, emerging research suggests that this relationship also works in reverse: thinking about the future can influence memory (Devitt & Schacter, 2018, 2020). In everyday life, people simulate possible future events every 16 minutes (D'Argembeau et al., 2011), and over half of the events we imagine eventually take place (Spreng & Levine, 2013). Moreover, these simulated events can be retained in memory over time, particularly if they are plausible and rich in episodic detail (Jeunehomme & D'Argembeau, 2017; McLelland et al., 2015). Therefore, if many simulated future events eventually take place, and these simulations are remembered over time, competition may arise between mental representations of the simulated and actual events (Devitt & Schacter, 2018). Take for example a university student about to take their final exam; before it takes place, they could imagine the upcoming exam going well or going poorly. The question is, after the exam, will the student remember the exam as going better or worse depending on how they imagined the exam beforehand?

Devitt and Schacter (2018) provided empirical evidence that episodic future simulation can interfere with subsequent memory for events when they come to take place. They asked younger adults to simulate future events, while focusing either on the event going either well (positive simulation condition) or going poorly (negative simulation condition). Participants then read neutral narratives that described the hypothetical outcomes of the events they simulated (as a stand in for the actual event). Each narrative contained emotionally positive and negative target details. A recognition test examining memory for original and altered versions of these target details was administered for half of the narratives, while the other half were tested after a 48hr delay. They found that positive future simulations produced a liberal response bias for positive details, and a conservative response bias for negative details. Put simply, participants were more likely to say “true” to positive target details in the recognition test, even when those details were not in the narrative, but were less likely to say “true” to negative details. Comparatively, negative future simulation did not interfere with subsequent memory. This “rosy memory” effect persisted across both immediate and delayed testing, suggesting that its impact was robust over time. Therefore, thinking about the future optimistically causes a positive memory bias (Devitt & Schacter, 2018).

Why might positive, and not negative episodic future simulation interfere with subsequent memory? Devitt and Schacter (2018) interpret their results as a form of affective misattribution within the source-monitoring framework (Johnson et al., 1993). Emotional valence is thought to differentially impact encoding processes; negative affect enhances specific item processing and therefore memory accuracy, and positive affect increases schematic processing and memory errors (Bless et al., 1996; Devitt & Schacter, 2018; Kensinger & Schacter, 2006; Storbeck & Clore, 2005). Therefore, memory for positive simulations are more conceptual and contain fewer cues useful for determining the source relative to negative simulation (Devitt & Schacter, 20018; Johnson et al., 1993). With fewer source cues available, the affect associated with positive simulations is likely to be misattributed as belonging to the narrative, which would then bias responses toward positive details (Devitt & Schacter, 2018).

Older adults think about the future as often as younger adults (Warden et al., 2019). Furthermore, as previously mentioned, aging is associated with deficits in source monitoring, making older adults more prone to memory errors (Devitt & Schacter, 2016). Specifically, older adults are susceptible to confusing imagined events with perceived events (Hashtroudi et al., 1990; Schacter et al., 1991) and misattributing simulated events as having actually occurred in the past (McDonough & Gallo, 2013). Therefore, if a failure in source monitoring is a contributing factor to the impact of future simulation on subsequent memory, older adults may be *more* prone to the biasing effect of positive and negative simulation (Devitt & Schacter, 2020). Building upon their prior work, Devitt and Schacter (2020) tested this idea. For older adults, neither positive nor negative future simulation biased subsequent memory. Instead, older adults were more liberal in their responses overall; that is, older adults responded "true" to details being part of the narrative in the recognition memory test, regardless of future simulation condition, and regardless of detail valence (Devitt & Schacter, 2020). In sum, thinking about a future event going well or going poorly did not selectively influence subsequent memory for that event once it takes place in older adults (Devitt & Schacter, 2020).

This result is surprising, given older adults are typically more vulnerable to memory interference (Archambeau et al., 2020). However, older adults are less likely to remember future simulations over time (García-Bajos et al., 2017), which raises the possibility that memory for the simulated events weakened across the delay before narrative encoding. To address this possibility, in a subsequent experiment Devitt and Schacter (2020) reduced this delay by having younger and older adults encode the overlapping narratives immediately after each simulation. This time, older adults showed a bias in memory after positive simulation, albeit still reduced compared to younger adults (Devitt and Schacter 2020). Therefore, older adults may be susceptible to simulation-induced memory interference, but this effect may depend on the future simulation remaining accessible during encoding of the later overlapping event.

However, this interpretation is not complete. Aging is associated with shifts in how emotional information is processed and remembered, including a well-documented positivity bias in attention and memory, whereby older adults preferentially attend to and remember positive over negative information (Mather & Carstensen, 2005). For instance, older adults are prone to falsely remembering positive experiences (Fernandes et al., 2008; Werheid et al., 2010), and emphasising the positive aspects of an otherwise highly negative event (Ford et al., 2018). Moreover, in a study conducted by García-Bajos et al., (2017), younger and older adults simulated emotional future events and later recalled their simulations. Relative to younger adults, older adults produced less negative future simulations, were more likely to recall positive simulations, and more likely to misremember negative simulations as being positive (García-Bajos et al., 2017). Given older adults demonstrate a high baseline positivity bias in memory, interpreting Devitt & Schacter's (2020) results is difficult. There may be less availability to further bias memory towards positive information in older adults, accounting for the reduced effect with age.

As such, several important questions remain regarding the mechanism underlying the influence of future simulation on memory for later events. Existing work has focused exclusively on emotional simulations, leaving it unclear whether this memory interference extends to other core features of episodic representations. If future simulation can bias later memory through source confusion, then emphasising sensory information during simulation may increase the likelihood that later memories are judged as containing more sensory content. A further unresolved issue concerns how aging modulates the biasing effects of episodic future simulation. Does this absence of bias in older adults reflect a reduced influence of simulation on subsequent memory more generally, or does it reflect characteristics of the emotional stimuli used in previous studies? Addressing these questions is essential for clarifying the mechanisms through which imagining the future shapes remembering, and for understanding how these processes change across the lifespan. Therefore, the present study addresses these gaps by removing emotional valence as the central manipulation while maintaining the core structure of the paradigm (Devitt & Schacter, 2018, 2020), allowing us to examine whether future simulation can bias later memory in older adults when the effect is not confounded with age-related positivity biases. As such, the present study investigated whether focusing on sensory information during episodic future simulation would increase later endorsement of sensory details in overlapping narratives, and whether this effect differs across younger and older adults.

1.7 Present Study

The main research question for the present study is: to what extent does focusing on sensory information during episodic future simulation influence response bias towards sensory details in an overlapping narrative, and how does this effect change with age? Participants were asked to simulate future events in response to cues (e.g., going to the beach), while focusing on either sensory information or emotion/thought information. An encoding phase followed, whereby participants read short stories describing the hypothetical outcome of their simulated events 'one year later'. Finally, participants returned one-two days later for the recognition phase, where they were shown true or false statements about the stories they read, and decided whether they believed each statement contained information from the story or not.

There are two main hypotheses for this research question. Because episodic future simulation has been shown to influence subsequent memory in prior work (e.g., Devitt & Schacter, 2018, 2020) it is conceivable that that the biasing affect observed in these studies extends beyond emotional valence to other qualitative features of episodic future simulation, such as sensory details. As such, we expect younger adults who simulate a sensory-focused event will have a liberal response bias for sensory details in the recognition phase. For older adults, two competing possibilities arise. First, although emotional simulations did not appear to produce strong memory bias in older adults in prior work, a different form of simulation may do so. In the present paradigm, sensory-focused simulations may increase overlap between imagined and later experienced details, and age-related source-monitoring difficulties may make it harder for older adults to distinguish simulated sensory information from details actually encountered in the narrative. If so, older adults may show a liberal response bias for sensory details following sensory-focused simulation. Second, older adults are more prone to forgetting simulations over time, which may reduce the likelihood of sensory-simulations influencing narrative encoding and therefore reducing the effect on subsequent memory; in this case, we would expect no bias in memory for older adults.

Chapter 2: Methodology

2.1 Ethical Approval and Consent

This study was approved by the University of Waikato Human Research Ethics Committee (approval number FS2021-21), and participants gave consent in a manner approved by the committee.

