The subjective experience and objective content of mental time travel

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Thesis Summary

Mental time travel is characterised by two abilities: autobiographical memory and episodic future thinking. Autobiographical memory is the ability to remember one's past (Tulving, 1972) and episodic future thinking is the capacity to imagine one's future (Atance & O'Neill, 2001). Both forms of mental time travel are accompanied by subjective experience. To understand these idiosyncrasies, 'subjective' or self-report measures are often adopted. 'Objective' measures, which allow the experimenter to score autobiographical events, are also commonplace. Yet many studies examine either one type of measurement or temporality of mental time travel. This thesis explores the subjective experience and objective content of autobiographical memory and episodic future thinking.

All studies adopted a cue word paradigm (Crovitz & Schiffman, 1974) to prompt discussion of autobiographical memories and imagined future events in healthy adults. The Autobiographical Interview scoring system (Levine et al., 2002) was used to objectively score the episodic content of these events. All studies employed phenomenological ratings to assess the participants' subjective experience of these episodes. One study used a trait-based questionnaire to explore broader subjective experiences. **Chapter 2** examined the relationship between subjective ratings and objective content, demonstrating correspondence between these measures in both temporalities. **Chapter 3** found that both subjective ratings and objective content were relatively stable across past and future events, presenting compelling evidence that mental time travel is a trait. **Chapter 4** evidenced a positive relationship between positive schizotypy and both event-based and trait-based subjective measures. Yet no relationships were observed with the objective measure.

The results from this thesis provide novel insights into: i) the constructs of mental time travel different measures are assessing, ii) similarities and differences between autobiographical memory and episodic future thinking, iii) the importance of mental imagery for remembering and imagining, and iv) the value of trial-level analyses for mental time travel research.

Preface

Chapter 2

The relationship between experimenter-scored and participant-scored measures of mental time travel. *Online poster presentation at British Neuroscience Association Festival of Neuroscience, April 2021.*

The relationship between the subjective experience of mental time travel and the objective number of episodic details. *Poster presentation at New Perspectives on Declarative Memory, University of East Anglia, June 2022.*

Chapter 4

Reed, L. S., Evans, L. H. (in press). The positive dimension of schizotypy is associated with self-report measures of autobiographical memory and future thinking but not experimenter-scored indices*. Memory*.

Mental time travel in positive, negative, and disorganised schizotypy. *Poster presentation at British Association for Cognitive Neuroscience Annual Meeting, Birmingham, May 2022.*

The positive dimension of schizotypy is associated with self-report measures of autobiographical memory and future thinking but not experimenter-scored indices. *Data blitz presentation and poster presentation at British Association for Cognitive Neuroscience Annual Meeting, Cardiff, September 2023.*

Contributors

For studies one and two, data collection and initial Autobiographical Interview scoring (Levine et al., 2002) was shared between me and Amy Baldwin, Claire Goodwin, Joshua Chalfen, and Nia Gronow. Data collection included participant recruitment, in-person interviews, and administration of questionnaires. Lucy Jackson and I then re-scored all transcripts to ensure that the scoring was consistent and that I was blind to schizotypy scores.

For study three, data collection and Autobiographical Interview scoring (Levine et al., 2002) was shared between me and Sheneil Goodman. Data collection involved participant recruitment and conducting an online Zoom/Qualtrics session. Each transcript scored by Sheneil was then double scored by me, and vice versa.

I completed all the analysis and wrote the thesis.

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Chapter 1: General introduction

1.1 General introduction to mental time travel

Mental time travel is the capacity to transcend the present moment, to remember one's past or imagine one's future (Tulving, 1985, 2002b). This term was coined by Endel Tulving (1985, 2002b), who proposed that recollective experience defies the unidirectionality of time; one of nature's most fundamental laws (Tulving, 2002b). Indeed, mental time travel evokes episodic details (objects encountered, people present, spatiotemporal information, sensory-perceptual details, and emotional details; D'Argembeau & Van der Linden, 2006; Vannucci et al., 2020) which engender a sense of re- or pre-living. For this reason, the brain has been likened to a time machine (Buonomano, 2017) that allows episodes from one's past and future to be experienced in the present moment. Many of us engage in this mental form of time travel frequently throughout our day, but rarely do we stop to contemplate this multi-faceted, subjective experience.

To convey the rich, subjective experience of mental time travel, Tulving (1972, 2002b) referred to the 'what', 'where', and 'when' of episodic memory. This early formulation emphasised the importance of episodic content (what), as well as the location (where) and time (when) in which the event occurred. This early work mainly focused on memory, but more contemporary views characterise mental time travel as a bidirectional process (see Box 1 for detail on terminology). For instance, Buckner and Carroll (2007) regard mental time travel as a form of self-projection, where one shifts perspectives from the present moment to an alternative perspective, in either the past or future. This idea was founded upon the observation that both remembering the past and imagining the future are supported by the same core brain network (Addis et al., 2007; Buckner & Carroll, 2007; Hassabis et al., 2007b; Szpunar, 2010; see section 1.4). This was a milestone finding which revolutionised the mental time travel literature. There is now a consensus that memory and future thinking are inextricably intertwined. Therefore, any discussion of mental time travel should consider both temporal directions.

Tulving's later work (2001, 2002b) described three fundamental components for mental time travel into either the past or future: i) chronesthesia, ii) a sense of self, and iii) autonoetic consciousness. The first component, chronesthesia, is an awareness of subjective time in which one can discriminate between the past, present, and future (Tulving, 2002a). Tulving (2002a) proposed that this was critical, as having an awareness of the subjective time in which one lives in makes it possible to mentally travel backward or forward with an appreciation of the present moment; knowing that the memory or future episode is not occurring now.

The second factor which makes mental time travel possible is an awareness and understanding of oneself (Tulving, 2001; 2002b). In Tulving's own words, "No traveler, no traveling" (Tulving, 2002b, p. 2). Research has repeatedly evidenced the importance of self for mental time travel, demonstrating that the two are inter-related. Not only is an awareness of oneself a pre-requisite for mental time travel (Tulving, 1985), but mental time travel is crucial for selfhood; the state of having an individual identity. It is widely accepted that remembering contributes to selfhood (Conway, 2005; McAdams, 2001; Prebble et al., 2013). Our memories present a catalogue of experiences which mould our understanding of who we once were as well as who we are today. The ability to project into the future is also critical for the self; our understanding of who we might be is provided by imagining future scenarios. Both forms of mental time travel give rise to a continuous sense of self which spans from an autobiographical past to a hypothetical future (Conway et al., 2019).

The final component, autonoetic consciousness, is an awareness of oneself as a continuous entity through time (Tulving, 1985, 2002b). Tulving regarded autonoetic consciousness as paramount, as having this awareness gives rise to the subjective experience which accompanies mental time travel, engendering a feeling of re- or pre-living. This is what distinguishes mental time travel from other mnemonic abilities, as unlike other forms of memory, this process is characterised by subjective experience. As it is a phenomenological experience, only truly understood by the experiencer, the study of mental time travel is challenging. Yet it is this very concept which makes mental time travel a compelling and fruitful area of research.

At its core, mental time travel is defined by subjective experience. Each time we remember the past or envision the future, it is an idiosyncratic and personal experience. The subjective element of mental time travel has captivated the minds of thinkers, philosophers, and researchers. Yet it is this same quality that presents challenges for empirical study

(Simons et al., 2022). Tulving placed great importance on the subjective experience of mental time travel, which he believed, “should be the ultimate object of interest, the central aspect of remembering that is to be explained and understood” (Tulving, 1983, p. 184). Since then, a great deal has been learnt about this aspect of mental time travel. For example, Simons’ papers have identified several components that constitute this subjective experience (e.g. reconstruction, multisensory experiences, the self, first-person perspective, social and cultural influences; Simons et al., 2022) and have outlined an interdisciplinary framework to further our knowledge of this phenomena (Simons et al., 2020). However, this work has focused on one form of mental time travel, largely neglecting its future-oriented counterpart. Less investigation has been conducted into the subjective experience of imagining the future, and how this process compares with remembering. To understand both forms of mental time travel, a more holistic approach is required.

To decipher this subjective experience, objective and subjective aspects of mental time travel have been differentiated in the literature (e.g. Clark & Maguire; 2020; Cooper & Ritchey, 2022; Folville et al., 2020; Richter et al., 2016). Performance-based indices such as episodic content (Clark & Maguire, 2020; Cooper & Ritchey, 2022; Levine et al., 2002), retrieval success and precision (Richter et al., 2016), and accurate recall (Egan, 1958) are typically defined as objective, and subjective experience is derived from various methods of self-report (e.g. phenomenological ratings; Boyacioglu & Akfirat, 2015; Johnson et al., 1988; Rubin et al., 2003; Sutin & Robins, 2007; Vannucci et al., 2020; diary methods; Woodberry et al., 2015; questionnaires; Berntsen et al., 2019; Palombo et al., 2013). This is of value in mental time travel literature, as it allows for separation of what is experienced by the individual from how they present to an experimenter. To understand the subjective experience of mental time travel, differentiating objective from subjective is the first critical step. To gain a comprehensive understanding of this phenomena, it is also fundamental that this is carried out for both temporalities of mental time travel. This thesis will employ both subjective and objective measures of mental time travel and implement them in both mental time travel into the past and future. This approach will provide a holistic examination, aiming to produce bidirectional insights into both the objective performance and subjective experience of mental time travel.

Box 1. Terminology

Prior research in this area has used a number of terms to refer to overlapping or in some cases, identical constructs. This section will clarify the terminology used in this thesis, to support the reader's understanding of the ideas explored.

Mental time travel will refer to the ability to re-experience the past and pre-experience the future. This term encompasses both temporal directions and will thus be used to describe both remembering the past and imagining the future, unless stated otherwise.

Episodic memory is the ability to remember personally experienced events that have occurred in one's own life (Tulving, 1972) whereas **autobiographical memory** refers to one's memory of their personal history which can include both episodic memories as well as general knowledge about oneself (Roediger & Marsh, 2003). Therefore, autobiographical memory will be used to refer to mental time travel into the past. On the other hand, **episodic future thinking** is the ability to imagine one's personal future (Atance & O'Neill, 2001) and will be the term used to denote future-oriented mental time travel.

Subjective experience will be used as a broad term which refers to how an individual visualises, feels, and generally experiences mental time travel. Within that, **autonoetic consciousness** will refer to Tulving's (1985) conceptualisation of subjective experience – an awareness of oneself as a continuous entity through time, **phenomenology** or **phenomenological detail** will be used to describe certain aspects of subjective experience (e.g. vividness, objects encountered, people present, spatiotemporal information, sensory-perceptual details, and emotional details), and **re-living** and **pre-living** will be used to denote the subjective experience of travelling backward or forward in time.

1.1.1 Episodic and semantic memory

An important step in understanding mental time travel, is to consider the two key systems which support it: episodic and semantic memory. In 1972, Tulving made the pioneering distinction between episodic and semantic memory. Our memory for personally experienced events (episodic memory) was differentiated from our general knowledge about the world (semantic memory; Tulving, 1972, 1983). In contrast to episodic memory which engenders autonoetic consciousness, semantic memory was proposed to engender noetic consciousness, which was described by Tulving (1985, 2002b) as a sense of knowing. For example, I know that 'London is the capital of England', despite not being able to recall the time that I learnt this information. This is an example of semantic memory as I am not re-experiencing an event from the past, I simply know this is a fact. It was later proposed that autonoetic consciousness includes but transcends noetic consciousness (Tulving, 2002b). Over three decades later, the episodic-semantic distinction remains influential in behavioural (Levine et al., 2002), neuropsychological (Kapur, 1999), and neuroimaging (Svoboda et al., 2006) literature. Although our understanding of the episodic-semantic distinction has evolved over the years, many aspects of Tulving's (1972) seminal work remain relevant today (see Renoult & Rugg, 2020 for review).

While proposed to be separable memory systems, Tulving also argued that episodic and semantic memory both involve conscious remembering, setting them apart from other mnemonic processes such as procedural memory, which is bound to the present moment (Tulving, 1983). Memory can be split into what can be consciously remembered or not (e.g. declarative and non-declarative; Squire & Zola, 1996; implicit and explicit; Schacter, 1987). Episodic and semantic are both forms of conscious memory but the context in which semantic memory is acquired, is generally unknown to the individual (Tulving, 1972). This hierarchy of distinctions in long-term memory systems is depicted in Figure 1.

Whilst these distinctions have been greatly influential in memory research, there is now growing evidence that the boundaries between episodic and semantic systems are not clearly defined. Although Tulving (1972) described episodic and semantic memory as functionally distinct, his work also emphasised their interdependent nature, suggesting that they constantly interact with one another (Tulving, 1982). This remains a contemporary view, with recent reviews of the episodic-semantic distinction demonstrating considerable overlap in the neural correlates of episodic and semantic memory (Renoult et al., 2019; Renoult & Rugg, 2020). The brain regions engaged in episodic memory are comparable to what is known as the 'general semantic network' (Binder, 2016; Renoult et al., 2019; Rugg & Vilberg, 2013), suggesting that episodic and semantic retrieval engage several common core brain regions. This contradicts Tulving's (1985) theory that episodic is distinct from semantic memory, due to the former involving autonoetic consciousness. Rather, the current view is that episodic and semantic memory are intertwined, with semantic memory providing knowledge which guides autobiographical recall (Fivush, 2011; Irish & Piguet, 2013; Levine et al., 2002; Renoult et al., 2019; Tulving, 2002b).

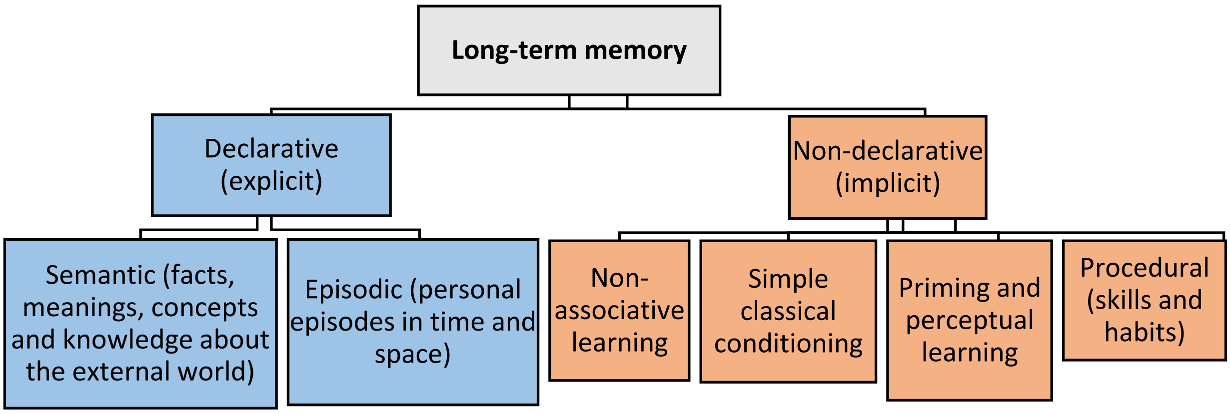


Figure 1. Distinctions between long-term memory systems adapted from Bartsch and Butler (2013).

1.2 Autobiographical memory

Autobiographical memory is our memory for personally experienced events which have previously occurred in one's own life; a mnemonic ability analogous with mental time travel into the past (see Box 1). It must be highlighted that unlike Tulving's conceptualisation which differentiated episodic from semantic, autobiographical memory is supported by both systems (Fivush, 2011; Levine et al., 2002; Renoult et al., 2019). Any autobiographical memory is likely to contain both episodic and semantic details, which both guide remembering (D'Argembeau, 2020; Irish & Piguet, 2013; Levine et al., 2002). In the literature, autobiographical memories are typically defined as episodes or occurrences which are recalled within a specific spatiotemporal context.

Autobiographical memories serve three broad classes of function: directive, social and self (Bluck et al., 2005; Bluck et al., 2010; Sow et al., 2023; Williams et al., 2008). Firstly, the directive function refers to problem-solving (Pillemer, 2003). Several autobiographical memories make up schemas that guide generic behaviour and specific memories are recalled in more novel circumstances. Secondly, social functions include developing and maintaining relationships by conversing about memories (Alea & Bluck, 2003; Bluck et al., 2005). This facilitates social interaction and can increase rapport between individuals. Finally, a coherent sense of self is informed by one's personal memories (Conway, 2005; Conway & Pleydell-Pearce, 2000). This understanding of oneself maintains self-identity and can engender self-insight and self-growth (Bluck et al., 2005). These broad functions are all vital for adaptive functioning and highlight the importance of one's autobiographical memory.

To understand autobiographical memory on a functional level, we must first consider the component processes which constitute remembering. Autobiographical memory involves three key processes: encoding, consolidation, and retrieval (Melton, 1963). Encoding refers to the mnemonic processing that occurs when an event is initially experienced – the first stage of converting this information into our autobiographical memory. After encoding, the process of consolidation transforms this information into a durable, long-term memory (Squire et al., 2015). This memory is then stored until either an internal or external cue provokes its retrieval. Retrieval is then guided by semantic memory, which provides a framework of episodic details which are schematically relevant for the particular episode (Irish & Piguet, 2013; Renoult et al., 2019; Renoult & Rugg, 2020). Finally, the event is experienced in rich episodic detail which evokes a sense of re-experiencing (Conway et al., 2004; Tulving. 2002b).

As discussed in section 1.1.1, there is increasing evidence that episodic and semantic memory are inter-dependent. In light of this research, the field is moving away from traditional memory distinctions. These traditional distinctions regard different mnemonic processes as discrete systems that are functionally separable. In the autobiographical memory literature, it is now understood that episodic and semantic memory systems are both involved in remembering (Irish & Piguet, 2013; Renoult et al., 2019; Renoult & Rugg, 2020). Semantic memory is critical in recounting memories as autobiographical knowledge about oneself, one's life story, and the world one lives in contextualises our episodic representations (D'Argembeau, 2020; Levine et al., 2004). This semantic knowledge can be further broken down into personal and general semantic memory (Renoult et al., 2012; Renoult et al., 2020). General semantics refer to information and facts about the world one lives in, and personal semantics are knowledge an individual holds about themselves, which has been deduced from prior experiences (Renoult et al., 2012; Renoult et al., 2020). For instance, if I recall the day I graduated from university, semantic knowledge about this period of my life (personal semantic memory) as well as cultural norms of graduation ceremonies (general semantic memory), will support my recollection of this episode. Although both types of knowledge are prevalent, personal semantics are most frequently associated with autobiographical memory (Conway & Pleydell-Pearce, 2000).

To understand the phenomenological experience of mental time travel into the past, it is important to consider the nature by which autobiographical memories are remembered. A common misconception is that memories are reruns of events which we have previously experienced – replicas of our experiences that can be viewed in the mind's eye as if watching a short film. In fact, it is well-established that memory is reconstructive (Bartlett, 1932; Schacter 1999; Schacter & Dodson, 2001; Conway & Pleydell-Pearce, 2000). Memories are not an exact replay of previously encountered events but rather, they are reconstructions based on elements of real events, schemas, current concerns and beliefs, semantic memories, and newly encountered information (Bartlett, 1932). The quintessential example of reconstructive memory is Bartlett's (1932) 'War of the Ghosts' experiment. In this study, English participants were asked to read and memorise a Native American folklore named 'War of the Ghosts' and when later tested on the story's details, various aspects were omitted or adapted to match English cultural norms. This was the first indication that memory might be unreliable and fallible to error. Since then, research has shown that autobiographical memories are prone to various errors such as transience, absent-mindedness, blocking, misattribution, suggestibility, bias, and persistence (Schacter, 1999; Schacter & Dodson, 2001). This suggests that while several relevant features of the initial event are reactivated, we are unable to store a single, fixed representation of any given event. Rather, the brain integrates multiple sources of information to form a conscious experience of the event which occurred (Schacter, 2012).

Another noteworthy aspect of reconstruction is the temporal compression which occurs when remembering, contrary to the initial experience which was encoded. A recent review revealed that in healthy individuals, several omissions of past experiences are made when remembering an autobiographical episode (D'Argembeau et al., 2022). The continuous flow of experience is not recalled but rather, a series of 'slices' containing temporal discontinuities are what constitute an autobiographical memory. If we re-visit the example of the day I graduated from university, I do not recall the entire day from start to finish, I reconstruct key moments such as throwing my cap in the air and shaking the chancellor's hand. I re-experience a whole day in a matter of seconds. When we consider how frequently we re-experience memories that are temporally compressed, the idea that our memories are fallible to error becomes far less surprising. Nevertheless, its reconstructive nature is an intriguing characteristic of autobiographical memory. While it appears to be non-adaptive, it has been theorised that autobiographical memory's reconstructive quality is what allows for another highly important mental function – the ability to imagine our future (Addis, 2018; Conway & Playdell-Pearce, 2000; Schacter & Addis, 2007).

1.3 Episodic future thinking

In 1985, Tulving observed that amnesic patient KC could not imagine the future. The ground-breaking finding was that his semantic memory for the time before his accident was preserved, despite demonstrating completely dysfunctional episodic memory and grossly impaired autonoetic consciousness, which resulted in an inability to imagine the future. This led to Tulving's pioneering idea that episodic memory supports mental time travel into the future, as well as the past (Tulving, 1985, 2002b, 2005). Since then, the term episodic future thinking has been coined to describe the ability to imagine events which might plausibly occur in one's future (Atance and O'Neill, 2001). Episodic future thinking allows us to imagine how potential scenarios in our life might unfold, permitting us to consider whether to perform a given action, or to amend our behaviour accordingly to mitigate potential complications. For instance, I might imagine having a difficult conversation with a family member, envisioning an adverse reaction to certain topics or phrasing. When this conversation subsequently takes place, I am likely to tailor what I say accordingly, due to having previously imagined this scenario. This example demonstrates how the ability to pre-experience the future is an evolutionary process, which facilitates adaptive behaviour in social settings (Suddendorf et al., 2009).

This future-oriented form of mental time travel serves various adaptive functions including decision making, emotion regulation, prospective memory, and navigation (Schacter et al., 2017). For instance, it improves delay discounting (i.e. farsighted options with greater rewards are favoured over nearsighted options with lesser rewards; Benoit et al., 2011; O'Donnell et al., 2017; Peters & Büchel, 2010), can reduce anxiety about worrisome events (i.e. imagining positive outcomes; Jing et al., 2016), increases task fulfilment (i.e. imagining fulfilment of upcoming task; Altgassen et al., 2015; Neroni et al., 2014; Platt et al., 2016), and guides spatial navigation (i.e. planning routes; Arnold et al., 2016; Brown et al., 2016; Horner et al., 2015). It is also important to note that one of the core features of episodic future thinking is its positivity bias. We tend to imagine future scenarios that are more positive than those which we remember (Berntsen & Bohn, 2010; Berntsen & Jacobson, 2008; Rasmussen & Berntsen, 2013; Salgado & Berntsen, 2020). This bias toward more positive outcomes ensures that this future-oriented form of mental time travel facilitates adaptive behaviour. Indeed, in cases of depression where the positivity bias is deficient (Miloyan et al., 2014; Roiser et al., 2011; Strunk & Adler, 2009), key functions such as goal fulfilment are often reduced (Dickson & MacLeod, 2004; Tiberius & DeYoung, 2023).

As with autobiographical memory, episodic future thinking allows one to mentally pre-experience events by integrating multiple sources of information and is too supported by both episodic and semantic systems (D'Argembeau, 2020; Schacter et al., 2012; Szpunar et al., 2014). Interestingly, we engage in mental time travel into the future more frequently than we remember the past (Anderson & McDaniel, 2019; Gardner & Ascoli, 2015). This suggests that this is a core feature of human consciousness. Yet future thinking has been studied far less extensively than its past-oriented counterpart.

1.4 Similarities between autobiographical memory and episodic future thinking

Numerous studies have demonstrated striking cognitive and neural similarities between episodic future thinking and autobiographical memory (Schacter et al., 2012). For instance, future thinking deficits have been repeatedly demonstrated in amnesia (Andelman et al., 2010; Hassabis et al., 2007b; Klein et al., 2005; Race et al., 2011), dementia (Alzheimer's disease; Addis et al., 2009b) and Mild Cognitive Impairment (Gamboz et al., 2010); as well as populations who experience milder forms of memory deficit including depression (Addis et al., 2016), schizophrenia (D'Argembeau et al., 2008), autism (Lind & Bowler, 2010), and post-traumatic stress disorder (Brown et al., 2013) patients. In healthy individuals, descriptions of past and future events are similarly moderated by emotional valence and temporal distance. Positive events have higher self-reported re- or pre-experiencing and temporally close events include more sensory and contextual details than distal ones (Arnold et al., 2011; D'Argembeau et al., 2011; D'Argembeau & Van der Linden, 2004; Trope & Liberman, 2003). Both forms of mental time travel are also comparably moderated by individual differences such as imagery abilities and emotion regulation strategies (Brown et al., 2012; D'Argembeau & Van der Linden, 2006). Finally, both autobiographical memory and episodic future thinking track parallel developmental trajectories, emerging and declining in similar age groups. Both capacities emerge around ages three to five, as demonstrated by the ability to answer questions about one's personal past and future (Suddendorf, 2010). Both processes then wane around age sixty-five, as individuals in this age range generate less episodic detail when describing past and future events (Schacter et al., 2013). Overall, these separate lines of research suggest that remembering the past and imagining the future respond to different variables in similar ways.

The advent of neuroimaging provided especially exciting insights into the mechanisms that support both autobiographical memory and episodic future thinking. In 2007, three studies found that areas traditionally associated with autobiographical memory were also activated when imagining the future (Addis et al., 2007; Hassabis et al., 2007b; Szpunar et al., 2007). *Science* reported this to be one of the top ten discoveries of the year (*Science*, 21 December, 2007, pp. 1848–1849). Since then, a wealth of studies have uncovered a network of brain regions involved in both autobiographical memory and future thinking, including the medial temporal lobes (particularly the hippocampus and parahippocampal cortex), the retrosplenial cortex/posterior cingulate cortex, posterior parietal cortex (particularly the angular gyrus), and the medial prefrontal cortex (Benoit & Schacter, 2015). This literature indicates that the default mode network is similarly engaged when remembering the past and imagining the future (Addis et al., 2007; Okuda et al., 2003; Szpunar et al., 2007) and is now considered the ‘core network’ which supports mental time travel (Benoit & Schacter, 2015). As a highly comparable pattern of brain activation underpins both forms of mental time travel, it has been theorised that the reconstructive nature of memory evolved to allow for future thinking (Conway & Pleydell-Pearce, 2000; Hassabis & Maguire, 2007; Schacter & Addis, 2007). Although the exact mechanism which ties these two processes remains a matter of debate (see section 1.6), there is a consensus that remembering the past and imagining the future are undeniably and inextricably linked.

1.5 Differences between autobiographical memory and episodic future thinking

It is important to note that remembering the past and imagining the future are not without their differences. As the evidence linking the two is so striking, this is often the emphasis in the literature. However, there is also substantial evidence that they are somewhat distinct. Three key differences have been demonstrated in neural activity, phenomenology, and in neuropsychological case studies (see Schacter et al., 2012 for a review) which will each be discussed in this section.

In comparison to remembering the past, imagining the future is associated with increased levels of neural activity, particularly in the hippocampus (Addis et al., 2007; Addis & Schacter, 2008; Addis et al., 2011a; Okuda et al., 2003; Weiler et al., 2010). One study examined this heightened activity in relation to subjective ratings concerning the amount of detail in which events were recollected. It was found that activity in the left anterior hippocampus was selectively associated with the amount of detail in future events (Addis & Schacter, 2008). This suggests that when imagining the future, more detailed events require higher levels of hippocampal activity. This might be due to the novelty of these episodes in comparison to memories – memories are reconstructed from previously experienced events whereas future imaginings require a much higher level of novel details. Not only does this demonstrate differences in the neural activity associated with remembering and imagining, but it alludes to distinct mechanisms between temporalities, which might be due to differing levels of novelty.

While both forms of mental time travel generally engender similar episodic content, past events tend to contain more specific information (Anderson & Dewhurst, 2009) and episodic detail (Addis et al., 2008; Addis et al., 2009a; Addis et al., 2010; Williams et al., 2020), as well as higher self-report ratings for visual and sensory aspects (D'Argembeau & Van der Linden, 2004, 2006). Increases in episodic detail also associate with increased activity in the visual cortices (Addis et al., 2009a) which may be due to the reactivation of the sensory-perceptual context in which the memory was initially perceived (Schacter et al., 2012); a process which would not occur for imagined future events. This highlights a blatant but important difference between remembering the past and imagining the future; past events have already been experienced whereas future scenarios are yet to occur. For autobiographical memories, there is cortical reinstatement of the cognitive processes engaged when the event was initially experienced (Roediger et al., 2002; Rugg et al., 2008). As the details of hypothetical scenarios are constructed from various memories rather than a singular event (Conway & Pleydell-Pearce, 2000; Hassabis & Maguire, 2007; Schacter & Addis, 2007), the same process of cortical reinstatement is unlikely to occur.

Finally, individuals with neuropsychological difficulties are often impaired in one direction of mental time travel but not the other (Schacter et al., 2012). When imagining the future, individuals with prefrontal lesions (Berryhill et al., 2010), Parkinson’s disease (De Vito et al., 2012) and semantic dementia (Duval et al., 2012; Irish et al., 2012a) all generate significantly less episodic detail than controls but perform normally when remembering the past. Conversely, patients with hippocampal damage can generate detailed future events despite experiencing memory deficits (Cooper et al., 2011; Hurley et al., 2011; Maguire et al., 2010; Squire et al., 2010). This dissociation in clinical samples is noteworthy. If there is one common mechanism responsible for both remembering and imagining, similar levels of impairment would be expected. As this is not the case, it is evident that to some degree, distinct mechanisms are driving each form of mental time travel.