2.2 Participants

The preregistration (see Appendix A) specified a target sample of 50 participants (25 younger adults, 25 older adults), based on a power analysis (G*Power; Faul et al., 2007) reported in a similar study (Devitt & Schacter, 2020) which indicated at least 24 participants per age group was necessary to detect an effect of simulation on response bias (power > .95, $\eta^2_p = 0.13$). Therefore, 27 younger adults were recruited through the University of Waikato's Introduction to Psychology Research Program (IPRP) participant pool and poster advertisements around the Hamilton campus. Younger adults who were recruited through the IPRP participant pool were compensated with 10 IPRP course credits for participation, or with a $10 voucher per hour if recruited outside of IPRP. In addition, 25 Older adults were recruited in Hamilton and surrounding areas via poster advertisements in community outlets targeted towards older adults (e.g., bowls clubs, SeniorNet) and social media (e.g., Facebook) and were compensated with a $10 voucher per hour.

Four participants were excluded from the final sample: two due to at-or-below chance performance on the recognition memory test, and two due to not returning for the second session. Therefore, data from 24 younger adults aged 18 – 35 years (*M*= 19.04, *SD* = 1.16; 18 females; six males), and 24 older adults aged 60+ years (*M* = 70.88, *SD* = 4.98; 16 females; eight males) were included in the final analyses. Our final sample size slightly deviated from the preregistration due to recruitment constraints. All participants were fluent English speakers with no history of neurological or psychiatric impairments and had normal or corrected–to–normal vision and hearing. Older adult participants were screened for healthy cognition using the Mini–Addenbrooke's Cognitive Examination (Mini–ACE), New Zealand's recommended cognitive impairment screening tool (Callow et al., 2015).). Older adults demonstrated no obvious signs of cognitive impairment, with a mean score of 27.46 (*SD* = 1.77, range = 24 – 30).

2.3 Stimuli

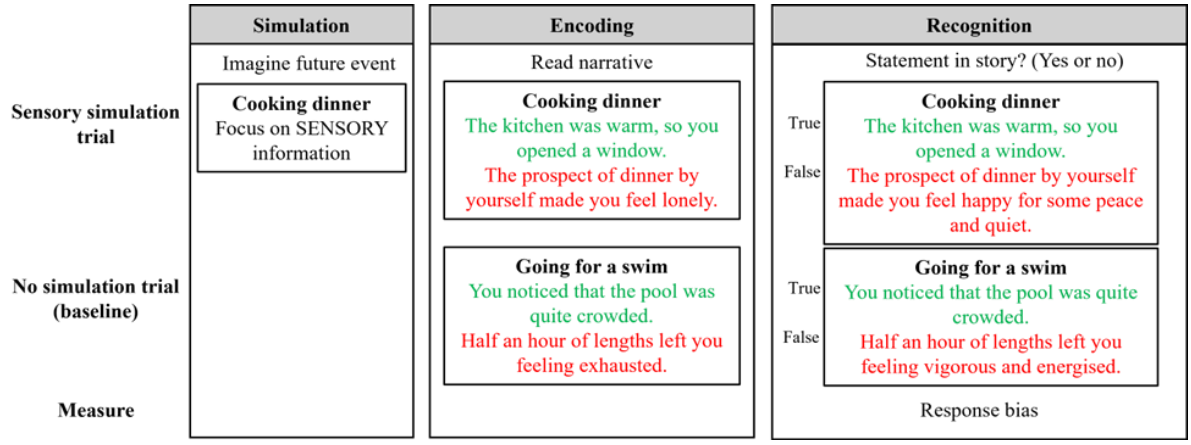
We devised short narratives (*M* = 261 words, *SD* = 21) in the second person for 12 scenarios that could plausibly be experienced in the next year (e.g., going on a nature walk). Each narrative contained 12 target details (four sensory details, four emotion/thought details and four neutral control details); refer to Appendix B for an example narrative. Verification that narrative target details were sensory or emotional/thought in nature (or unclear) was completed by three independent raters. If at least two raters agreed on the classification (e.g., that a detail was sensory), the detail was retained under that category. Cases where all raters disagreed were resolved through discussion and/or adjusting the detail. Total agreement on verification of target details was 87% for both emotion details and sensory details; four emotion details and five sensory details were adjusted as a result of disagreement.

2.4 Procedure

Individuals interested in participating in the study emailed us or signed up to participate through IPRP; individuals were screened for eligibility and emailed a participant information sheet. Eligible participants completed the study in person, individually, in a private testing room located at the University of Waikato Hamilton campus. This study utilised an adapted version of the future-past paradigm (see Figure 1) which identifies the influence of future thinking on memory, and has been validated in younger and older adults in previous studies (e.g., Devitt & Schacter, 2018, 2020). The paradigm comprised two sessions, spaced 48-hr apart for younger adults, and 24-hr apart for older adults to equate memory performance (Devitt & Schacter, 2018, 2020). Session 1 involved a simulation phase and an encoding phase, while session 2 involved a recognition phase (see Appendix C for the full experimental protocol). The full paradigm was programmed and administered on a computer screen using E-Prime (Psychology Software Tools, Pittsburgh, PA). Before commencing the study, participants re-read the participant information sheet, signed the consent form, and filled out a demographic questionnaire. Each phase is described in more detail below.

Figure 1.

Overview of the Adapted Future-Past Paradigm, including Sensory (Green) and Emotion/Thought (Red) Statements



Note: This figure depicts the trials relevant to the primary research question; the full paradigm is explained below.

2.4.1 *Simulation Phase*

In the simulation phase, participants were presented with eight of the 12 scenarios (randomly selected) and were asked to imagine a future event that might happen in the next year, while focusing primarily on either sensory information (e.g., five senses; what the participant can see, hear, smell, feel, taste) or emotion/thought information (e.g., how the participant emotionally feels, what thoughts occur); (four of each, random order). The remaining four scenarios were withheld to form the no simulation condition. Future events were to be plausible, not previously experienced by the participant, and focused on one day within the next year. For each simulated event, participants described aloud as much information as possible within three minutes, while being audio recorded. The experimenter remained in the room during the audio-recording, and provided general prompts if the participant stopped speaking before the time was up (e.g., "Is there anything else that comes to mind?").

A bell sounded to indicate the end of the three minutes, then participants rated their simulation on a 7-point scale for vividness (1 = very vague, 7 = highly vivid), amount of sensory information (1 = none, 7 = rich in sensory information), amount of emotional/thought information (1 = none, 7 = rich in emotional/thought information). Participants also rated emotional valence (1 = strongly negative, 4 = neutral, 7 = strongly positive), imagination difficulty (1 = very easy, 7 = very difficult), and plausibility (1 = very implausible, 7 = highly plausible). Finally, participants indicated whether the event was imagined from a first person (through own eyes), or third person perspective (bird's eye view).

2.4.2 *Encoding Phase*

The encoding phase followed a 15-minute break. Participants were told to pretend that it was a year later, and they were going to find out how the events they simulated played out via short narratives. 12 narratives were presented one at a time in random order: eight corresponding to the simulated events (sensory simulation and emotion/thought simulation) and four describing entirely new events (no simulation condition). Participants were instructed to read each narrative carefully, at their own pace, and then rate the narrative on a 7-point scale for interest (1 = not interesting, 7 = very interesting), amount of sensory detail (1 = none, 7 = rich in sensory detail), amount of emotional/thought detail (1 = none, 7 = rich in emotional/thought detail). They also rated the emotional valence of the story (1 = strongly negative, 4 = neutral, 7 = strongly positive). Finally, participants rated how well they could visualise the story (1 = no picture in mind, 7 = could picture taking place like a movie).

2.4.3 *Recognition Phase*

In session two, participants completed a recognition test for target narrative details. Participants were presented with a narrative title, followed by 12 corresponding target details: four true details (original target statements) from the narrative (two sensory, two emotion/thought), four false details (altered versions of original target statements) from the narrative (two sensory, two emotion/thought) and four control distractor details (two true, two false). Filler details were included to mask the purpose of the study for participants, and so are not included in the statistical analyses. Details were presented one at a time, and for each, participants were asked to indicate whether they read that information in the narrative or not by pressing either 1 or 0 on the keyboard (mapping to "yes" or "no" was counterbalanced across participants). There was no response time limit. At the end of the questions, participants were asked to make more ratings on a 7-point scale about the narratives they read during the encoding phase: emotional valence (1 = strongly negative, 4 = neutral, 7 = strongly positive), amount of sensory details (1 = none, 7 = rich in sensory details), amount of emotional/thought details (1 = none, 7 = rich in emotional/thought details).