While remembering and imagining are undeniably and inextricably linked, research has demonstrated differences between autobiographical memory and episodic future thinking at neural, cognitive, and behavioural levels. Considering these differences, a bidirectional approach will be adopted whereby both directions of mental time travel will be examined within the same sample. This will clarify that any potential differences in temporality are not simply due to sample characteristics or any other arbitrary variables.

1.6 Theories of mental time travel

There is a consensus that autobiographical memory and episodic future thinking are related, as they are similarly deficient in clinical populations, contain comparable episodic content, track the same developmental trajectories, and rely on the same neural network. Yet the exact mechanisms which underpin this linkage remains a matter of debate. Several models (e.g. the constructive episodic simulation hypothesis; Schacter & Addis, 2007; Addis, 2018; the scene construction theory Hassabis & Maguire 2007; the self-memory system; Conway & Pleydell-Pearce, 2000; the semantic scaffolding hypothesis; Irish et al 2012a, 2012b, Irish & Piguet 2013) have attempted to explain this connection, yet there is no prevailing theory. Each of these theories are outlined below.

1.6.1 The constructive episodic simulation hypothesis

One of the notable theories is the constructive episodic simulation hypothesis, developed by Schacter and Addis (2007) to explain the reconstructive nature of memory. As this aspect of recollection results in various errors, this begs the question, what is the evolutionary value of reconstructive memory? Schacter and Addis (2007) argue that reconstruction is adaptive because it allows for imagining the future. They propose that the episodic memory system provides the perfect neurocognitive architecture to flexibly extract and recombine episodic details to imagine future events. This theory postulates that the ability to imagine the future relies on the capacity to remember the past. As the future is not an exact reproduction of the past, aspects of our memories are extracted and recombined to form future events. The constructive episodic simulation hypothesis holds that a highly similar process of reconstruction is involved in autobiographical memory. When both remembering the past and imagining the future, episodic details are extracted from a pool of episodic memories then flexibly recombined to simulate either an event which might happen in the future, or a reconstruction of an event which has happened in our past. While the degree of reconstruction depends on the temporality of the episode, being more heavily reconstructed the more novel the scenario; the same process is assumed to underlie both forms of mental time travel. Recalling a memory involves re-activation of episodic details and relational processing to re-integrate such details into a representation that is re-coded. Whereas when imagining the future, relevant episodic details are activated, recombined, and encoded into a newly constructed event representation (Schacter & Addis, 2007). This common process of 'constructive episodic simulation' is interpreted as the key mechanism responsible for the striking similarities between autobiographical memory and episodic future thinking.

As detailed in section 1.5, there are some notable differences between mental time travel into the past and future. The enhanced hippocampal activity that occurs in future thinking in comparison to autobiographical memory, is interpreted by the constructive episodic simulation hypothesis as reflecting the more extensive constructive processes which occur when we imagine the future (Schacter & Addis, 2007; Schacter et al., 2012). The authors of this theory propose that in future thinking, details from memories are extracted from memories and flexibly recombined into a novel event – a process which would require more novel associations among event details and higher levels of construction than autobiographical memory. This notion was supported by an fMRI study by Addis et al. (2007) which asked participants to press a button when they first generated either a past or future event, and then subsequently engaged in mental elaboration of this event. Activity in the hippocampus was increased for future as compared to past events in both the construction and elaboration phase, but particularly whilst participants were constructing the episode. This finding was taken as support for this theory, as it appears that heightened neural activity is associated with the construction of episodic details.

In further support of the constructive episodic simulation hypothesis, tasks which typically enhance episodic memory have been shown to improve future thinking. For instance, completing an episodic specificity induction, which is designed to enhance episodic retrieval, also boosts performance on future thinking tasks (Jing et al., 2016; 2017; Madore et al., 2014; Madore & Schacter, 2016). During the episodic specificity induction, participants watch a short video and subsequently receive a series of probes. In theory, this encourages the construction of episodically rich events by teaching participants to focus on episodic details during retrieval. Indeed, as compared to various control conditions, receiving the episodic specificity induction has been shown to selectively increase the generation of episodic detail when subsequently asked to describe both past (Madore et al., 2019) and future (Madore et al., 2014; Madore & Schacter, 2016) events prompted by picture cues. Descriptions were scored for both episodic and non-episodic details, but increases were only observed in episodic content. In a further condition, participants were also asked to describe the pictures, rather than use them to prompt a memory or future thought. In this condition, there were no significant increases in episodic content, suggesting that generic processes such as descriptive ability, narrative style, or inhibitory control cannot account for the similarities observed between the past and future conditions (Madore et al., 2014). As both directions of mental time travel are enhanced by this intervention, this supports the idea that future thinking is reliant on the episodic memory system; one of the key notions of the constructive episodic simulation hypothesis.

The other critical idea, that mental time travel relies on constructive recombination, has also been supported by the episodic specificity induction. The authors proposed that if the process of mental time travel is reconstructive, the episodic specificity induction should additionally result in increases in false recall. Indeed, when participants were presented with Deese-Roediger-Mcdermott (DRM; Deese, 1959; Roediger & McDermott, 1995) lists of words, they were more likely to state that a non-studied lure item appeared on the list after having received the episodic specificity induction in comparison to a control condition (Thakral et al., 2019). Overall, this work supports the notion that autobiographical memory and episodic future thinking rely on a common process of constructive episodic retrieval.

Addis (2018) recently proposed an updated theory which argued there should be a shift in emphasis, away from the 'episodic' to the 'constructive' and the 'simulation'. While the 2007 theory suggests that episodic future thinking relies on the episodic memory system, Addis (2018) proposes that both directions of mental time travel rely on one common process: constructive episodic simulation. This theory is based on the notion that memories are not 'special' and that the similarities between autobiographical memory and episodic future thinking are too striking to assume one is reliant on the other. While Addis (2018) acknowledges that remembered and imagined events differ in temporal direction, content

(Addis et al., 2008; Addis et al., 2010), phenomenology (D'Argembeau & Van der Linden, 2004), and veridicality (Schacter & Addis, 2007), she argues that these differences are superficial. Rather, it is emphasised that both are multimodal event representations which are constructed using the same mechanisms. Remembered and imagined events are constructed in the same way within the brain - the default mode network flexibly interacts with regions which represent perceptual content, semantic information, and schemas to construct, encode, and reconstruct mental events. This updated theory suggests that rather than a higher reliance on construction (Schacter & Addis, 2007), heightened activity in the hippocampus and medial prefrontal cortex is due to a higher reliance on schemas during episodic future thinking. Addis (2018) proposes that dependence on schemas exists along a continuum in which remembered events are least reliant and novel projections are most reliant. This means autobiographical memories contain more perceptual details (D'Argembeau & Van der Linden, 2004) which will result in some differences in brain activity, despite engaging in the same 'constructive episodic simulation' process. Therefore, differences in brain activity do not necessarily support the notion that autobiographical memory and episodic future thinking are separable. Addis (2018) proposes that mental time travel relies on the same underlying process, regardless of whether the recounted event takes place in the past or the future.

1.6.2 The scene construction theory

A competing theory has proposed that an alternative mechanism is what ties remembering the past with imagining the future. This theory outlined by Hassabis and Maguire (2007) proposes that scene construction, the process of creating and maintaining complex mental scenes, is what links these two processes. The authors define scene construction as the retrieval of semantic and sensory information, integrated into a coherent spatial context which can be later manipulated and visualised (Hassabis & Maguire, 2007). This theory is based upon the fact that both remembering the past and imagining the future are accompanied by complex mental imagery of an event played out within a spatial context. This model is supported by evidence that scene construction is not limited to autobiographical memory and episodic future thinking. It underlies various functions such as navigation, imagining fictitious experiences, viewer replay, vivid dreaming, and theory of mind (Hassabis & Maguire, 2007). The default mode network is similarly engaged in these disparate functions in addition to mental time travel. Hence Hassabis and Maguire (2007) argue that its key role is to support recollective experience by allowing for the imagination of a coherent scene. Indeed, neuroimaging evidence has demonstrated that when healthy individuals are asked to retrieve fictitious experiences whilst in the scanner, activity is demonstrated in brain regions that are typically engaged in mental time travel: the hippocampus, parahippocampal gyrus, retrosplenial cortex, posterior parietal cortex, ventromedial prefrontal cortex, and middle temporal cortices (Hassabis et al., 2007a). As these regions are activated when imagining fictitious scenes, this suggests their primary function is not temporal, but that they are activated when remembering and imagining to construct a coherent scene. This supports the notion that scene construction is the common mechanism linking mental time travel into the past and future, as well as several other atemporal processes.

Support for the scene construction theory has largely come from amnesic patients with bilateral hippocampal damage. One study asked participants to imagine new experiences which were not temporal, self-relevant, or plausible in response to verbal cues outlining commonplace scenarios (Hassabis et al., 2007b). In comparison to healthy controls, amnesic patients outlined descriptions that were strikingly deficient in spatial coherence, contained less detail and were more fragmented. As deficits in spatial coherence were particularly marked, the authors proposed that this is the critical mechanism of the hippocampus during mental time travel, and that a lack of richness and fragmented descriptions stem from this disruption. Therefore, the hippocampus supports scene construction through its ability to process spatial information which in turn, supports mental time travel by allowing for imagination of a coherent scene within a spatial context (Hassabis et al., 2007a). This theory proposes that the primary role of the hippocampus is not mnemonic, but mnemonic processing is supported by the hippocampus due to its core function being scene construction, which is critical for mental time travel. The notion that the hippocampus enables scene construction has received support from the neuroimaging literature, as a review of fMRI studies indicated that this region is critical for complex spatial navigation and is specifically important for the discrimination of complex scenes (Lee et al., 2012). The authors have taken this as supporting evidence as it suggests that the hippocampus, an area that is critical for mental time travel (Buckner, 2009; Schacter & Addis, 2009), appears to be a key mechanism for scene construction.

Research into the boundary extension effect has provided further support for the theory that the hippocampus enables scenes construction. Boundary extension is a normally occurring process whereby people remember seeing more of a scene than they did, because they have elaborated beyond the borders of the original stimulus. Mulllaly et al. (2012) found that across three independent measures, patients with selective bilateral hippocampal damage had significantly impaired boundary extension relative to healthy matched controls. This suggests that damage to the hippocampus results in a reduced capacity to envision scenes beyond physical input, demonstrating the mechanism by which the hippocampus supports scene construction. Chadwick et al. (2013) provided further insight into the mechanism supporting this process, by using fMRI in healthy controls. They found that the boundary extension effect occurred soon after scenes were viewed, and that this effect was associated with activity in the hippocampus and parahippocampal cortex. Using connectivity analysis, they also found that the hippocampus exerted a top-down influence on the parahippocampal cortex as well as other regions such as the visual cortex, suggesting that the hippocampus was driving the boundary extension effect.

Taken together, these studies led Maguire and Mulllaly's (2013) to hypothesise that the hippocampus is automatically and implicitly constructing scenes all the time. It is not only involved in processing what you see but it is also constructing what you cannot see. This aligns with the scene construction theory, as it supports the idea that the primary role of the hippocampus is not purely mnemonic. Memory impairments in patients with hippocampal damage are regarded as by-products of spatial processing deficits – as these individuals are unable to visualise what is outside of their immediate view, they have problems with mental time travel, as well as spatial navigation and imagining fictional scenes (Maguire & Mullally, 2013). Overall, the scene construction theory proposes that for the hippocampus, the construction of scenes is critical (Hassabis & Maguire, 2007; Maguire & Mullally, 2013). As both past and future events are recounted within a scene template, which is automatically and implicitly provided by the hippocampus, this is thought to explain the commonalities between remembering the past and imagining the future.

1.6.3 The self-memory system

Other theoretical perspectives have emphasised different factors. Conway and colleagues proposed the theory that an individual's sense of self is the critical component of mental time travel. This theory is known as the self-memory system (Conway & Pleydell-Pearce, 2000). The key principle of this theory is that mental time travel and goals of the self are closely and reciprocally linked (Conway et al., 2019; Conway & Pleydell-Pearce, 2000). The self-memory system assumes that representations of both the past and future are constructed from the same knowledge structures, containing a combination of autobiographical knowledge and ideas about the self (Conway et al., 2019). Specifically, mental time travel is supported by three types of knowledge structure which flexibly interact with one another: i) the conceptual self which contains abstract representations of the past, present, and possible future selves, ii) the autobiographical knowledge base containing life story schema, which are hierarchically organised into lifetime periods, general events, and event-specific knowledge, and iii) a pool of episodic details used for generating specific memories and future representations (Conway et al., 2019). As in the constructive episodic simulation hypothesis, the self-memory system offers an interpretation on why autobiographical memory is reconstructive in nature.

Conway and colleagues propose that the primary function of the self-memory system is to combine autobiographical knowledge into representations that are compatible with the current goals of the working self (Conway & Pleydell-Pearce, 2000; Conway et al., 2019). Based on goal compatibility, the self-memory system determines what knowledge will or will not be used to construct an autobiographical memory or future thought, and knowledge which is inconsistent with one's goals may be inaccessible or distorted. This has been supported by several case studies in which individuals with frontal lobe damage have demonstrated confabulations which are more positively biased than their reality (Conway & Tacchi, 1996; see Conway & Pleydell-Pearce, 2000 for an overview). Conway and colleagues suggest that these confabulations are based on false memories. These false memories have been generated in the self-memory system in order to maintain a cohesive relationship between the working self and representations of the past (Conway & Pleydell-Pearce, 2000; Conway et al., 2019). Furthermore, the goals of the working self are also informed by autobiographical knowledge. For example, if I can recall having a successful career then I may have a goal to receive a promotion. If I can recall several episodes of unsuccess and career setbacks however, then it is unlikely that I will have the same goal. Conway proposes that if the latter were to occur, this contradiction between one's goals and their autobiographical knowledge would suggest a breakdown in the normal functioning of the self-memory system, as autobiographical knowledge constrains the goals of the working self.

In support of this theory, if we consider cases in which mental time travel is impaired, its role in establishing one's self concept is overwhelmingly clear. It is commonly known that individuals with severe memory impairments, such as amnesia and dementia, experience uncertainty about their sense of self and who they once were, as a result of not being able to remember their past (Buñuel, 2011; Squire and Kandel, 2003; Tulving, 1983). The clinical literature has also supported the notion that this relationship is reciprocal, as disruptions to the self can also lead to impairments in mental time travel. Mental time travel deficits are commonly observed in schizophrenia (Berna et al., 2016; Hallford et al., 2018; Ricarte et al., 2017; Zhang et al., 2019), a disorder characterised by a distorted sense of self (D'Argembeau et al., 2008; Frith & Done, 1989). This supports the fundamental notion of the self-memory system; that mental time travel is reciprocally related to the conceptual understanding of the self (Conway, 1996, 2005, 2009; Conway et al., 2005 Conway & Pleydell-Pearce, 2000).