2.5 Statistical Analyses

All statistical analyses were performed using SPSS, v.30 (SPSS Inc., Chicago, IL). This study employed a mixed 2x2x2 factorial design with age group (younger vs. older adults; between–subjects), simulation focus (sensory–focused simulation vs. no simulation; within–subjects), and detail type (sensory target details vs. emotion/thought target details; within–subjects). A factorial design involves the simultaneous manipulation of two or more independent variables, allowing the examination of both the main effects of each factor and the interaction effects between factors (Albers & Kratochwill, 2010). Analyses focused specifically on the sensory-focused simulation and no simulation conditions, as the emotion/thought simulation condition was not directly relevant to the primary research question. Both sensory and emotion/thought target detail types were retained within the analyses; including emotion/thought target details allowed us to determine whether any observed response bias following sensory-focused simulation was specific to sensory details or reflected a general liberal response tendency across both target detail types.

We used signal detection measures to quantify recognition memory performance. Signal detection theory is a framework used to analyse performance in recognition memory tasks by separating memory sensitivity from response tendencies (M. J. Hautus et al., 2021). In memory recognition paradigms, participants must decide whether a presented stimuli was previously encountered ("old") or not ("new"); these responses can then be classified into hits and false alarms. In the present study, a *hit* occurs when a previously presented sensory or emotion/thought detail is *correctly* endorsed as "old", whereas a *false alarm* occurs when a new sensory or emotion/thought detail is *incorrectly* endorsed as "old" rather than "new". Both hits and false alarms were calculated from participants' responses during the recognition phase and served as the basis for calculating discriminability (*d'*) and response criterion (C).

Discriminability refers to memory sensitivity, or how well participants can distinguish between "old" and "new" items. We calculated discriminability using *d'*, by subtracting the standardized proportion of false alarms from that of hits (Hautus et al., 2021). Higher *d*' values indicate greater discrimination between true (old) and false (new) details. Response criterion refers to the decision threshold participants adopt when judging whether a detail was previously encountered, independent of memory sensitivity. We calculated response bias using C, by multiplying the sum of the standardized hit and false alarm rates by –0.5. Higher C values indicate a more conservative response bias (i.e., more likely to say "false" regardless of memory status), whereas a lower C indicates a liberal bias (more likely to say "true"). To correct for response proportions of 0 or 1, we used 1/(2N) and 1–1/(2N), respectively (Hautus, 1995).

To address our primary research question (to what extent does focusing on sensory information during episodic future simulation influence response bias towards sensory details in an overlapping narrative, and how does this effect change with age?), a repeated measures ANOVA was run with age group, simulation focus, and detail type for response bias (C).

Separate repeated measures ANOVAs using the same factor structure were also conducted to examine discriminability (*d*'), hit rates, and false alarm rates for completion. Where significant main effects or interactions were observed, pairwise comparisons were conducted to examine simple effects and clarify the direction of differences between conditions. Pairwise comparisons were adjusted for multiple comparisons using Bonferroni correction.

Chapter 3: Results

3.1 Subjective Ratings

To first verify that participants followed instructions for sensory-focused simulation, we conducted paired-samples t-tests for younger and older adults comparing their subjective ratings of how much sensory information and how much emotion/thought information their simulated event contained. Successful adherence to instructions would be reflected in higher ratings for sensory information relative to emotion/thought information. For younger adults, sensory information ratings (M = 5.07, SD = 1.09) were significantly higher than emotion/thought information ratings after sensory-focused simulation (M = 4.09, SD = 1.33); t (23) = -5.75, $p < .001$, 95% CI [-1.33, -0.65], d = 0.59. Similarly, for older adults, sensory information ratings (M = 4.97, SD = 1.40) were also significantly higher than emotion/thought information ratings (M = 4.36, SD = 1.68); t (23) = -3.09, p = .003, 95% CI [-0.996, -0.217], d = 0.32. In summary, both younger and older adults reported their sensory-focused simulations as having significantly more sensory information than emotion/thought information, suggesting adherence to task instructions.

3.2 Recognition Measures

We next investigated whether focusing on sensory information during episodic future simulation influences response bias for emotion/thought details and sensory details in the recognition test. We conducted a 2x2x2 repeated measures ANOVA with group (between-subjects; younger, older), simulation type (within-subjects; no simulation, sensory simulation), and detail type (within-subjects; emotion details, sensory details) for response bias (C). Additionally, a separate 2x2x2 repeated measures ANOVA was conducted using the same factor structure to examine discriminability (*d*'). Means for both signal detection measures can be found in Table 1.

Table 1.

Mean Recognition Measures for Emotion and Sensory Details of Narratives Preceded by No Simulation and Sensory Simulation (Discriminability [d'] and Response Bias [C] in Younger and Older Adults

		Younger Adults		**Older Adults**	
Recognition Measure	Simulation Condition	Emotion Details	Sensory Details	Emotion Details	Sensory Details
C	No Imagination	-0.10 (0.45)	0.06 (0.42)	-0.21 (0.44)	-0.13 (0.33)
	Sensory Imagination	0.00 (0.41)	0.01 (0.34)	-0.25 (0.36)	-0.27 (0.33)
d'	No Imagination	1.21 (0.85)	1.17 (0.85)	1.27 (0.73)	1.43 (0.79)
	Sensory Imagination	1.45 (0.69)	1.33 (0.83)	1.01 (0.94)	1.41 (0.86)

Note: SD is presented in parentheses.