1.6.4 The semantic scaffolding hypothesis

While the theories discussed thus far have focused on mechanisms which are consistent in both forms of mental time travel, other theories focus on the cognitive architecture which distinguishes these processes. Irish, Piguet and colleagues (2012a, 2012b, 2013) proposed the semantic scaffolding hypothesis, which postulates that in comparison to autobiographical memory, episodic future thinking is more reliant on semantic memory, as imagining a novel occurrence is more dependent on general knowledge. This theory is based upon the observation that individuals with semantic dementia, a neurodegenerative disease characterised by impaired semantic memory and intact episodic memory (Hodges & Patterson, 2007; Pick, 1892), demonstrated greater impairment in tasks which required mental time travel into the future. For instance, the authors conducted several studies using an adapted version of the autobiographical interview (Levine et al., 2002; see section 1.7.1

for a full description of this measure) in which autobiographical events are recalled and scored for episodic and non-episodic details (Irish et al., 2012a; Irish et al., 2012b; Irish & Piguet, 2013). They found that semantic dementia patients demonstrated higher levels of impairment in the future condition as they generated more non-episodic details which were related to recent or repeated events, and unrelated to the event prompted by the experimenter (Irish & Piguet, 2013). Despite explicit instructions to describe an event which was novel, most of the future events generated by semantic dementia patients were reproductions of previously experienced events (Irish et al., 2012a). The authors speculated that the semantic dementia participants did this to compensate for their deficits in semantic memory, which is necessary for imagining an episode in the future. This led to the conclusion that the episodic memory system is not sufficient for episodic future thinking and that for mental time travel into the future, semantic memory is critical.

1.6.5 A brief note on the similarities and differences between theories of mental time travel

As there is no prevailing theory, it is important to highlight some of the similarities and differences between these different models of mental time travel. A distinguishing notion of the original constructive episodic simulation hypothesis (Schacter & Addis, 2007) is that the ability to envision the future is dependent on the episodic memory system. On the contrary, Addis' (2018) updated model, the scene construction theory (Hassabis & Maguire, 2007), and the self-memory system (Conway & Pleydell-Pearce, 2000) propose that both forms of mental time travel rely on one common mechanism. Hassabis and Maguire (2007) argue that this mechanism is scene construction, Addis (2018) maintains that it is constructive simulation, and Conway and colleagues (Conway & Pleydell-Pearce, 2000; Conway et al., 2019) propose it to be the self. Akin to the latter theories, the semantic scaffolding hypothesis (Irish & Piguet, 2012a, 2012b, 2013) suggests that the episodic memory system is not sufficient for mental time travel. In contrast, this model focuses on what distinguishes past- and future-oriented mental time travel as opposed to their linkage: their different levels of dependence on the semantic memory system. While there is disagreement on whether future thinking relies on the episodic memory system and what the exact linking mechanism is, there is agreement amongst all the theories described in terms of the constructive element of mental time travel.

1.7 Measures of mental time travel

Due to its multi-faceted and subjective nature, measuring mental time travel is challenging. Traditional measures of episodic memory include procedures such as recognition tests, questionnaires, the remember-know procedure, and inducing or prompting memories in the laboratory (Dere et al., 2008). More specifically, assessments of mental time travel tend to fall under two broad categories: 'objective' measures which are scored by the experimenter and 'subjective' measures that are scored by the participant. While various types of objective measure exist (e.g. retrieval success and precision; Richter et al., 2016; fluency tasks; Coste et al., 2015; MacLeod et al., 1993; MacLeod et al., 1998; response times; D'Argembeau & Van der Linden, 2004; sentence completion tasks; Anderson & Dewhurst, 2009; Raes et al., 2007), here, the term objective is used to refer to scoring procedures which allow the experimenter to code the participant's descriptions of autobiographical events, according to dimensions including their content (Hassabis et al., 2007b; Levine et al., 2002) and specificity (Williams & Broadbent, 1986). Conversely, the term subjective will be used to refer to questionnaires and rating scales which allow the participant to rate their subjective experience of mental time travel. This section will discuss measures belonging to both categories which are frequently employed in the literature.

1.7.1 Objective measures of mental time travel

Before objective scoring can take place, memories or future occurrences must be elicited by the experimenter. While several paradigms exist, the cuing method is perhaps the most widely used paradigm in the autobiographical memory field. Initially created by Galton (1879) and later developed by Crovitz and Schiffman (1974) to test episodic memory, the cuing method uses cues to prompt retrieval of personal autobiographical memories. Whilst most of the research has used words as cues for autobiographical recall, other stimuli such as odors, pictures, and sounds have also been employed (Berntsen et al., 2013; Chu & Downes, 2000; Herz & Cupchik, 1992). In any case, participants are presented with a series of cues and asked to discuss specific autobiographical memories in response to each cue. Typically, memories must not exceed 24 hours and should be specific in time and place. More recently, the cuing method has been modified in order to assess episodic future thinking (Addis et al., 2008; Addis et al., 2016; Brown et al., 2013; Maccallum & Bryant, 2011; Raffard et al., 2013). In these modified paradigms, the procedures remain largely similar but rather than or in addition to describing previous experiences, participants are asked to imagine and discuss hypothetical events which could be personally experienced in one's future. Several versions of the cuing procedure and their respective scoring systems are discussed.

One of the most prevalent ways of objectively scoring is to code the specificity of autobiographical events, which is commonly assessed using either the Autobiographical Memory Test (Williams & Broadbent, 1986) or the Autobiographical Memory Interview (Kopelman et al., 1989). These measures assess whether the participant can generate specific memories, or conversely, if their memory is overgeneral. In the Autobiographical Memory Test, participants are presented with cue words or phrases and in the Autobiographical Memory Interview they are given several life periods (childhood, early adulthood, and recent information; Kopelman et al., 1989). The Autobiographical Memory Test measures the presence or absence of specific events while the Autobiographical Memory Interview scores specificity on a scale of zero to three (Williams & Broadbent, 1986). Whilst both the Autobiographical Memory Test and Autobiographical Memory Interview were initially developed to measure memory specificity, the Autobiographical Memory Test was later adapted to examine episodic future thinking (Williams et al., 1996). In both past and future versions of the task, this scoring system differentiates between specific (events which occurred at a particular time and place and last no longer than one day), extended (events which last longer than one day), and categoric (thematic summaries of events) events (Williams & Broadbent, 1986; Williams et al., 1996). Although both tests have produced greatly influential findings, measuring autobiographical specificity has two key limitations. First, the distinction between episodic and semantic memory is not addressed in either measure of specificity, even though research has demonstrated the key role of this to autobiographical memory (Renoult & Rugg, 2020; Tulving, 1972). Second, despite being a multi-faceted construct, events are only differentiated in terms of how specific they are. Important aspects of autobiographical memory such as episodic detail and content are not considered when scoring for specificity.

The Autobiographical Interview (AI; Levine et al., 2002) is considered the gold standard instrument as it can be used to objectively quantify the amount and type of detail generated in autobiographical memories. In the traditional AI paradigm, participants are asked to recall memories from different life periods which are specific in time and place, whilst also being audio recorded. Typically, five life periods are required: early childhood (up to age 11), adolescent-teenage years (ages 11-17), early adulthood (ages 18-35), middle ages (ages 35-55), and the previous year. The original protocol outlined three stages: recall, general probe, and specific probe (Levine et al., 2002). In the first stage, participants are instructed to recall and describe events in as much detail as possible, without any interruption from the experimenter. In the second stage, general probes are used to clarify instructions and to encourage participants to focus on a single event if they have only provided non-specific statements (e.g. "Is there anything else you can tell me?"). At this stage, no general probes are required if the participant provides a detailed account of an event which references a specific time and place. Once recall and general probe conditions are completed for all five events, specific probes are administered. The specific probes form a structured interview that was adapted from the Memory Characteristics Questionnaire (Johnson et al., 1988). They are designed to elicit specific details which are organised into five categories: event, time, time integration, place, sensory information, and emotion/thought. Each category is assessed using a standardised question which is modified according to the event.

Addis et al. (2008) later adapted the AI to examine age-related differences in episodic future thinking. Adapted from Crovitz and Schiffman's (1974) procedure, the modified AI is a semi-structured interview which presents participants with various cue words or specific time periods as the basis for retrieving past events and imagining future events. Subsequent studies have used different cues such as images, sentences, autocues, or combinations of multiple cues (e.g. the experimental recombination paradigm; Addis et al., 2010), but it is common practice to use cue words. Like the standard AI, participants are asked to recall or imagine episodes lasting no longer than 24 hours and occurring in a specific spatiotemporal context. The original version developed by Addis and colleagues provided participants three minutes to describe each event (Addis et al., 2008), but subsequent studies have used various time limits as well as no time limit at all (e.g. Benoit et al., 2016; Cole et al., 2012; Lapp & Spaniol, 2017; Madore & Schacter, 2016). If insufficient detail is provided, the experimenter can use either general or specific probes to elicit more information. This adapted version is now commonly used over the traditional version of the AI as it allows for examination of past and future events using identical procedures and has less time constraints by reducing the number of probes.

Following both the AI and adapted AI interview procedures, responses are transcribed in preparation for scoring. Subsequently, responses are segmented into distinct sections to allow the experimenter to score for internal (episodic details related to the main event; Levine et al., 2002) and external (details unrelated to the main event; Levine et al., 2002) details. Details are typically grammatical clauses referencing a unique occurrence, observation or thought, which are then categorised by the experimenter as either internal or external. Internal details describe the episodic content such as what happened, who was there, and the time and place of the event (see Figure 2 for description of the scoring categories). Internal details can also be subcategorised into event (e.g. happenings and occurrences, people and objects present), time (e.g. times, dates, days, seasons), place (e.g. countries, cities, rooms, areas within a room), perceptual (e.g. auditory, olfactory, tactile, taste, and visual information), and emotion/thought (e.g. feelings and thoughts) details. External details are generally non-episodic and comprise semantic details and information that is repeated or tangential to the main event. External details can also be divided into external event, semantic, repetitions, or other subcategories (see Figure 2). In order to reduce the subjectivity of scoring, any detail which could be considered episodic should be scored as internal (i.e. the benefit of the doubt rule; Levine et al., 2002) and in the case of a participant describing more than one autobiographical event, the event that was described in most detail is considered the main event. This scoring system has been used in over two hundred studies and has reliably detected memory deficits in patients with medial temporal lobe damage (Addis et al., 2007; Miller et al., 2020; St-Laurent et al., 2009), mild cognitive impairment (Murphy et al., 2008), Alzheimer's disease (Irish et al., 2011), and depression (Söderlund et al., 2014). Psychometric evaluation of the AI scoring has also demonstrated high inter-rater reliability, replicable age effects, robust internal consistency across timepoints, and positive correlations with standard, performance-based episodic memory tasks (Lockrow et al., 2023). This suggests the AI presents a highly reliable and robust measure which can be used to examine the multi-faceted phenomena of mental time travel.

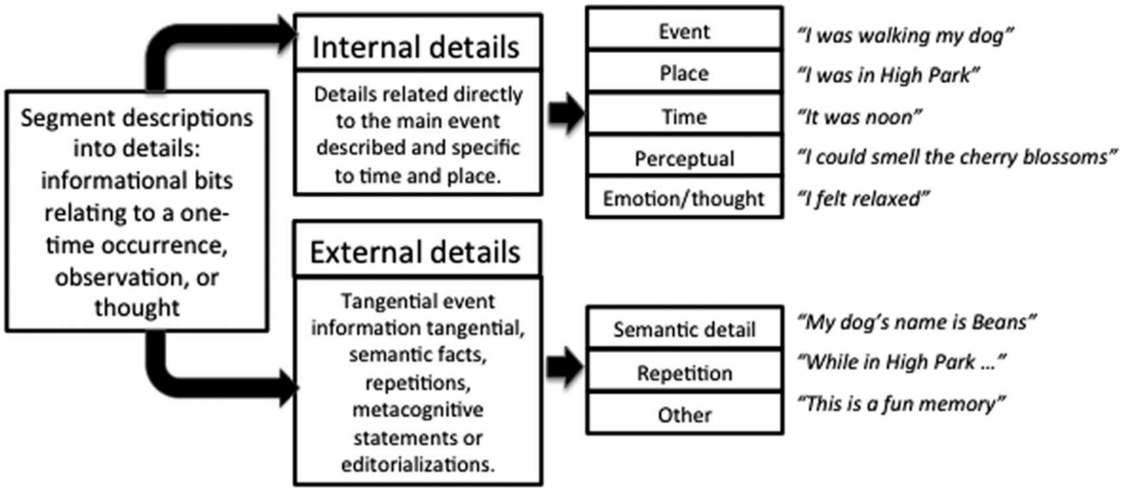


Figure 2. Description of the AI scoring subcategories taken from Sheldon and Levine (2016).

The scene construction task (Hassabis et al., 2007b) is often used as an alternative to the AI as it is also considered a measure of episodic content. During the scene construction task, participants are presented with various scenarios (e.g. 'Imagine you're lying on a white sandy beach in a tropical bay'; Hassabis et al., 2007b) and asked to imagine and describe each scenario in as much detail as possible before receiving general probes. These descriptions are recorded and then later transcribed for scoring. The event descriptions are scored using the Experiential Index, a composite score of the richness of the imagined experience (Hassabis et al., 2007b). The Experiential Index ranges from 1 ("not experienced at all") to 60 ("extremely richly experienced") and is comprised of four subscales. The first subscale reflects the content of the imagined event. Alike the AI, the content score is calculated by segmenting the event description into a set of statements before categorising them as either a spatial reference, entity presence, sensory description, or thought/emotion/action. Unlike the AI, any statement which does not fall under one of these subcategories is discarded and the maximum score for all content subcategories is 7 (overall maximum score of 28).

The second component of the Experiential Index is the participant's subjective sense of presence and perceived salience of the imagined event, which is rated by the participant on two 5-point scales. Each of these ratings contributes to the overall composite score. The third subscale refers to the quality of the event construction, which is determined by the extent to which the participant's description evoked a sense of experiencing for the experimenter. This is scored on a 11-point scale (0= no picture at all, 10= vivid, extremely rich picture). The final component, the spatial coherence index, is comprised of eight statements which describe the integration and contiguity of the scene (e.g. "I could see the whole scene in my mind's eye") and four statements which describe fragmentation (e.g. "It was a collection of separate images"). Participants can select as many or as few statements that they feel are applicable and gain one point for each integration/contiguity statement and lose one point for each fragmentation statement. Only positive spatial coherence ratings are included in the Experiential Index. Each subscale is then rescaled in the final calculation of the Experiential Index to weight each aspect appropriately. The content component is given the highest weighting (~50%), the quality of event construction is the second highest (~30%), and the two participant rated subscales carry the least weight (sense of presence and perceived salience carries ~7% and the spatial coherence index carries ~10%).

The Experiential Index is a reliable measure which has been used in numerous studies across various populations (Hassabis & Maguire, 2007; Hill & Emery, 2013; Hurley et al., 2011; Lind et al., 2013; Lind et al., 2014; Maguire et al., 2010; Rendell et al., 2012; Squire et al., 2010; Zeman et al., 2018). However, the Experiential Index is a composite score of experimenter-scored and participant-scored measures which each relate to different aspects of imagined experience. Because one of the key aims of the thesis is to separate subjective and objective components of mental time travel, it is fundamental that the objective measure is scored by the experimenter only. As objective content can be assessed readily and reliably using the AI and adapted AI procedures, this scoring protocol will be employed as the objective measurement in this thesis.

1.7.2 Subjective measures of mental time travel

Due to its subjective quality, it is common practice to employ self-report measures to assess mental time travel. These measures tend to be either event-based (e.g. the Memory Experiences Questionnaire; Sutin & Robins, 2007; the Assessment of the Phenomenology of Autobiographical Memory; Vannucci et al., 2020; Memory Characteristics Questionnaire; Johnson et al., 1988; Autobiographical Memory Questionnaire; Rubin et al., 2003, Autobiographical Memory Characteristics Questionnaire; Boyacioglu & Akfirat, 2015) or trait-based (e.g. The Autobiographical Recollection Test; Berntsen et al., 2019; The Survey of Autobiographical Memory; Palombo et al., 2013). Event-based measures assess the phenomenology of particular events (e.g. 'My memory for this event involves visual detail'; Vannucci et al., 2020) whereas trait-based measures assess everyday mnemonic abilities (e.g. 'specific events are difficult for me to recall'; Palombo et al., 2013). Both types of subjective measure are discussed.

1.7.2.1 Event-based subjective measures of mental time travel

Event-based subjective measures require participants to rate their subjective experience of autobiographical events. These ratings refer to phenomenological characteristics which are to be assessed according to a multiple point Likert scale (Miloyan & McFarlane, 2019). For instance, if the participant is required to rate the vividness of the event, the top score might have the label 'extremely vivid' whereas the bottom score might be labelled 'not at all vivid'. Although this is the most common form of subjective rating, some measures provide binary response options. If the participant is to rate whether they experienced the episode from either an observer or field perspective for example, they might only be provided with two options. Numerous phenomenological properties have been researched using this method, such as how vividly the event is experienced, specific episodic details, the feeling of re-living or pre-living, the perspective in which it was perceived, emotional aspects, as well as several other important characteristics (e.g. coherence, accessibility, rehearsal, specificity, personal importance, confidence; Miloyan & McFarlane, 2019; Vannucci et al., 2020). Vividness ratings (e.g. vividness, clarity, richness) relate to the clarity of the recollection, and is compared to the experience of actual perception, as if that event were happening in that moment (D'Angiulli et al., 2013). Ratings of episodic details relate to specific categories of episodic content, which might refer to information taken in through certain senses (e.g. visual, sound, smell, touch, taste) or other details such as objects and people present, as well as spatiotemporal information. Re- and pre-living ratings assess the subjective experience of travelling backward or forward in time. These ratings may refer to re-living as a general feeling (e.g. re-/pre-living, autonoetic consciousness, sense of presence) but can also measure certain aspects of this experience (e.g. sensory re-living, auditory re-living, visual re-living, spatial re-living). Perspective ratings ask whether the episode was experienced from a first-person or third-person perspective, as this has shown to vary between individuals (see Simons et al., 2022 and Zaman & Russell, 2022 for reviews). Finally, emotional ratings vary from the level of arousal evoked by the event, the emotional intensity in which it was experienced, and whether it was perceived as positive or negative. Such ratings are commonly employed in studies of mental time travel to measure a large variety of subjective experiences (Miloyan & McFarlane, 2019).

These rating scales are often derived or adapted from measures including the Memory Characteristics Questionnaire (MCQ; Johnson et al., 1988), the Memory Experiences Questionnaire (MEQ; Sutin & Robins, 2007), the Autobiographical Memory Questionnaire (AMQ; Rubin et al., 2003), the Autobiographical Memory Characteristics Questionnaire (AMCQ; Boyacioglu & Akfirat, 2015), and the Autobiographical Characteristics Questionnaire (ACQ; Berntsen and Jacobsen, 2008). As there is considerable overlap in the characteristics assessed across these questionnaires, the Assessment of the Phenomenology of Autobiographical Memory (APAM; Vannucci et al., 2020) was developed by Vannucci and colleagues to provide an inclusive measure of phenomenological characteristics. The APAM combines the questions from the MCQ, MEQ, AMQ, and ACQ into a 27-item questionnaire, where each item relates to a distinct phenomenological property. This covers a much larger range of characteristics than the measures mentioned above. In the original validation study of the APAM, participants were asked to come up with autobiographical memories in response to 12 different cue words, then to rate each memory according to the APAM. The participant's scores for a single phenomenological property were calculated by averaging the scores across all 12 memories. Each of the 27 items showed adequate levels of internal consistency and unidimensionality across multiple and diverse cues. This suggests that the APAM measures the same properties of autobiographical memory regardless of the cue administered, leading the authors to the conclusion that the phenomenology of autobiographical memory is a stable characteristic that can be reliably assessed using the APAM. Furthermore, Vannucci and colleagues later developed a web-based version of the APAM which replicated the psychometric properties of the paper-and-pencil version (Vannucci et al., 2021). All 27 items showed high internal consistency across various cue words and time points (i.e. across a period of 7-10 days). Not only does this validate the web-based version of the APAM, but it also demonstrates that the measurement is consistent over time. This provides further support for the APAM as a measure of the phenomenology of autobiographical memory. To summarise, the APAM is a comprehensive measure of phenomenological characteristics and is reliable, regardless of whether it is implemented in-person or online.

1.7.2.2 Trait-based subjective measures of mental time travel

Following the discovery of vast individual differences in autobiographical memory (see section 1.8), The Survey of Autobiographical Memory (SAM; Palombo et al., 2013) was developed to assess mnemonic traits. Contrary to the event-based ratings described above, the SAM explicitly states: "When answering, don't think about just one event; rather, think about your general ability to remember specific events". The full SAM is a 26-item self-report questionnaire comprised of four dimensions: episodic autobiographical memory, semantic memory, spatial memory, and future thinking (Palombo et al., 2013). These are rated on a five-point Likert scale from strongly disagree to strongly agree. The SAM is divided into four subcategories, referring to a participant's self-reported capacity for episodic (8 items; e.g. "Specific events are difficult for me to recall"), semantic (6 items; "I can learn facts easily, even if I don't remember where I learned them"), and spatial memory (6 items; "In general, my ability to navigate is better than most of my family/friends"), as well as their ability to imagine future events (6 items; "When I imagine an event in the future, the event generates vivid mental images that are specific in time and place"). Distinct from performance-based measures which assess the characteristics of specific events, the SAM subscales measure an individual's everyday mnemonic abilities. Validation analyses of the SAM have supported the factor structure of the spatial memory and future thinking dimensions and replicated expected dissociations between episodic and semantic dimensions, as well as expected gender differences in spatial memory (Palombo et al., 2013). This suggests that the SAM can provide insightful information on naturalistic, everyday mental time travel and how this relates to other individual differences. There are also some limitations of the SAM which will be discussed in Chapter 4.

Another measure of individual differences is The Autobiographical Recollection Test (ART; Berntsen et al., 2019). The ART measures seven trait-based properties of autobiographical memory: reliving, vividness, visual imagery, scene, narrative coherence, life story relevance, and rehearsal. Each of the seven subcategories are assessed by three items, designed to reflect the conceptual breadth of each component (e.g. vividness: "My memories for past events have lots of details"; "My memories of past events are vivid"; "My memories of past events are clear, not fuzzy, or clouded"; Bentsen et al., 2019). Each of the items were either adapted from the AMQ (Rubin et al., 2003) or MCQ (Johnson et al., 1988), or inspired by research on involuntary memory, flashbulb memory, narrative identity, narrative coherence, autobiographical memory in clinical disorders, and neuropsychological studies on imagery and scene construction (Berntsen et al., 2019). The authors devised the full 21-item scale as well as the 'brief ART' which is comprised of seven items (one relating to each dimension). In the original validation study of the ART, both scales demonstrated a high degree of test-retest reliability for a period of up to five weeks (Berntsen et al., 2019). In addition, each of the seven subcategories were demonstrated to be separable but highly correlated. This suggests that they are attributable to one underlying factor – autobiographical memory.

While both the ART and the SAM assess individual differences in trait mnemonics, the ART is a unified measure of autobiographical memory and the SAM assesses individual differences in different domains (i.e. autobiographical memory, episodic future thinking, semantic memory, and spatial memory). Both the full and brief versions of the ART correlate with all four SAM subscales, but particularly the SAM episodic subscale (Berntsen et al., 2019; Ece et al., 2023) and all seven subcategories show similar correlational patterns. This suggests that these measures are assessing similar constructs. However, the ART is designed to measure one form of mental time travel whereas the SAM covers both past and future domains. As it is critical that a bidirectional approach is adopted in thesis, the SAM will be adopted when examining trait-based abilities.

1.7.3 The relationship between subjective and objective measures of mental time travel

Despite the widespread and inter-changeable use of both objective and subjective measures, very little is known about the relationship between these different types of assessment. The degree to which subjective experiences map on to objective content has been examined predominantly in three ways: i) neuroimaging studies, ii) neuropsychological case studies, and iii) in ageing. As discussed in section 1.4, many studies have uncovered a network of brain regions involved in episodic retrieval. Although there are overlapping brain regions and networks associated with subjective versus objective recollection, they also associate with distinct areas (Fandakova et al., 2021; Richter et al., 2016; Simons et al., 2022; Spaniol et al., 2009; Thakral et al., 2020). Furthermore, neuropsychological case studies have demonstrated disjunctions at the behavioural level. For instance, individuals with lesions to the posterior parietal cortex demonstrate an intact ability to objectively recollect contextual details of past experiences but impairments in the subjective state of remembering (Ciaramelli et al., 2010, 2017; Davidson et al., 2008; Hower et al., 2014; Simons et al., 2010). Finally, research in ageing populations has shown that in comparison to younger adults, older adults display significantly reduced objective memory performance but have similar or even higher ratings on subjective memory indices (Addis et al., 2010; Addis et al., 2011b; Duarte et al., 2008; Folville et al., 2021; Mark and Rugg, 1998). Collectively, these separate lines of research indicate that while there is a 'core' episodic memory network, certain regions appear to be differentially implicated in subjective versus objective retrieval, and these abilities dissociate in ageing.

From the work reviewed above it is clear there are separable aspects of subjective experience and objective recollection, but it might still be anticipated that in healthy young volunteers there is some degree of correlation between them. This was examined by Herrman (1982) in a review of the relationship between a broad range of memory questionnaires and performance on laboratory-based episodic memory tasks. Although the questionnaires were reliable, the relationships ranged from not statistically significant to moderate magnitude. It should be noted that this study, as well as other research which has examined this relationship, employed laboratory-based tasks to measure episodic memory rather than the scoring systems detailed above which assess autobiographical memory. These assessments can be limited in response options, with many tasks only having binary responses such as whether the participant was able to correctly recover a particular piece of contextual detail or not (although see Harlow & Donaldson, 2013 and Richter et al., 2016 for continuous measures of retrieval precision). This thesis explores an alternative approach and will examine autobiographical rather than episodic memory. Both the AI scoring (Levine et al., 2002) and subjective measures of mental time travel will be explored, thus allowing for the multi-faceted nature of mental time travel.

Several studies have examined the relationship between the AI and self-report questionnaires related to autobiographical memory. For example, in a sample of 217 healthy young participants, Clark and Maguire (2020) administered the AI, where participants were asked to recall and describe autobiographical memories from four specific time periods, as well as a battery of questionnaires on memory abilities (Survey of Autobiographical Memory, Palombo et al., 2013; Memory Experience Questionnaire, Sutin & Robins, 2007; and Subjective Memory Questionnaire; Bennett-Levy & Powell, 1980). Contrary to expectations, they did not find any significant correlations between the internal details scored by the experimenter and any of the questionnaires or their subdimensions. This suggests that subjective and objective measures are tapping into different aspects of mental time travel. There are also other studies which have not found significant relationships between internal details on the AI and the SAM (Palombo et al., 2013; Setton et al., 2021 although see Armson et al., 2021 for an exception).

The research discussed thus far has examined the relationship between trait-based questionnaires and internal details on the AI. In healthy participants there is not a great deal of research which has examined the link between event-based ratings and internal details for past events, and that which has been conducted is mixed. Clark and Maguire (2020) did not find a significant relationship with vividness ratings in their sample, but Lockrow et al (2023) did in theirs. This is potentially surprising given that it is generally thought that there will be a relationship between the vividness of recalled autobiographical episodes and the number of internal details (e.g. Moscovitch et al., 2016).

There has also been very little research looking at the correspondence between objective performance in imagining future events and participants' subjective experiences of them. Clark and Maguire (2020) used the scene construction task and its Experiential Index scoring procedure to examine this relationship. They found a weak positive relationship between the Experiential Index and SAM future scores, but this did not survive correction. Also as noted in section 1.7.1, the Experiential Index is composed of objective and subjective assessments. Rather than assessing the relationship with trait-based questionnaires, Thakral et al. (2020) examined the relationship between the AI and vividness ratings in a group of young healthy volunteers. These participants were placed in an MRI scanner and asked to imagine future events in response to cues, then on each trial were asked to assess the vividness of the construction. Outside the scanner, participants reported what they had thought about in the scanner and these narratives were scored using the AI (Levine et al., 2002). On an individual participant basis, correlations were completed between vividness ratings and internal details for that event. Across participants, it was found that these correlations were significantly greater than zero. This provides some preliminary evidence that there is a relationship between an experimenter-scored index and the participant's subjective experience, when thinking about personal events in the future.

From the literature reviewed above, the exact relationship between subjective experiences and objective content is obscure. The memory research has tended to focus on subjective measures that are trait-based and in episodic future thinking, the subjective-objective relationship has received little empirical evaluation. Whether these measures correspond is a key question for the mental time travel literature, as the presence or absence of a positive relationship will provide valuable insight into the constructs each measure is assessing. As this question cannot be answered by the present literature, it will be addressed in this thesis.