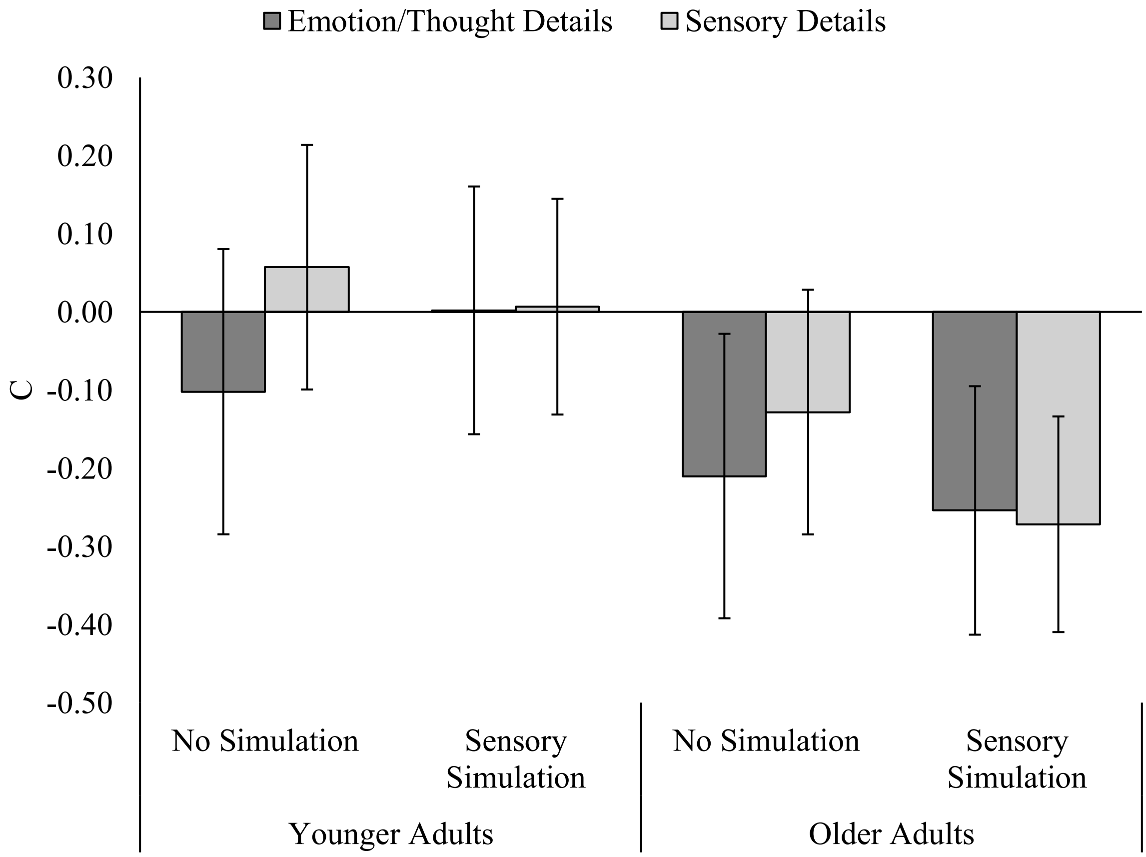
3.2.1 *Response Bias*

For response bias, there was a significant main effect of age group F (1, 46) = 6.84, p = .012, η^2_p = .130, indicating that younger and older adults differed in their overall response style; younger adults were more conservative, and older adults were more liberal overall (see Figure 2). There were no significant main effects of simulation F (1, 46) = 0.44, p = .513, η^2_p = .009, or detail type F (1, 46) = 1.86, p = .180, η^2_p = .039. Therefore, participants were not more likely to adopt a different response style depending on whether they completed sensory-focused simulation or no simulation, or whether the details retrieved were sensory or emotion/thought. There were also no significant two-way interactions: simulation and age group F (1, 46) = 1.40, p = .224, η^2_p = .029; detail type and age group F (1, 46) = 0.37, p = .548, η^2_p = .008; simulation and detail type F (1, 46) = 2.02, p = .162, η^2_p = .042, or three-way interaction between simulation, detail type, and age group; F (1, 46) = 0.10, p = .756, η^2_p =

.002. Therefore, the difference between younger and older adults' response styles did not depend on whether they completed sensory-focused simulation or no simulation, nor on whether the details were sensory or emotion/thought.

Figure 2.

Mean Response Bias for Emotion and Sensory Details for No Simulation vs. Sensory Simulation Conditions in Younger Adults and Older Adults



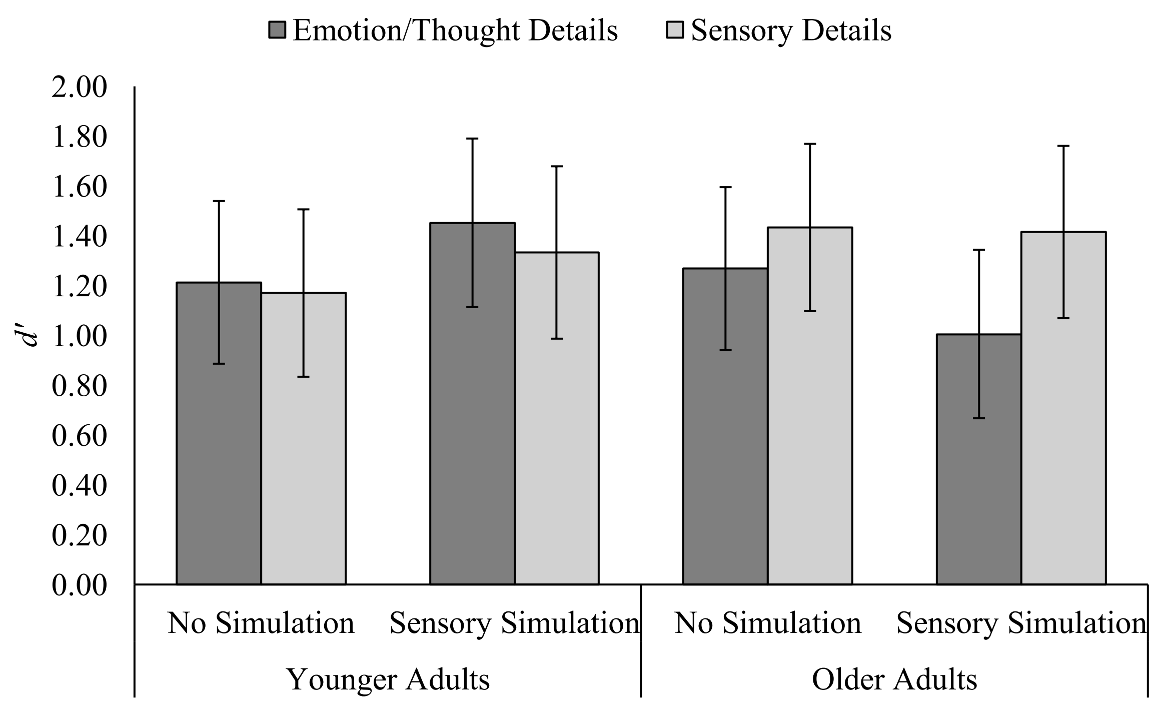
Note: Error bars represent 95% Confidence Intervals.

3.2.2 *Discriminability*

For *d'*, there were no significant main effects of simulation F (1, 46) = 0.068, p = .795, η^2_p = .001, detail type F (1, 46) = 1.161, p = .287, $\eta^2_p{}^2$ = .025, or age group F (1, 46) = 0.007, p = .934, η^2_p = .000. Therefore, participants' ability to distinguish between true and false details did not significantly differ between the sensory-focused simulation or no simulation conditions, sensory or emotion/thought details, or between younger and older adults. There were no significant two-way interactions: simulation and age group F (1, 46) = 2.176, p = .147, η^2_p = .045; detail type and age group F (1, 46) = 3.723, p = .060, η^2_p = .075; simulation and detail type F (1, 46) = 0.134, p = .716, η^2_p = .003. This non-significant interaction suggests that the effect of sensory-focused simulation versus no simulation on participants' ability to distinguish true from false details did not depend on age and did not differ for sensory versus emotion/thought details. Finally, there was no significant three-way interaction between simulation, detail type, and age group; F (1, 46) = 0.487, p = .489, η^2_p = .010, therefore, the ability to discriminate between true and false details was not altered by prior simulation, whether the detail was emotion/thought or sensory, or by the age of the participants. Graphed means for discriminability across younger and older adults can be found in Figure 3.

Figure 3.

Mean Discriminability for Sensory and Emotion/Thought Details for No Simulation vs. Sensory Simulation Conditions in Younger Adults and Older Adults



Note: Error bars represent 95% Confidence Intervals.

3.3 Hits and False Alarms

To investigate whether focusing on sensory information during episodic future simulation influences hit rates and false alarm rates, we conducted a 2x2x2 repeated measures ANOVA run with group (between-subjects; younger, older) and simulation type (within-subjects; no simulation, sensory simulation) and detail type (within-subjects; emotion details, sensory details) for hits and false alarms. Means for both hits and false alarms can be found in Table 2.

Table 2.

Mean Corrected Hits and False Alarms for Sensory and Emotion/Thought Details Preceded by No Simulation and Sensory Simulation in Younger and Older Adults

		Younger Adults		**Older Adults**	
Recognition Measure	Simulation Condition	Emotion Details	Sensory Details	Emotion Details	Sensory Details
Hits	No Simulation	0.74 (0.16)	0.68 (0.21)	0.79 (0.16)	0.79 (0.15)
	Sensory Simulation	0.75 (0.17)	0.73 (0.19)	0.76 (0.19)	0.83 (0.14)
False Alarms	No Simulation	0.33 (0.24)	0.28 (0.18)	0.35 (0.21)	0.30 (0.19)
	Sensory Simulation	0.25 (0.17)	0.27 (0.16)	0.41 (0.20)	0.35 (0.21)

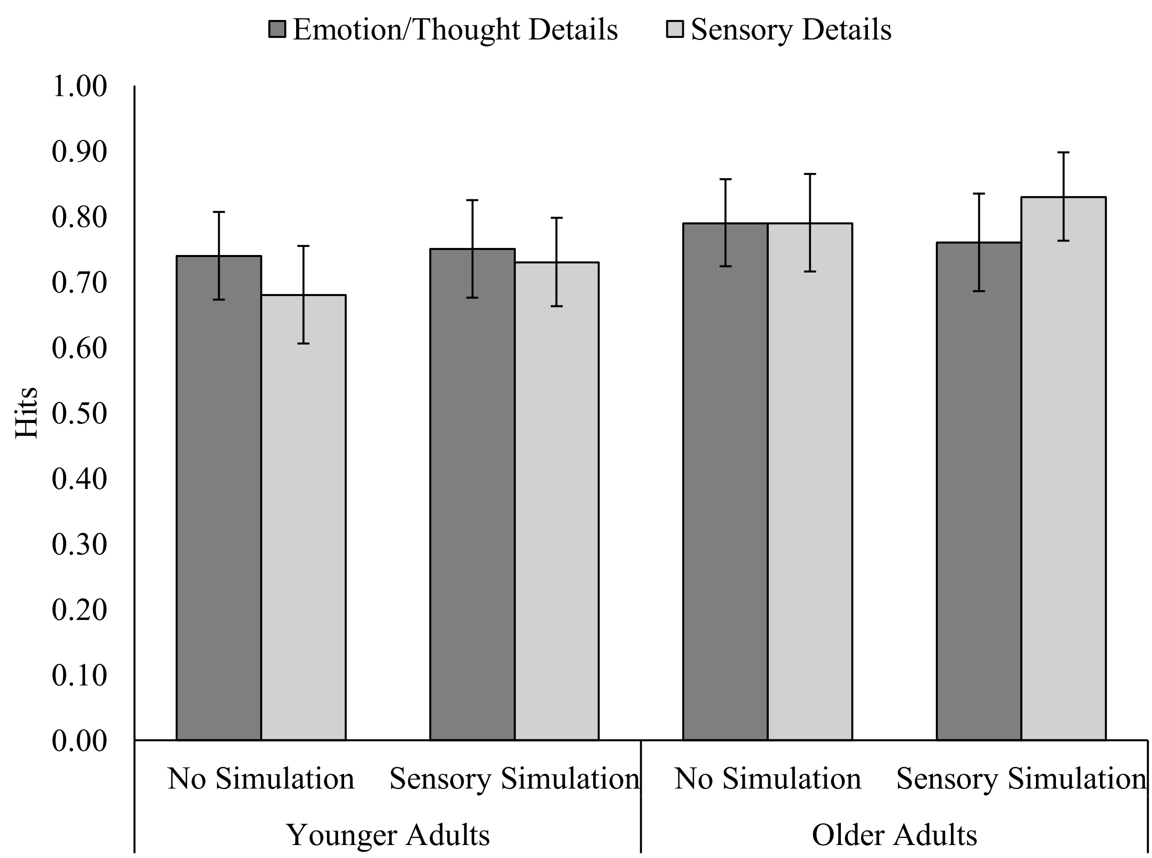
Note: SD is presented in parentheses.

3.3.1 *Hits*

For hits, a significant main effect of age group was found F (1, 46) = 4.65, p = .036, η^2_p = .09, indicating that younger and older adults differed in overall hit rates; older adults had a higher hit rate compared to younger adults (see Figure 4). There were no significant main effects of simulation F (1, 46) = 0.37, p = .545, η^2_p = .008, or detail type, F (1, 46) = 0.03, p = .859, η^2_p .00. Therefore, participants were not more likely to have higher or lower hit rates depending on whether they completed sensory-focused simulation or no simulation, or whether the details retrieved were sensory or emotion/thought. There was a significant interaction between detail type and age group F (1, 46) = 4.22, p = .046, η^2_p = .08. Bonferroni-adjusted pairwise comparisons showed that older adults had significantly higher hit rates than younger adults for sensory details (p = .003), while no age difference emerged for emotion/thought details (p = .519); there was no difference between sensory and emotion/thought details within each age group (younger adults p = .102; older adults p = .141). No other two-way interactions were significant: imagination and age group F (1, 46) = 0.17 p = .678, η^2_p = .00; imagination and detail, F (1, 46) = 1.90, p = .175, η^2_p = .04. There was no significant three-way interaction between imagination, detail, and age group F (1, 46) = 0.08 p = .784, η^2_p = .00. Therefore, the difference between younger and older adults' hit rates did not depend on whether they completed sensory-focused simulation or no simulation, nor on whether the details were sensory or emotion/thought.

Figure 4.

Mean Corrected Hits for Sensory and Emotion/Thought Details for No Simulation vs. Sensory Simulation Conditions in Younger Adults and Older Adults



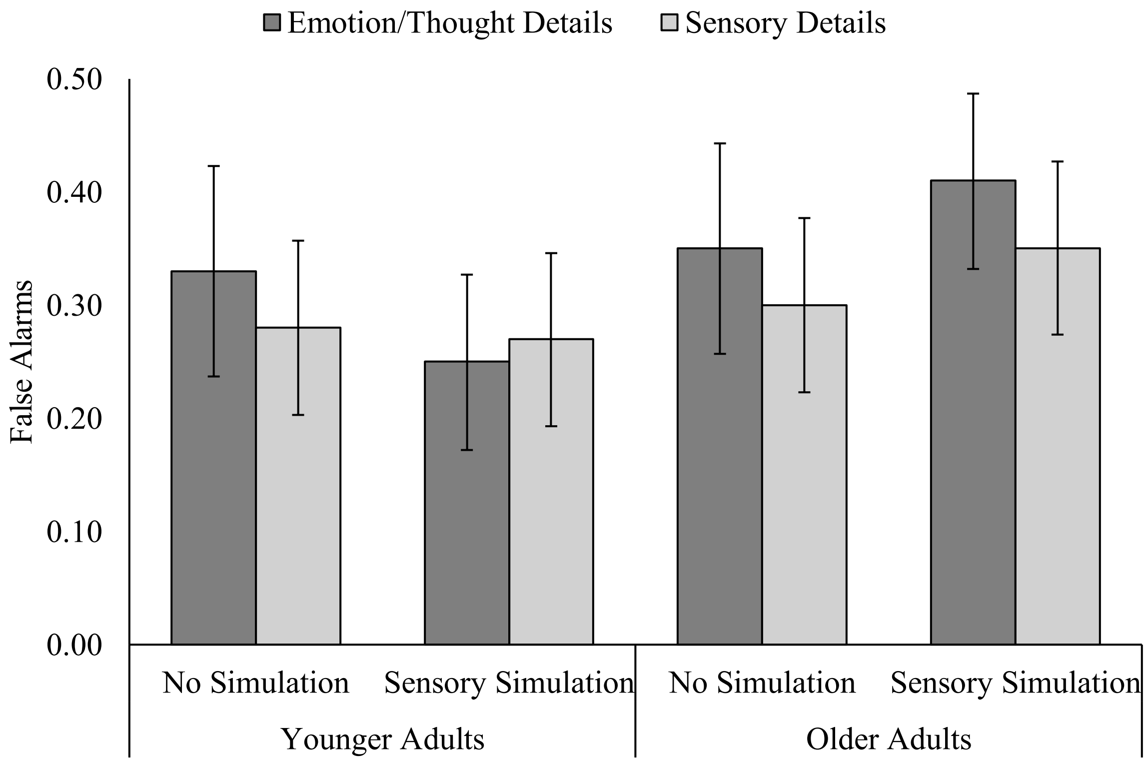
Note: Error bars represent 95% Confidence Intervals.

3.3.2 *False Alarms*

For false alarms, there were no significant main effects for imagination F (1, 46) = 0.03, p = .857, η^2_p = .001, detail type F (1, 46) = 2.73, p = .105, η^2_p = .056, or age group F (1, 46) = 3.29, p = .076, η^2_p = .067. This finding suggests that false alarm rates did not differ depending on whether participants completed sensory-focused simulation or not, did not differ between sensory and emotion/thought details overall, and did not differ between younger and older adults. There were no significant two-way interactions between simulation and age group, F (1, 46) = 3.99, p = .052, η^2_p = .080; simulation and detail type, F (1, 46) = 0.23, p = .637, η^2_p=. 005; or detail type and age group, F (1, 46) = 0.65, p = .424, η^2_p = .014. Therefore, false alarm rates did not differ across detail types depending on whether participants completed simulation or not, did not differ between younger and older adults across sensory and emotion/thought details, and simulation did not affect younger and older adults differently. No significant three-way interaction was found between imagination, detail type, and age group F (1, 46) = 0.67, p = .419, η^2_p = .014. Therefore, false alarm rates were not altered by prior simulation, whether the detail was emotion/thought or sensory, or by the age of the participants. See Figure 5 for graphed false alarm means across younger and older adults.

Figure 5.

Mean Corrected False Alarms for Sensory and Emotion/Thought Details for No Simulation vs. Sensory Simulation Conditions in Younger Adults and Older Adults



Note: Error bars represent 95% Confidence Intervals.