1.8 Individual differences in mental time travel

The notion that autonoetic consciousness varies between individuals was critical to Tulving's (1985) conceptualisation of mental time travel. This theory has remained prominent - the idea that we differ in our ability to remember is a commonly held view amongst researchers (Dafni-Merom & Arzy, 2020) as well as the general population. It has been proposed that autobiographical memory is a 'trait' in which the way people remember differs between individuals yet remains relatively stable within them, when tested across different tasks and time periods (Palombo et al., 2013; Palombo et al., 2018; Sheldon et al., 2016). This theoretical perspective aligns with the wider literature which shows that cognitive processes such as executive control (Kane & Engle, 2002; Miyake & Friedman, 2012) and working memory (Daneman & Carpenter, 1980; Unsworth & Engle, 2007) are capacities which differ between participants but are consistent within the individual across time. Autobiographical remembering, as measured by the SAM, has also been shown to associate with a distinct pattern of medial temporal connectivity to posterior regions supporting visual-perceptual processing (Sheldon et al., 2016). This suggests that individual differences in mental time travel are accompanied by neural variabilities, indicating that those with an enhanced capacity to remember are better able to access and construct detailed images of a past occurrence. However, intra- and inter-individual differences are often not distinguished in the literature, with evidence for stability within and variability between individuals both being labelled as support for 'individual differences' (e.g. Palombo et al., 2018). To clarify, inter-individual differences reflect variability between people, whereas intra-individual differences are changes found in the same person when tested across different timepoints and contexts (Beckmann et al., 2020). Here, the evidence for intra- and inter-individual differences are reviewed separately.

1.8.1 Intra-individual differences in mental time travel

The commonly accepted view that autobiographical memory is a trait (Palombo et al., 2013; Palombo et al., 2018; Sheldon et al., 2016) presupposes that mental time travel is stable. Yet memories from our personal past can differ in the ways in which we experience them. Some memories can be extremely vivid, containing specific and rich contextual information so detailed that when remembering, it can almost feel as if we are reliving them. Other memories can lack clarity and seem dim, with a paucity of sensory details which leads us to question the recollection and be unconfident in the particulars. Yet the efficacy of trait-based measures (e.g. the Survey of Autobiographical Memory; Palombo et al., 2013; the Autobiographical Recollection Test; Berntsen et al., 2019) which ask the participant to assess their general abilities, are reliant on the assumption that there is little variation between autobiographical episodes within individuals. However, few studies have examined the assumption that mental time travel is stable across different autobiographical events.

The idea that mental time travel is stable is generally not examined explicitly but has been addressed when papers have examined the internal consistencies of self-report questionnaires, as part of validation analyses. This is typically assessed using Cronbach's alpha, which is calculated by correlating the score from each item with the total score for each participant, and then comparing this correlation to the variance for all individual item scores (Cronbach, 1951). This has been done to validate rating scales which purport to measure the same construct across multiple autobiographical episodes, but in doing so has provided evidence for the stability of certain characteristics. For instance, several studies have demonstrated that responses to the Memory Experiences Questionnaire (Sutin & Robins, 2007) are relatively consistent across various forms of memories such as self-defining events (Sutin & Robins, 2007; Luchetti et al., 2016), childhood memories (Sutin & Robins, 2010; Luchetti et al., 2016), positive and negative episodes (Luchetti et al., 2016), and memories experienced from both observer and vantage perspectives (Sutin & Robins, 2010; Mooren et al., 2016). The Memory Experiences Questionnaire assesses a wide range of phenomenological characteristics including vividness, coherence, accessibility, time, perspective, sensory details, visual perspective, emotional intensity, sharing, distancing, and valence (Sutin & Robins, 2007). Internal consistency has been demonstrated in all these characteristics, suggesting that the overall phenomenology of autobiographical memory is stable within individuals, regardless of the characteristic being assessed. Indeed, self-report questionnaires such as the Autobiographical Memory Characteristics Questionnaire (Boyacioglu & Akfirat, 2015), Autobiographical Memory Questionnaire (Rubin et al., 2003; Talarico & Rubin, 2003), and APAM (Vannucci et al., 2020; Vannucci et al., 2021) assess additional characteristics and also have relatively high internal consistencies (most αs > .70). This suggests that various ratings of autobiographical memories are relatively stable, supporting the assumption that mental time travel is a trait.

While most of the literature has unintentionally evidenced intra-individual stability in memory, Rubin (2021) explicitly examined this issue by investigating twelve theoretically important characteristics of autobiographical memory (reliving, vividness, belief, visual, scene, contents, specific time, auditory, coherence, centrality, rehearsal, emotion). In two sessions separated by various time intervals, participants detailed seven different memories prompted by distinct cues. They then provided ratings related to these twelve properties. The cues in each session were broadly similar classes of events, some of which were closely related (e.g. ‘with a close friend’ and ‘with a close family member’) while others were loosely related (e.g. ‘that changed your life’ and ‘at an important religious or national holiday’). Internal consistencies (all α > .80) indicated that all characteristics were reliable and stable in both sessions and there was little difference in stability over intervals ranging from one week to one month. This provides compelling evidence that the subjective experience of remembering the past is stable within individuals.

As imagining the future relies on a similar cognitive architecture as autobiographical memory (Conway & Pleydell-Pearce, 2000; Hassabis & Maguire, 2007; Schacter & Addis, 2007; Schacter et al., 2012), much of the literature is based on the theoretical assumption that episodic future thinking is part of the same individual difference dimension and therefore, is similarly stable. However, the study of intra-individual differences in episodic future thinking remains in its infancy. To date, two studies have assessed the consistency of phenomenological ratings across different imagined future experiences, examining only two characteristics overall. Both studies demonstrated good stability for the visual perspective adopted (field vs observer) when imagining future events both within (Berg et al., 2021; Verhaeghen et al., 2018) and across (Berg et al., 2021) sessions. In addition, Berg et al. (2021) showed that vividness ratings were also consistent. This provides preliminary evidence that, alike autobiographical memory, an individual’s subjective experience of imagining the future is stable across different episodes.

While there is considerable evidence that mental time travel is stable across subjective ratings, few studies have examined intra-individual stability using objective assessments. Research on measures such as the AMT has demonstrated that specificity is stable across memories within individuals (Sumner et al., 2014). However, despite being considered the gold standard instrument, little research has assessed intra-individual variability using the AI scoring (Levine et al., 2002). Although some longitudinal studies have looked at the consistency of internal details for the same memory (Barry et al., 2021; Campbell et al., 2011; Nadel et al., 2007), only one study has assessed intra-individual differences by examining the stability of internal details across different memories. In this study, Lockrow et al. (2023) compared the number of internal details generated across different lifetime periods (childhood, teenage years, early adulthood, middle adulthood, late adulthood; Levine et al., 2002) in a large sample of younger and older adults. They found that internal detail scores were robustly correlated across the different time periods, suggesting that the detail scores for each episode are measuring the same individual difference dimension. This indicates that internal details are stable across memories from different life periods, but no research has looked at the stability of internal details across future events.

From the literature reviewed above, it is evident that there are considerable gaps in our knowledge about intra-individual variability in mental time travel. While there is substantial evidence that subjective ratings are consistent across autobiographical memories, few studies have examined whether this result is replicated in future thinking. The studies which have been conducted on future events have only focused on two subjective attributes: visual perspective and vividness. Furthermore, whether objective episodic content is stable across autobiographical episodes remains a question which is largely unanswered, with support from only one study. In addition, no studies have examined the stability of objectively scored future thinking experiences. As a great deal of the literature is based on the theoretical assumption that mental time travel is stable, this is an important avenue which will be empirically investigated in this thesis.

1.8.2 Inter-Individual differences in mental time travel

The theory that mental time travel is a trait is largely based upon the discovery that autobiographical abilities can vary substantially between individuals (Palombo et al., 2018). Some individuals experience highly superior autobiographical memory (HSAM) where memories are highly accessible and recollected in extremely rich sensory-perceptual detail (Leport et al., 2012), whilst others suffer from severely deficient autobiographical memory (SDAM) in which memories are recollected with great difficulty and with a paucity of episodic details (Palombo et al., 2015). While HSAM and SDAM represent extreme ends of the inter-individual difference dimension, robust differences have also been observed between male and female (Andreano & Cahill, 2009; Bauer et al, 2003; Pillemer et al., 2003; Rubin & Berntsen, 2009) as well as older and younger (Rubin & Berntsen, 2009; Rubin & Schulkind, 1997) participants; providing compelling evidence that autobiographical memory differs between individuals. There is also evidence that episodic future thinking differs similarly with age (Addis et al., 2008; Addis et al., 2010; Gaesser er al., 2011), gender (Compère et al., 2018), and cognitive style (Beaty et al., 2018). However, these differences are less established in the future thinking research.

Inter-individual variability has also been examined within the context of psychiatric conditions. Individuals with depression (Söderlund et al., 2014; Sumner et al., 2010), post-traumatic stress disorder (Moradi et al., 2008), bipolar disorder (Mowlds et al., 2010), and schizophrenia (Ricarte et al., 2017; Zhang et al., 2019) have shown robust impairments in autobiographical memory, and some research suggests these deficits extend to episodic future thinking (Hallford et al., 2018). This provides robust support for the existence of inter-individual differences in mental time travel, presenting a rich avenue for autobiographical research. Schizophrenia will be focused on in this thesis and the literature in this area will be discussed in detail in the subsequent sections.

1.8.2.1 Mental time travel in schizophrenia

A psychiatric disorder of particular relevance to autobiographical abilities is schizophrenia. This condition is characterised by positive (delusions, hallucinations, abnormal motor behaviour), negative (diminished emotional expression, avolition), and cognitive (disorganised speech, thought, and attention) symptoms (Andreasen et al., 1995). One of the core characteristics of schizophrenia is a disrupted sense of selfhood, leading to it commonly being referred to as 'a disorder of the self' (Sass & Parnas, 2003). Self-disturbance is multi-faceted in schizophrenia, manifesting as diminished self-affection, hyper-reflexivity, and disrupted self-awareness (Sass & Parnas, 2003). It is thus unsurprising that mental time travel, an ability reciprocally related to the self (Conway, 2005; McAdams, 2001; Prebble et al., 2013), is significantly altered in schizophrenia.

Reviews and meta-analyses have shown that individuals with schizophrenia experience robust disturbances in both autobiographical memory (Berna et al., 2016; Ricarte et al., 2017; Zhang et al., 2019) and episodic future thinking (Hallford et al., 2018). The key finding being that schizophrenia patients' mental time travel is overgeneral, such that when presented with a cue and asked to describe a specific event relating to that cue, they are more likely to come up with a non-specific or repeated event. Reviews of this research suggest that compared to controls, schizophrenia patients generate significantly less specific past (Berna et al., 2016; D'Argembeau et al., 2008; Ricarte et al., 2017; Zhang et al., 2019) and future events (D'Argembeau et al., 2008; Hallford et al., 2018). Although this is a useful and influential finding, other core characteristics of mental time travel have received less attention and are therefore not as well-understood. Specifically, episodic content and phenomenological experience are both important parameters of mental time travel, but there has been less focus on these measures in the schizophrenia literature.

Different objective scoring systems have demonstrated consistent deficits in schizophrenia patients for past and future events. For instance, the Autobiographical Memory Enquiry (Danion et al., 2005) accompanied by the Williams et al. (1996) scoring method and the scene construction task (Hassabis & Maguire, 2007) and its Experiential Index scoring procedure have each suggested that schizophrenia patients generate less episodic detail than healthy controls when describing memories (Nieto et al., 2019) and future imaginings (Raffard et al., 2010) respectively. Comparable results have also been found across AI studies examining different forms of mental time travel. Specifically, schizophrenia patients describe past (Dassing et al., 2020; Potheegadoo et al., 2014) and future (Gündüz et al., 2020; Yang et al., 2019a) events with significantly less internal details than controls. This suggests that regardless of the measure, when scored objectively, schizophrenia patients generate reduced episodic detail. Indeed, a recent review of the future thinking research concluded that, when scored by the experimenter, the richness of schizophrenia patients' event descriptions is significantly impaired in comparison to controls (Brunette & Schacter, 2021); with schizophrenia patients consistently describing events which contained less episodic detail.

The review by Brunette and Schacter (2021) also examined subjective assessments but found that the studies employing these measures produced variable results. Different studies demonstrated both attenuated (Allé et al., 2020; Berna et al., 2016; Painter & Kring, 2016; Raffard et al., 2010; Raffard et al., 2013; Ricarte et al., 2017; Yang et al., 2018; Yang et al., 2019b) and enhanced experiences (Raffard et al., 2010), as well as a lack of difference between patients and controls (De Oliveira et al., 2009; Malek et al., 2019; Raffard et al., 2016). Various studies replicated the impairments found using objective measures, demonstrating that for future events, schizophrenia patients provide lower ratings than controls on a wide range of phenomenological characteristics (vividness; Yang et al., 2018; Yang et al., 2019b; sensory details, contextual details, referential information; Raffard et al., 2013; Painter & Kring, 2016; sense of presence and perceived salience; Raffard et al., 2010;

pre-experiencing; Yang et al., 2018). Several meta-analyses and studies which have looked at past events also report a similar pattern of results, demonstrating that by their own report, individuals with schizophrenia were poorer at remembering the details of the event, had less vivid and more fragmented recollection, and less sense of reliving the event compared to controls (Alle et al., 2020; Berna et al., 2016; Ricarte et al., 2017). Although interestingly, Raffard et al. (2010) found within the schizophrenia group that individuals with higher positive symptoms had an enhanced sense of presence in future events. However, some research has shown no differences between schizophrenia and control groups. In future thinking, De Oliveira et al. (2009) found no differences in self-reported abilities to pre-experience (i.e. autonoetic awareness) and Raffard et al. (2016) reported no differences in ratings of sensory details, contextual information, and self-referential information. Similarly, a study on autobiographical memory found no group differences between schizophrenia patients and controls in their ratings of vividness (Malek et al., 2019). As the studies employing subjective measures present mixed results, the relationship between schizophrenia and the subjective experience of mental time travel remains somewhat ambiguous. While most studies demonstrate differences between schizophrenia and control groups, some research has failed to find any group differences when looking at self-report.

One potential explanation for this mixture of results is that the deficit in mental time travel could be related to a particular dimension of schizophrenia symptoms. Indeed, a notable gap in this literature is that due to these mixed results, how these deficits relate to the different dimensions of schizophrenia is unclear. As positive, negative, and disorganised dimensions are each associated with distinct cognitive deficits (Strauss, 1993), knowing which dimension relates to a given deficit is key to understanding the development of schizophrenia pathology, as well as developing targeted interventions. Yet much of the research has not examined these relationships and the research which has examined positive and negative symptoms has produced variable results. For instance, it has been demonstrated that negative symptoms are associated with experimenter-scored measures of episodic content (Raffard et al., 2010; Yang et al., 2019b), positive symptoms are correlated with self-reported sense of presence (Raffard et al., 2010), and some research has shown that there are no relationships with either dimension (Raffard et al., 2013).