Chapter 4: Discussion

Episodic future simulation is a crucial cognitive process that allows people to pre-experience possible future events by flexibly recombining episodic details of past experiences, supporting functions such as decision-making, prosocial intentions, and prospective memory (Altgassen et al., 2015; Benoit et al., 2011; Boyer, 2008; Gaesser et al., 2018; Neroni et al., 2014; O'Donnell et al., 2017; Schacter et al., 2017). Previous research suggests that optimistically thinking about a future event biases memory for positive details about the event once it comes to take place in younger adults (Devitt and Schacter 2018) but not older adults (Devitt and Schacter 2020). To the best of our knowledge, no research has examined whether the influence of future thinking on later memory extends beyond emotional information. Additionally, questions remain regarding how aging modulates the biasing effect of episodic future simulation. Based on these gaps in existing research, we collected data from 24 younger and 24 older adults to examine whether focusing on sensory information during episodic future simulation influences response bias for sensory details in overlapping narratives, and whether this effect changed with age.

4.1 Manipulation Check

Before interpreting our study's results, it is important to establish that our findings are unlikely to reflect a failure of the experimental manipulation itself. Manipulation checks are commonly used to assess whether participants perceived, understood, or responded to the experimental manipulation in the intended manner (Hauser et al., 2018). We asked participants to subjectively rate how much sensory information and how much emotion/thought information their simulated event contained. Younger and older adults rated their sensory-focused future simulations as containing more sensory detail than emotion/thought detail, suggesting that they were following task instructions. Our findings are therefore unlikely to reflect failed task engagement and cannot be attributed to an error in our experimental manipulation.

4.2 Younger Adults

We hypothesised that younger adults would have a liberal response bias for sensory details after sensory-focused simulation, in accordance with prior literature showing that episodic future simulation can interfere with memory for an overlapping event once it comes to take place (e.g., Devitt and Schater 2018, 2020). If sensory-focused future simulations behaved similarly to positive-focused future simulations as seen in Devitt and Schacter, (2018), we would expect to see a liberal response bias for congruent details (sensory details) and a conservative response bias for incongruent details (emotion/thought details). Contrary to our hypothesis, sensory-focused simulation did not bias subsequent memory for sensory details. Therefore, whereas positive future simulation biased younger adults' memory toward positive details in previous work (e.g., Devitt and Schacter, 2018), focusing on sensory information during episodic future simulation did not produce a similar effect toward sensory details in the present study.

Why might the findings of Devitt and Schacter (2018) not extend to sensory-focused future simulations? One possibility surrounds the role of emotion and how future simulations are remembered over time. For a sensory future simulation to interfere with later memory for the narrative, the simulated event must be sufficiently accessible during narrative encoding. Research by Szpunar et al., (2012) demonstrates that emotional future simulations may be more accessible across a shorter delay, relative to non-emotional, or *neutral* future simulations. In their study, Szpunar et al., (2012) asked participants to generate episodic memories, including familiar people, places, and objects; experimenters then randomly recombined this information into person-place-object simulation cues. In a subsequent experimental session, participants were given these simulation cues along with an emotion 'tag' (positive, negative, or neutral). Participants were then instructed to generate a plausible future event that could occur within the next five years, containing the specified person, place, and object, and would invoke the emotion indicated by the tag (Szpunar et al., 2012). After delays of either 10-min or one day, participants were given a cued recall test which contained two elements of the simulation cue (e.g., object and place) and were instructed to recall the third element (e.g., person).

One critical finding was that after the 10-minute delay, both positive and negative simulations were recalled more frequently than neutral simulations (Szpunar et al., 2012); it may be that over a shorter delay, emotional simulations may form more accessible memory traces than neutral simulations. Relating back to the present study, our participants rated the emotional valence of their sensory future simulations as neutral (*M* = 4.54, *SD* = 1.37), with 69.1% of ratings falling within the neutral range (3–5). Given the 15-min delay between simulation and narrative encoding, participants' neutral sensory simulations may have been less accessible by the time participants encoded the overlapping narratives, thereby reducing the effect of simulation on subsequent memory. However, this interpretation is not entirely straightforward. At a longer delay of 1-day, Szpunar et al., (2012) found that positive and neutral future simulations were recalled equally better than negative future simulations. Therefore neutral simulations can remain accessible across longer retention intervals, challenging this account that our null effects may have resulted from neutral emotional valence. But, to further complicate matters, participants' neutral simulations were slightly positively biased in valence, which Szpunar et al., (2012) suggest may have contributed to their retention over the longer delay.

Therefore, an alternative explanation for our null findings is that sensory simulation encouraged item-specific processing. In this case, sensory simulation might behave similarly to negative future simulations, as seen in Devitt and Schacter, (2018). Negative affect is thought to enhance item-specific processing, whereby attention is directed toward distinctive perceptual and contextual details of an event, rather than the broader gist or general meaning (Bowen et al., 2018; Buchanan, 2007; Kensinger, 2009; Storbeck, 2013; Storbeck & Clore, 2011; Williams et al., 2022). From a source monitoring perspective (Johnson et al., 1993), we make judgements on whether a mental representation is imagined or real based on its qualitative features (Johnson et al., 1988; Johnson & Raye, 1981). If sensory simulations provided more source cues, sensory information generated during simulation may have been easier to attribute to the simulation itself rather than to the later narrative. More specifically, sensory simulations may have produced distinctive perceptual cues, such as visual, auditory, or tactile details, which helped participants discriminate between what they had imagined and what they later read. As a result, sensory information from the simulation may have been less likely to be misattributed as belonging to the narrative, thereby reducing the likelihood of a liberal response bias for sensory details.

Although discriminability, hits, and false alarms were not central to the primary research question, these additional measures were examined to provide a more complete account of recognition performance in younger adults. Together, these measures indicate whether future simulation influenced participants' memory accuracy for the narratives. Across all three measures, no significant effects of sensory-focused simulation emerged: discriminability, hit rates, and false alarm rates did not differ between the simulation and no-simulation conditions, nor between sensory and emotion/thought details. These null effects were expected, given that in previous studies (e.g., Devitt and Schacter 2018, 2020) no effects of simulation across discriminability, hits, and false alarms in younger adults were observed; therefore, our study aligns with these findings.

4.3 Older Adults

Our results for older adults align with our alternative hypothesis that sensory-focused simulation would not bias later memory for sensory details. For prior simulation to interfere with memory for the overlapping narrative, the simulated event would need to remain accessible across the 15-minute interval between simulation and narrative encoding. However, older adults are prone to forgetting imagined future events over time (García-Bajos et al., 2017). In the present study, older adults completed sensory future simulations before later encoding the corresponding narratives, meaning that the respective simulations may have no longer been retrievable when the overlapping narrative was encountered, reducing the effect of simulation on subsequent memory. This interpretation is consistent with (Devitt & Schacter, 2020) who found that after a 15-min interval between simulation and narrative encoding, older adults did not show an effect of simulation on later memory. However, when simulation memory was supported by having participants read the relevant narrative immediately after each simulation, older adults showed similar effects to younger adults. Therefore, at least part of the reason why older adults may be immune to the impact of episodic future simulation on subsequent memory stems from an inability to retrieve the simulated event during narrative encoding. However, given that younger adults also did not show an effect of sensory-focused simulation on subsequent memory, the interpretation of our results for older adults is not so clear cut. The possibilities for our null results outlined in the previous section may also apply to older adults. Specifically, sensory-focused simulation may have lacked the emotional salience necessary to influence later memory, or they may have encouraged item-specific processing that helped preserve the distinctiveness of the imagined event.

Implementing a future study to disentangle these possibilities might involve holding the sensory focus constant while varying the emotional valence of the simulated event and the delay between simulation and narrative encoding. For instance, younger and older adults could imagine future events that are sensory-focused, with varying valence (i.e., positive or neutral), before encoding overlapping narratives either immediately or after a 15-min delay. If older adults show an effect of simulation on subsequent memory only when narratives are encoded immediately, and regardless of simulation valence, this would support the idea that simulation memory decays rapidly over time. If the absence of a bias in the present study was due to the neutral nature of the simulations, then positive sensory simulations should make participants more prone to the influence of simulation on later memory. Finally, if sensory future simulation prevents bias because it promotes item-specific processing, then both neutral and emotional sensory simulations should not produce a bias relative to no simulation.