Therefore, there is no clear indication of how episodic content or phenomenological ratings relate to the symptoms of schizophrenia. One possible explanation for these inconsistent results relates to the different measures used to assess mental time travel. As the studies cited examined relationships with both objective (Raffard et al., 2010; Yang et al., 2019b) and subjective (Raffard et al., 2010) assessments, which may be measuring different constructs (see section 1.7.3), it is also plausible that these measures associate with different symptom dimensions.

How mental time travel manifests in schizophrenia is uncertain based on the present literature. While objective measures have demonstrated robust deficits across both temporalities, subjective measures have revealed more variable results. The evidence of impairment is less robust when using subjective assessments as in addition to deficits, these measures have revealed enhancements, as well as no differences at all. There are several important inconsistencies across these studies, which might be driving the heterogeneity of these results. Different temporalities (past and future), modes of measurement (subjective and objective), and symptom dimensions (positive and negative) have been examined across studies. As no single study has encompassed all these variables, our understanding of how mental time travel relates to schizophrenia remains obscured. This thesis will explore each of these variables within the same sample by adopting a continuum approach to schizophrenia, which will be discussed in the following section.

1.8.2.2 Mental time travel in schizotypy

Some researchers have taken a dimensional approach to schizophrenia. According to this view, many of the symptoms seen in this disorder, such as hearing voices and an inability to experience pleasure, can also be found in the general population (Claridge, 1997; Johns & Van Os, 2001; Raine, 2006; Van Os, 2003). This collection of personality characteristics and experiences, thought to reflect the subclinical expression of schizophrenia, is known as schizotypy. The frequency, severity and extent of distress and impairment is likely to vary but these experiences provide a complementary way of looking at schizophrenia or psychotic experiences. This can be done without some of the confounds present when testing individuals with schizophrenia, such as medication and chronicity effects. Just like schizophrenia, it is a multi-dimensional construct defined by three components, which loosely map onto positive, negative, and disorganised symptoms found in schizophrenia (Johns & van Os, 2001). A number of studies have found that individuals high in these schizotypy dimensions are more likely to develop psychotic disorders (Chapman et al., 1994; Grant et al., 2018; Kwapil et al., 1997), highlighting the validity of this concept.

Some studies have adopted this approach. Yang et al. (2018) found that when using an experimenter-scored measure, college students who scored highly on social anhedonia generated impoverished emotion/thought details in future events. In contrast, Winfield and Kamboj (2010) found that healthy participants who scored higher on the positive dimension of schizotypy (e.g. experiencing hallucinatory or delusion-like experiences) provided subjective ratings reflecting greater olfactory and gustatory details as well as a heightened sense of subjective time travel for past and future events, in comparison to individuals scoring lower on this scale. Similarly, a recent study by Allé et al. (2023) looking at autobiographical memory using a variety of self-report measures found that the positive dimension of schizotypy was associated with enhanced: olfactory details, intensity of emotion, personal importance, and accessibility. This study found very little evidence for relationships with the negative dimension of schizotypy. These studies indicate different patterns of associations between schizotypy and mental time travel into the past and future, which might be due to whether they focus on autobiographical memory or future thinking, the specific dimension of schizotypy (negative versus positive), and/or the use of a subjective or objective measure.

1.9 Aims of the thesis

This thesis aims to evaluate contemporary questions in the field of autobiographical memory by examining both the objective content and subjective experience of mental time travel. Because mental time travel is both subjective and multi-faceted in nature, examining different levels of measurement is critical to gaining a complete understanding of this phenomenon. This is often under-appreciated in the field, with numerous studies opting for either experimenter-scored or participant-scored measures, and proposing interpretations based on the assumption that they are assessing the same constructs of a highly complex mental process. This thesis will implement both subjective and objective forms of measurement which assess various characteristics of mental time travel. While autobiographical memory has been the subject of research for several decades, episodic future thinking is a relatively recent area of study. Hence mental time travel into both the past and future will be examined. This bidirectional approach will clarify differences in temporality which have been observed across numerous studies that have assessed either autobiographical memory or future thinking separately. Although the similarities between remembering the past and imagining the future are striking, it has been evidenced that these forms of mental time travel are not without their differences. Although theoretically, future thinking is likely to mirror the findings demonstrated in autobiographical memory, research has shown that this is not always the case. To further our knowledge about mental time travel, these similarities and differences must be empirically tested, not implicitly assumed.

Chapter 2 addresses a fundamental question in the memory literature, about the correspondence between objective content and subjective experience. This is an important topic to examine. If there is a relationship this would suggest that subjective judgements are based on the quantity of episodic details remembered. Under these circumstances, the subjective experience could be a proxy for, and a reliable index of, the richness of the retrieved episode. However, if there is no relationship this would call into question what attributes are used when participants make judgements about their memories. There is relatively little research in this area, presumably because researchers have assumed that they are linked. Yet a key recent study (Clark and Maguire, 2020) suggests that they are not. This thesis will examine this issue in a more comprehensive and detailed manner than previously. This relationship will be examined in i) both past and future autobiographical events in the same study and ii) several subjective and objective measures, to capture the multi-faceted nature of mental time travel. As this has not been done in previous work, two independent studies will be conducted, thus allowing for examination of the robustness of these relationships. Moreover, a more advanced way of analysing the data will be utilised, which has not previously been applied in this area. This will allow these associations to be assessed more sensitively at the trial level.

Chapter 3 will test the notion that mental time travel is a stable intra-individual difference. The question of whether mental time travel is stable is pressing, as much of the literature assumes that abilities to remember the past and imagine the future are both trait-like capacities. There are important practical implications for this research as i) the use of trait-based questionnaires and ii) the common practice of summing or averaging scores across events both presuppose that mental time travel is somewhat consistent within individuals. The reliability and validity of these measures thus depends on this idea, but few studies have examined it explicitly. Chapter 3 examines whether objective content and subjective experience are stable across different episodes in the same testing session. This will be tested using both the AI scoring (Levine et al., 2002) and subjective ratings of past and future events, addressing the critical gaps in this literature. Across two independent studies, a vast range of subjective ratings will be examined across future episodes; extending the previous research which has only looked at vividness and perspective ratings. These studies will also assess the stability of internal details across both past and future events, building upon the very limited research which has only looked at autobiographical memory (Lockrow et al., 2023). The internal subcategories will also be examined. This has not been done before, despite the multi-faceted nature of mental time travel.

In **Chapter 4**, the relationship between mental time travel and schizotypy is examined. This chapter addresses an extremely mixed body of literature, by implementing both subjective and objective assessments, and examining mental time travel into both the past and future. As many of the previous studies have examined either autobiographical memory or episodic future thinking using either subjective or objective measures, it is unclear whether differences in results between studies are reflective of differences between i) past and future, ii) subjective and objective measurement, or are simply due to sample characteristics such as length of illness or medication effects. This chapter examines both forms of mental time travel using both the AI scoring system (Levine et al., 2002) as well as two different forms of subjective measurement: phenomenological ratings and a trait-based questionnaire. This research will take a dimensional approach to schizophrenia by examining psychometric schizotypy in healthy individuals (Claridge, 1997; Johns & Van Os, 2001; Raine, 2006; Van Os, 2003). This approach is advantageous as it is not confounded by epiphenomena, which is a well-known limitation of schizophrenia research (Claridge, 1997;

Buckley et al., 2009; Murray et al., 1990). Yet this approach has only been adopted in a select number of studies. The studies which have examined schizotypy have either used subjective measures only, not looked at both temporalities, or have only examined one dimension of schizotypy. In this chapter, both the positive and negative dimensions of schizotypy will be examined to gain a more nuanced understanding of its relationship with mental time travel, and the psychometric experiences underlying it. This will extend the work that has been conducted in this area by providing a comprehensive examination of how schizotypy relates to mental time travel across different temporalities, levels of measurement, and dimensions of schizotypy. This has not yet been done previously in either the schizotypy or schizophrenia literature. By examining across these different variables, Chapter 4 aims to disentangle the factors driving the mixed results which have preceded.

Chapter 2: The relationship between the subjective experience of mental time travel and objective content

2.1 Introduction

A critical question in the literature, and which is the subject of this chapter, is whether there is correspondence between the subjective experience and objective content of mental time travel. This is a fundamental question as if there is correspondence, this would suggest that subjective ratings are informed by the amount of episodic detail that one can retrieve for a given episode. Thus, higher vividness ratings would be anticipated to be associated with greater access to episodic detail information (D'Angiulli et al., 2013; Moscovitch et al., 2005). Under these circumstances, it could be concluded that these different indices are tapping similar or overlapping constructs. Although if there is no relationship, this would indicate that each measure is gauging distinct facets of mental time travel.

As outlined in section 1.7.3, several studies have demonstrated a dissociation between the AI and self-report measures of autobiographical memory (Clark & Maguire, 2020; Palombo et al., 2013; Setton et al., 2021). A possible reason why these studies failed to find this relationship is that the two measures being correlated differ in their level of specificity as well as what is being rated. These studies used the SAM, which measures mnemonic ability at the trait level (Palombo et al., 2013). In contrast, the AI is an event-based instrument which measures task performance. As trait-based questionnaires require the participant to generalise their abilities, it is arguably unsurprising that this measure lacks correspondence with an assessment of episodic content related to particular episodes. Moreover, events elicited by the word cue method are also more likely to be from a more recent time period (Janssen et al., 2005). Therefore, when the participant narrates this memory, this represents not their general ability but one of their more robust memories. These mismatches might account for the lack of accord in questionnaire-based memory measures and the AI.

To eliminate this issue, some research has assessed the link between vividness ratings scored after each narration. Thus, the objective measure is at the event level and so is the subjective rating. Yet as discussed in section 1.7.3, these studies present mixed results (Clark & Maguire, 2020; Thakral et al., 2020). It is possible that this relationship has been occluded by the way in which researchers typically examine it. It is usual for participants to recount several autobiographical experiences and then to complete a subjective measure after each of them. The scores for all the AI measures and subjective ratings are then aggregated across trials. Therefore, the two aggregated scores are then correlated together across all participants. This approach does not allow for a direct comparison between participants' vividness ratings and the amount of objective episodic content at the event level. Instead, an approach which assesses this relationship at the trial level is needed, such as mixed-effects modelling (Baayen et al., 2008). This technique assesses relationships on a trial-by-trial basis. Hence it is appropriate for the clustered structure of the data (i.e., where trials are nested within each participant and are not statistically independent; Wright, 1998), due to each participant contributing several events. This approach has been used with laboratory-based tasks to address the correspondence between memory accuracy and various subjective measures, such as memory confidence (Wong et al., 2012), source memory judgements (Folville et al., 2020), and feeling of knowing (Brooks et al., 2021). It has not been applied to autobiographical data to examine the alignment of memory scores from different assessments.

As discussed in Chapter 1, there is now compelling evidence that remembering the past and imagining future experiences share striking cognitive and neural similarities (for reviews see Schachter et al., 2012 and Szpunar, 2010). Yet few studies have examined the correspondence between objective performance and subjective experience in episodic future thinking. As detailed in section 1.7.3, Clark and Maguire (2020) failed to find a robust relationship between SAM future scores and the Experiential Index. There are several possible reasons why they did not find a relationship. One issue, as outlined earlier, is that there are different levels of measurement operating: trait-based for the questionnaire and event-based for the objective measure. Moreover, as mentioned in section 1.7.1, the Experiential Index is comprised of experimenter-scored dimensions and participant ratings and is therefore not a pure measure of objective memory ability. Thakral et al. (2020) looked at internal details and vividness ratings and demonstrated a positive relationship under these circumstances (see section 1.7.3 for further detail). This provides preliminary evidence that when both measures are event-based, there is correspondence between objective content and the subjective experience of imagining the future.

The aim of the present study is to examine the correspondence between participant's subjective experiences and the objective content for past and future autobiographical events, which has not been assessed previously in the same study. This will be completed by giving young healthy participants cue words and asking them to recollect an episode from the past or to imagine an event in the future involving that word. Their descriptions will be scored according to the established criteria set out in the AI (Levine et al., 2002) and after each narration, participants will be asked a series of questions about their experience. This study extends previous research by not just examining the link between vividness and AI internal details but also looking at the relationship between internal details and re-/pre-living ratings as well as the subcategories which contribute to the internal detail score (event, perceptual, time, place, emotions/thoughts) and the corresponding participant ratings for these. There are no previous studies which have done this, but this approach will give a more nuanced understanding of this relationship, given the multi-faceted nature of mental time travel (Palombo et al., 2018).

In previous studies, a variety of analysis techniques have been used to explore the association between the participant's subjective memory state and experimenter-scored indices, some of which might have obscured the relationship or been less sensitive to finding it. In the present study mixed-effects modelling will be used, so that data can be examined at the trial level, and it can be determined whether the relationship is similar for past and future autobiographical events. It is anticipated that a positive relationship will be found between internal details and both vividness and re-/pre-living ratings, as well as participants' subjective experiences and the corresponding objective content score for event/perceptual, spatiotemporal, and emotion/thought details. Two independent studies were conducted to test this hypothesis.

2.2 Method – study 1

2.2.1 Participants

82 healthy undergraduate participants were recruited to take part in the first study in exchange for course credits. The sample size was determined based on a power calculation which showed that for a one-tailed correlation with an alpha of $p < .05$, a sample size of $n = 67$ or greater was needed to achieve statistical power of 0.8 with a medium effect size of 0.3. As mixed-effects modelling is a more sensitive analysis than correlation, this was adopted as a reasonable sample size to recruit. Of these eighty-two participants, thirty were excluded due to one experimenter not administering the AI in the standard way. For example, this experimenter was not using the standardised probes in cases where the participant did not provide sufficient detail. The remaining sample comprised 52 undergraduate students (46 female) who were aged between 18-39 years (mean age = 20) and who were fluent in English. Written consent was obtained from all participants prior to testing. This research was reviewed and approved by Cardiff University School of Psychology Ethics Committee.

2.2.2 Materials

2.2.2.1 Cue word paradigm

Participants completed an adapted version of the Galton-Crovitz cue word paradigm (Crovitz & Schiffman, 1974) which was audio recorded by the experimenter. A series of ten cue words were presented both verbally and visually (using cue cards) to prompt discussion of both past and future events, with half in each condition. It was required that all events were spatiotemporally specific and did not exceed 24 hours. In addition, future events were required to be novel and plausible given the participant's current plans. Participants described five events for one temporal direction (past or future) before beginning the next condition. The order of temporal condition was counterbalanced across participants, resulting in two versions of the task (past then future, future then past). The cue words were divided into two groups (Group A = Birthday, Holiday, University, Home, Shopping; Group B = Day Trip, Party, Christmas, Family, Pets/Animals) which were also counterbalanced across past and future conditions. The order in which cue words were presented was consistent in all conditions.