Discriminability, hits, and false alarms were also examined to provide a more complete account of recognition performance in older adults. Interestingly, older adults showed higher hit rates for sensory details than younger adults. This pattern is somewhat unexpected, given that older adults typically show fewer hit rates than younger adults on recognition memory tasks (e.g., Fraundorf et al., 2019; Hennessee et al., 2018; Huh et al., 2006). Perhaps our sample of older adults were relatively high-functioning or especially motivated. This may be particularly relevant given evidence that in-person laboratory testing can sometimes negatively impact older adults' memory performance through evaluative pressure or age-based stereotype threat (Régner & Huguet, 2025), whereby concerns about confirming negative stereotypes regarding ageing and memory can impair performance in formal testing environments (Chasteen et al., 2005). In this context, older adults who were willing to attend and complete our study in-person may have been individuals who were less affected by such pressures, potentially contributing the results observed here. However, this finding should be interpreted cautiously and would benefit from replication in a sample exhibiting age-related memory decline. In terms of the other recognition measures, no significant effects of sensory-focused simulation emerged for discriminability or false alarm rates: neither measure differed between the simulation and no-simulation conditions, nor between sensory and emotion/thought details. These effects were expected and align with previous studies (e.g., Devitt and Schacter 2018, 2020) which also found no effect of simulation on discriminability and false alarms.

4.4 Implications

The present study contributes to research on episodic future simulation by examining, for the first time, whether simulation-related memory interference extends beyond emotional content and to sensory information. We provide new insight into the cognitive consequences of episodic future simulation by showing that its influence on later memory is not limited to whether people imagine the future but depends on the kind of information that is carried forward from simulation into later encoding. By expanding on existing research from emotional to sensory-focused simulation, our study clarifies that simulation-related memory interference may not be a consequence of future thinking itself but may be constrained by the content and accessibility of the simulation. By examining whether future simulation shapes later memory in younger and older adults, this study highlights a potential trade-off: reduced influence of future thinking on memory may protect older adults from falsely incorporating imagined details into later experiences, but it may also mean that imagined future events are less likely to guide later behaviour. This has practical relevance for understanding how older adults use future thinking in daily life, including remembering plans, preparing for upcoming situations, and making decisions. More broadly, our findings suggest that supporting the accessibility and usefulness of future simulations may be important for helping older adults maintain independence and future-oriented functioning.

4.5 Limitations and Future Directions

The present study has limitations that should be considered when interpreting results. Firstly, in contrast to participant-generated future simulations, our study used experimenter-generated narratives that served as substitutes for personally experienced events. While this approach allowed for tight experimental control over the content of the events and the sensory and emotion/thought details later tested, memory for experimenter-generated narratives may differ from memory for stimuli that more closely replicates real-world, or naturalistic stimuli (e.g., Bailey & Smith, 2024). Accordingly, it remains unclear whether the present findings would generalise to real-world situations in which people imagine future events and later recall genuinely experienced overlapping episodes.

Future studies could address this limitation by adapting the future-past paradigm to include more ecologically valid stimuli, such as videos (Zacks et al., 2001), picture stories (Magliano et al., 2017), or even virtual reality (Radvansky & Copeland, 2006). Virtual reality may be especially useful; For instance, sensory details could be manipulated through the appearance, sounds, and spatial layout of the environment, whereas emotion/thought details could be manipulated through dialogue, social interactions, facial expressions, or the overall outcome of the event. This would allow future research to examine whether sensory-focused simulation biases memory when later events are encoded in a context that more closely approximates real-world experience, while still allowing sensory and emotion/thought details to be tested at recognition.

A second limitation is that valence was not fully counterbalanced or independently validated across narrative details. In our adapted version of the future-past paradigm, we devised two versions of each narrative to balance item effects. Generally, one version of each narrative was intended to be more positive and the other more negative, however this distinction was not consistent across all narrative details. More specifically, while we classified whether narrative details were sensory or emotion/thought in nature, we did not classify if they were positive or negative. As a result, differences in valence may have introduced variability across stimuli, making it more difficult to determine whether memory performance in the recognition phase was influenced by the intended manipulation or by unvalidated emotional valence between items. Future studies should validate detail valence using independent raters to ensure narratives are fully and reliably counterbalanced for item effects.

4.6 Conclusion

Episodic future simulation refers to the ability to imagine and pre-experience possible future events by flexibly recombining details from past experiences. The present study was the first to examine whether a sensory-focused future simulation could bias subsequent memory for sensory details in overlapping narratives, extending previous work showing that positive future simulation can bias later memory in younger adults but not older adults. Contrary to our predictions, sensory-focused simulation did not influence response bias for sensory details in either younger or older adults. These findings suggest that the effects of future simulation on later memory may not generalise beyond emotional content and may depend on the type of information emphasised during simulation. The absence of bias may reflect the largely neutral nature of the sensory simulations, meaning they were not retained strongly enough to interfere with later narrative encoding; alternatively, sensory-focused simulation may have promoted item-specific processing, reducing source confusion between imagined and encountered details. For older adults, the null effect may also reflect greater decay of simulation memory across the delay between simulation and narrative encoding. Future research should disentangle these possibilities by examining how simulation valence, sensory focus, and delay jointly influence whether imagined future events shape later memory.

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Appendix A
Preregistration

1) Have any data been collected for this study already?

No, no data have been collected for this study yet.

2) What's the main question being asked or hypothesis being tested in this study?

To what extent does focusing on sensory information during episodic future simulation influence bias in memory for sensory details, and does this effect change with age? It is hypothesised that younger adults will have a liberal response bias to sensory details after sensory-based imagination, while older adults will not show a bias.

3) Describe the key dependent variable(s) specifying how they will be measured.

Memory for sensory details after episodic future simulation, measured by hits, false alarms, and d' during the 'recognition phase'. Our main DV will be C (criterion), which is a measure of response bias.

4) How many and which conditions will participants be assigned to?

We will have 2 within-subjects imagination conditions:

Sensory-Focused Condition - (e.g., what people and places look like, what items are present)

Control Condition (no sensory-focused imagination).

We will also recruit younger and older adults (18-35 years and 65+ years) for between subjects comparisons.

5) Specify exactly which analyses you will conduct to examine the main question/hypothesis.

We will use a mixed-design ANOVA to examine the main effects of age group (younger vs. older adults) condition (sensory imagination vs. no imagination) and detail (sensory vs. emotion) on memory accuracy, as well as the interaction effect between these factors. Post-hoc tests will be conducted to explore specific group differences if the ANOVA detects significant differences between both age-groups.

6) Describe exactly how outliers will be defined and handled, and your precise rule(s) for excluding observations.

We will exclude participants for indicators of task non-compliance. Specifically, if a participant provides descriptions of future events that are less than 1.5 minutes long for 3 or more events, if they read through 3 or more narratives at a rate of 20 seconds or less, or if they achieve at or below chance on the recognition memory test.

7) How many observations will be collected or what will determine sample size? No need to justify decision, but be precise about exactly how the number will be determined.

We will recruit 25 younger adults (aged 18-35 years) and 25 older adults (aged 65+ years), with a total of 50 participants. This sample size is consistent with prior work (Devitt & Schacter, 2019).

8) Anything else you would like to pre-register?

(e.g., secondary analyses, variables collected for exploratory purposes, unusual analyses planned?)

Older adults will be screened for healthy cognition using the Addenbrooke's Cognitive Examination Revised, a widely used screening tool for early signs of dementia that has been validated for the New Zealand population.

Appendix B
Example Narrative

PAINTING ON BEACH

Your friend invited you to have a day painting on the beach. You thought it was a strange idea but agreed to go for the new experience. The beach was crowded today, which made you anxious. You both began to walk down the beach in search of a spot. The sand was black and piping hot on your feet. You found a spot to set up, and your friend unpacked their art supply box. The sun beat down warm on your skin. You were given a canvas and decided to do an abstract picture, but you had trouble deciding on which colour to start with. Eventually you chose a navy blue, and a short, bristled paintbrush. You started applying paint onto your canvas in broad strokes. You found the painting was very soothing. By this stage your friend's painting was already starting to take form, and you saw that they were painting an underwater scene. There were clouds in the distance, but they did not look very threatening. You reached for a tube of forest green paint, but as you opened it some splattered onto your shirt. You were upset because this was a shirt that you liked. As they worked, your friend started humming a tune. They glanced over at your painting and smirked, which made you feel bad. There were more clouds now, and you hoped the rain would hold off long enough for you to finish. You tried blending some colours on your canvas, and they merged to make a beautiful gradient effect. Your friend applied the final flourish to their painting. The wind picked up, blowing sand onto your painting, which you tried in vain to protect. Raindrops started splattering on your head. Your painting was not quite the way you wanted it to be, but you decided it was satisfactory enough to be finished.

Appendix C

Experimental Protocol

Session 1

Instructions

In this study we are looking at how people remember events in the past, and how they imagine events that might happen in the future. Today I'm going to be getting you to do two tasks. One: you will imagine potential future events that could happen in the next year, two: you will read short stories describing hypothetical scenarios.

Imagination

In the first task, I am going to be giving you some everyday scenarios, such as going on a nature walk. For each scenario, I would like you to imagine yourself in this event in the future.

I would like you to imagine a single event happening on a particular day in the next year, that is from a specific time and place. For example, if you see the event GOING ON A NATURE WALK, rather than telling me about a 3 week trip that you will do, I would like you to focus in on one particular day of that trip. I do not want you to remember something that you have done before in the past, but I want you to invent a scenario that hasn't happened to you before.

When creating these future scenarios, you can be creative, but you cannot be totally unrealistic, so you can't tell me about going for a walk on the moon, for example. So you want to think about scenarios that are plausible given your plans and thoughts about the coming year. I would like you to imagine these events through your own eyes, as if you are actually experiencing them.

Importantly, you will imagine each event in one of two different ways. The first way will have you focus on the sensory detail of the event. So you should focus on imagining details about your 5 senses: what you can see, hear, smell, feel, taste. On these trials, it will tell you to focus on SENSORY information. The second way you will imagine future events is by focusing on the emotional and thought detail of the event. So you should focus on your internal thoughts and feelings during the event. On these trials, it will tell you to focus on EMOTION/THOUGHT information.

You will be asked to describe each event aloud. You will be given three minutes to describe as much detail as you can about it. I want you to say everything that comes to mind about the event. When you hear the bell, we will have to move on to the next section.

I will be recording your response, but these recordings will be kept completely confidential, your name will not be on any of the recordings. As with all data we collect from you, they will be coded with a unique participant number, and they will be stored in a secure place. Is this ok with you?

So to summarise, you will describe aloud a future imagination about the scenario that you will see on the screen. You will imagine each event with either a focus on SENSORY information, or on EMOTION/THOUGHT information. There will be 8 events to imagine total. Let's get started on a practice event.

Start practice, save instructions below for when the ratings show up.

Prompts if the participant finishes speaking early:

- Is there anything else you can tell me?
- Are there any other details that come to mind?
- SENSORY FOCUSED TRIALS: Are there any more details about what you can visualise or hear, or other information from your senses?
- EMOTION/THOUGHT FOCUSED TRIALS: Are there any more details about what you might be thinking or feeling?

Checks after the practice event:

- *Was the event specific (on a single day)?*
- *Was the event set in the future, in the next year?*
- *Was the event focused on sensory or emotional information?*

Now you will be asked to answer a couple of questions about the event. Each of these questions will appear on the computer screen, and you will press a button depending on your answer.
First, you will rate generally how detailed or <u>vivid</u> the event is in your mind, from 1 to 7. If it was vague, give it 1, or up to a 7 if it plays out like a movie in your mind.
Next you will rate the amount of <u>sensory</u> information the event contains. Give it a 1 if it has no sensory information, or up to a 7 if it was rich in sensory detail.
Next you will rate the amount of <u>emotion or thought</u> information the event contains. Give it a 1 if it has no emotion or thought information, or up to a 7 if it is rich in emotion and thought detail.
Then you will rate the <u>type of emotion</u> you would feel if you were in this event. Give it a 1 if you would feel strongly negative, a 4 if you would feel neutral, and a 7 if you would feel strongly positive.
Next, you will rate how <u>difficult</u> it was to imagine this event. Give it a 1 if it was very easy to imagine, and up to a 7 if it was incredibly difficult to come up with anything.
Next, you will rate how <u>plausible</u> this event is. Give it a 1 if you think it is completely implausible, and would never happen, and up to a 7 if you think it is plausible and could definitely happen in your future.
Finally, you will decide from what <u>perspective</u> you saw the event. There are two ways we remember or imagine events; either through our own eyes, as if we are back in our own shoes seeing the event unfolding around us; or from an external or bird's eye view.

[Example of future events can be described, if needed:]
<u>Imagine SENSORY FOCUSED future – DAY TRIP</u>
Next week, I will be visiting Auckland, and I see myself doing some sightseeing around the city with my friend from Auckland, Sarah. I'm waiting for her to meet me at the Sky Tower, and I'm looking at all the displays and information about the history of the Sky Tower as I wait. I can smell food wafting down from a restaurant somewhere above. My friend shows up and I give her a huge hug, then we take the elevator up. The weather is gorgeous, and I can see for miles in every direction. At the top it's pretty crowded, I can hear a lot of commotion from a large family group nearby about who gets to stand on the glass floor. We decide to sit in a seat and share cookies my friend brought, which are crunchy and delicious. I take photos of the view from different windows and I get my turn standing on the glass floor looking down at the ground, and everyone looks like ants and toy cars down there.

<u>Imagine EMOTION FOCUSED future – DAY TRIP</u>

Next week, I will be visiting Auckland, and I see myself doing some sightseeing around the city with my friend from Auckland, Sarah. I'm waiting for her to meet me at the Sky Tower, wondering where she could be and worried we've somehow missed each other. She finally shows up and I give her a huge hug, it's been forever since I last saw her and I've really missed her. We take the elevator up and I'm really excited to see the view. At the top it's pretty crowded, so we decide to take a seat and wait for some people to leave. I'm pretty hungry, and so I'm really glad that my friend brought cookies to share. I take photos of the view from different windows and I get my turn standing on the glass floor looking down at the ground, and I can't shake the thought that the floor will fall through.

Once participant has finished all imagination trials, give them a break for 15 mins. If they do not want a break, then ask them to complete the puzzle pack instead. There should be 15 mins between imagination and encoding phases.

Encoding

Imagine we have now time travelled, and it is now a year later. In this second task you're going to find out hypothetically how these scenarios actually played out. You will be reading short stories describing each scenario that you imagined and what really took place. You will also read stories about new scenarios that you did not imagine. These stories will be presented on the computer screen, each is about a paragraph in length. There is no time limit, so please read through each story carefully, at your own pace. There are 12 stories total.

After reading each story, press ENTER to move on, and you will answer a couple of questions about how you found the story.

First, you will rate how <u>interesting</u> you found the story, from 1 to 7. If you found it boring, give it 1, or up to a 7 if you found it really interesting.

Then you will rate the <u>emotion</u> of the story, where 1 is strongly negative, 4 is not emotional, and 7 is strongly positive.

You will rate the amount of <u>sensory</u> information the story contains. Give it a 1 if it has no sensory information, or up to a 7 if it was rich in sensory detail.

You will rate the amount of <u>emotion or thought</u> information the event contains. Give it a 1 if it has no emotion or thought information, or up to a 7 if it is rich in emotion and thought detail.

Next, you will rate how well you could <u>visualize</u> the story in your mind. Give it a 1 if you formed no picture in your mind, and up to a 7 if you could picture it taking place as if a movie was playing in your mind. Each of these questions will appear on the computer screen, and you will press a button depending on your answer.

<u>Session 2</u>

Recognition

Last session you imagined future events, then read stories about how those hypothetical scenarios could have played out. Today I am going to be asking you some questions to see how well you remember these <u>stories that you read</u>. For each scenario, I am going to be showing you a number of statements. Some of these statements contain information that you read about last session, and some of them contain information that is different from what was in the stories. Your task is to decide whether you believe each statement contains information that is from the story or not. Each of these questions will appear on the computer screen, and you will press a button to indicate your decision.

At the end of the questions, you are going to make some more ratings about the stories. First, you will rate the emotion of the story, where 1 is strongly negative, 4 is not emotional, and 7 is strongly positive. Then you will rate the amount of sensory information the story contained. Give it a 1 if it has no sensory information, or up to a 7 if it was rich in sensory detail. You will rate the amount of emotion or thought information the event contained. Give it a 1 if it has no emotion or thought information, or up to a 7 if it is rich in emotion and thought detail.

After memory test:

Thanks for answering those questions. Out of interest, what do you think was the purpose of us asking you those questions? What did you think was the purpose of imagining the scenarios last session?

Note down their response in the excel demographic sheet