2.2.2.2 Autobiographical interview scoring

The audio recordings were transcribed and scored according to the standardised AI scoring procedure (Levine et al., 2002). Responses were segmented into distinct sections in order to score for internal and external details. Details were typically grammatical clauses referencing a unique occurrence, observation or thought (Levine et al., 2002). Details were scored as internal if they directly pertained to the main event and external if they were unrelated to the main event (Levine et al., 2002). Internal responses were subcategorised into event, time, place, perceptual, and emotion/thought details (see Table 1). In the case of a participant describing more than one event, the event that was described in most detail was considered the main event.

Scoring was completed by two raters and all transcripts were double scored. An intra-class correlation analysis (ICC; two-way random model conducted in IBM SPSS statistics 26) was conducted to evaluate the inter-rater consistency across all AI subcategories. Significant ICCs (all $ps < .01$) were observed for both the broader categories (internal: $r= 0.99$; external: $r= 0.97$) and their subcategories (internal: event $r=0.99$; time $r= 0.99$; place $r= 0.99$; perceptual $r= 0.93$; emotion/thought $r= 0.94$).

Table 1. *Description of coding subcategories used in scoring of modified Galton-Crovitz cue word paradigm adapted from Levine et al. (2002)*

Category	**Subcategory**	**Description**
Internal	*Event*	Happenings, actions, people present, people's behaviours, objects present
	Time	Times, dates, days, weeks, seasons, years, indications of temporal order of events, frequencies, durations
	Place	Countries, cities/town, area, street, building, room, area within room, relative positioning to other people/objects
	Perceptual	Auditory, olfactory, tactile, taste, and visual details including colours and patterns, as well as indications of the weather
	Emotion/Thought	Feelings and thoughts of the individual within the given episode
External		Semantic information, autobiographical details unrelated to the identified main event, repetitions, and metacognitive statements

2.2.2.3 Subjective ratings

Following each event description, participants completed a short self-report questionnaire. The questionnaire assessed the overall vividness of each event (1= not vivid, 7= very vivid), the participant's sense of re-/pre-living ('To what extent did you feel you were experiencing this memory as if you were actually there?' 1= Not at all, 7= It felt like I was really there) as well as the clarity of episodic details including event/perceptual ('Details including people, objects, and surroundings...), time ('The time in which this event takes place...'), place (The location where this event takes place...'), and emotions/thoughts ('My own thoughts and feelings when the event takes place...') which were all rated using a scale of 1-7 (1= not at all clear, 7= extremely clear and distinct).

2.2.2.4 Oxford-Liverpool Inventory of Feelings and Experiences

The Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE; Mason et al., 1995; Mason & Claridge, 2006) was administered following completion of the cue word paradigm. The O-LIFE is a validated measure of schizotypy (Mason et al., 1995; Mason & Claridge, 2006), designed to elicit a normal distribution of responses. The O-LIFE consists of 159 questions and measures schizotypy on four subscales: Unusual Experiences, Introvertive Anhedonia, Cognitive Disorganisation, and Impulsive Non-conformity. The Unusual Experiences scale measures positive schizotypy (perceptual aberrations, magical thinking, and hallucinations e.g. "Do you ever feel that your thoughts don't belong to you?"), the Introvertive Anhedonia scale measures negative schizotypy (a lack of enjoyment from social and physical sources of pleasure and avoidance of intimacy e.g. "Are there very few things you have ever really enjoyed doing?"), the Cognitive Disorganisation scale detects cognitive deficits and disorganised aspects of schizotypy, and the Impulsive Nonconformity scale relates to a lack of self-control (Mason & Claridge, 2006). The O-LIFE is not analysed in this chapter (see Chapter 4 for analysis of the O-LIFE).

2.2.3 Procedure

All participants were tested in-person and individually. The experimenter explained that participants would be presented with a series of cue words and that they were to use each word to either remember an event from the past or imagine an event in the future. It was clarified whether the past or future condition would take place first and that they would be notified before commencing the next condition. Participants were asked to describe each event in as much detail as possible, refer to a specific place and time, and to choose an event lasting no longer than 24 hours. Before commencing the future condition, participants were instructed to imagine events that were both plausible and had not happened before. In the instance that a participant failed to provide sufficient detail, they were probed using a standardised prompt such as 'Are there any other specific details you can think of?'. The experimenter presented each cue word on a cue card, as well as stating it verbally as part of the standardised instructions. No limit was implemented on the amount of time participants took to describe each event. Once the participant had confirmed that their description was complete, they were asked to give their subjective ratings about the event. This procedure was repeated for all ten cue words. Following completion of the cue word paradigm, the O-LIFE was administered. Participants were fully debriefed at the end of the study. One hour was scheduled for each participant.

2.2.4 Data analysis

As has been done in previous studies, the AI scores and participant ratings for time and place were aggregated to form a spatiotemporal category (Hodgetts et al., 2017; Irish et al., 2011). The AI scores for event and perceptual were also aggregated to form an event/perceptual category which aligned with the corresponding participant rating.

Linear mixed-effects modelling was used to assess the relationship between the objective detail variable and corresponding participant ratings on a trial-by-trial basis. Linear mixed-effects modelling using the GAMLj package was implemented in Jamovi software. The models treated the participants and cue words as random effects. More specifically, the models included random intercepts for both participant and cue words. In all models, the dependent variable was the participant ratings, the objective content score was a continuous predictor, and the temporal condition (past or future) was a categorical predictor. The interaction between the objective content measure and temporal condition was also examined to determine if these relationships differed by temporal condition. Objective content score and temporal condition were added as fixed effects. It should be noted that Jamovi: i) automatically mean-centres all continuous predictors to ensure that the range of any newly created variables (i.e. interactions) are kept around the means of the data, which helps with interpretation of the data and improves the chances of convergence (Cohen et al., 2002) and ii) implements the Satterthwaite method for degrees of freedom, which leads to differences in the denominator degrees of freedom between different analyses. The contrast coding of the categorical predictor was set to 'simple' which means the 'first group' was compared to the subsequent groups whilst centring the contrast to 0. As the 'first' and 'subsequent' groups are defined by alphanumeric order, the future condition was the first group, and the past condition was the subsequent group (future – past); the mean of the future condition was compared against the mean of the past condition. Five of these models were examined between: i) experimenter-scored internal details and participant reported vividness, ii) experimenter-scored internal details and participant reported re-/pre-living, iii) experimenter-scored event/perceptual details and participant event/perceptual ratings, iv) experimenter-scored spatiotemporal details and participant spatiotemporal ratings, and v) experimenter-scored emotion/thought content and participant emotion/thought score.

Given that many of the studies in this area have used correlations to examine this relationship, these analyses were also completed to draw parallels with the existing research. Correlations were conducted using composite scores in which the raw number of objective details and subjective ratings were totalled across all five cues for each temporal direction.

2.3. Results – study 1

2.3.1 Linear mixed-effects models

The mixed-effects models revealed that internal details was a significant predictor of vividness ($b = 0.030$, $SE = 0.006$, $F(1, 505) = 23.32$, $p < .001$) and re-/pre-living ($b = 0.031$, SE

= 0.006, F(1, 515) = 31.72, p <.001) ratings, and that the experimenter's scores for event/perceptual (b = 0.039, SE = 0.009, F(1, 506) = 17.62, p < .001), spatiotemporal (b = 0.150, SE = 0.029, F(1, 471) = 120.45, p < .001), and emotion/thought (b = 0.108, SE = 0.033, F(1, 509) = 10.75, p = .001) details were all significant predictors of their subjective, self-report counterparts.

The internal details x temporal condition interaction (b = 0.020, SE = 0.011, F(1, 482) = 3.62, p = .058; see Figure 3A) for the vividness model and the event/perceptual x temporal condition interaction (b = 0.017, SE = 0.016, F(1, 489) = 1.17, p = .281; see Figure 3C) were both not significant. However, the internal details x temporal condition was significant for the re-/pre-living model (b = 0.025, SE = 0.009, F(1, 480) = 7.54, p = .006; see Figure 3B). The spatiotemporal x temporal condition interaction (b = 0.105, SE = 0.051, F(1, 483) = 4.30, p = .039; see Figure 3D) and the emotion/thought x temporal condition interaction (b = 0.167, SE = 0.059, F(1, 476) = 8.13, p = .005; see Figure 3E) were also both significant.

Simple effects analysis was conducted for the re-/pre-living, spatiotemporal and emotion/thought models in each temporal condition. Internal details was a significant predictor of re-/pre-living ratings in both conditions but was stronger in future events (b = 0.044, SE = 0.009, F(1, 511) = 25.4, p < .001) than in past events (b = 0.018, SE = 0.005, F(1, 513) = 11.7, p < .001). Spatiotemporal details was also a significant predictor in both conditions but was stronger in future events (b = 0.203, SE = 0.113, F(1, 516) = 19.91, p < .001) than in past events (b = 0.097, SE = 0.035, F(1, 515) = 9.49, p = .002). Emotion/thought details was a significant predictor in future events (*b* = 0.192, *SE* = 0.052*, F*(1, 498) = 13.38, *p* < .001), but not in past events (*b* = 0.024, *SE* = 0.034*, F*(1, 495) = 0.50, *p* = .480).

In all models, temporal condition significantly predicted the dependent variable, indicating that higher subjective ratings were reported in past events than in future events (bs = >-2.173, all ps <.001).

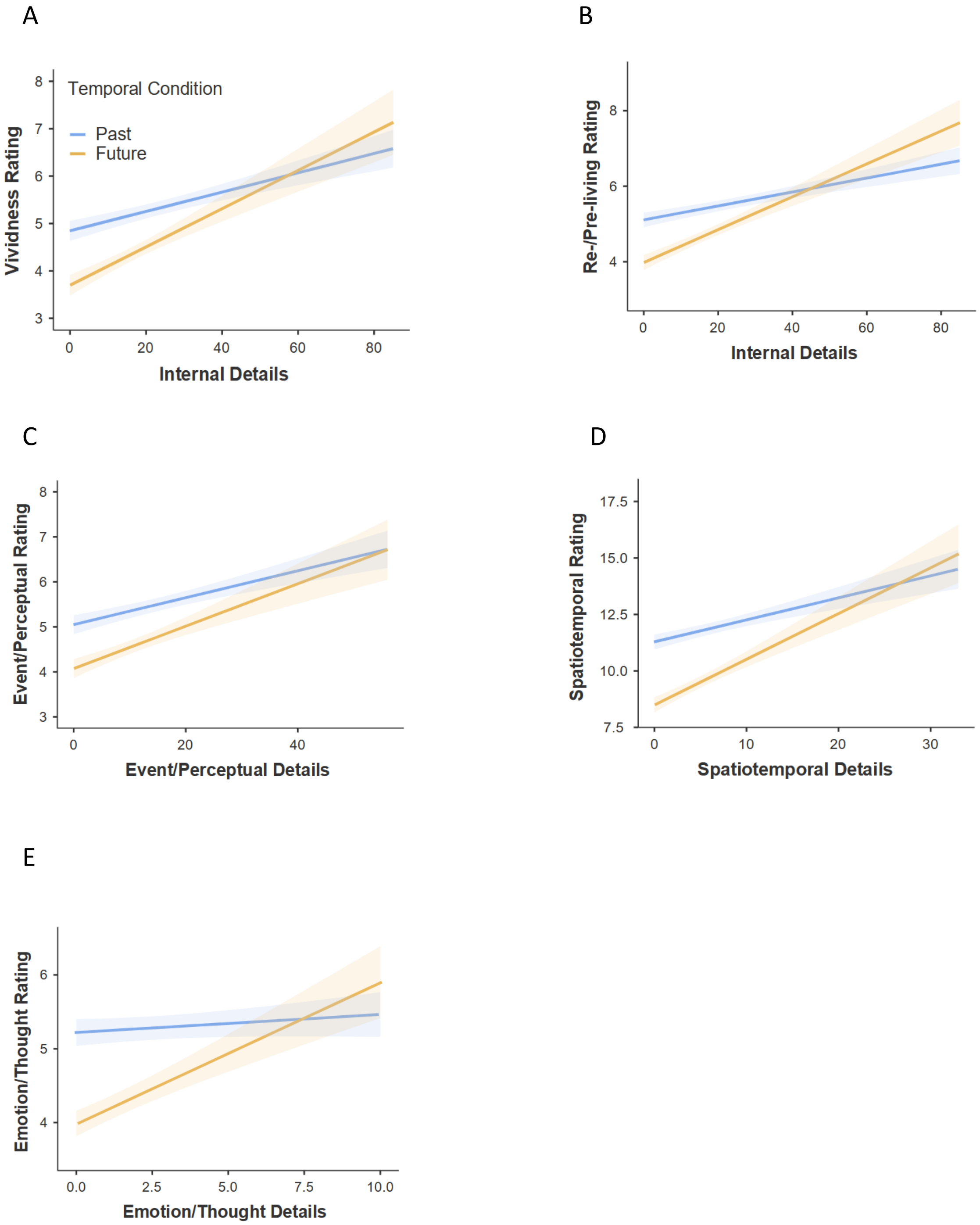


Figure 3. Results of study one's linear mixed-effects models for A) internal details and vividness B) internal details and re-/pre-living C) event/perceptual details D) spatiotemporal details E) emotion/thought details. Objective experimenter-scored details are on the X-axis and participant's subjective ratings are on the Y-axis. Regression lines are shown for each temporal condition (past in blue, future in orange). Shaded areas represent the standard error.

2.3.2 Correlations

To ensure continuity with previous research which has used correlations to assess the correspondence between subjective ratings and content scored by the experimenter, this type of analysis was also conducted. As all the composite scores were found to violate normality (Ws= .75-.97, all ps <.001), Kendall's Tau correlations were calculated. Kendall's Tau was chosen over Spearman's rho due to its lesser sensitivity to outliers and asymptotic variance (Croux & Dehon, 2010).

As shown in Table 2, there were no significant relationships between experimenter-scored variables and participant ratings when examining past events. Yet in the future condition, there were significant correlations between the broad internal category and both vividness and pre-living ratings as well as spatiotemporal and emotion/thought measures. Given that there are some differences in the correlations between temporal conditions, some descriptive statistics are presented in Appendix A.

Table 2. *Kendall's Tau correlation coefficients between internal details and subjective ratings for past and future events in study one*

	Past		**Future**	
	τ_b	**p**	τ_b	**p**
Internal – Vividness	.10	.17	**.22**	**.01**
Internal-Re-/Pre-living	.10	.16	**.20**	**.02**
Event/Perceptual	.10	.16	.10	.15
Spatiotemporal	.10	.16	**.17**	**.04**
Emotion/Thought	.04	.33	**.26**	**.01**

Note. Significant correlations are in bold. P-values can be different for the same correlation coefficients because all values have been rounded to two decimal places.

2.4. Summary and rationale for study 2

The mixed-effects modelling conducted on the trial-by-trial data demonstrated that there is a positive relationship between the objective content scored by the experimenter and subjective ratings provided by the participant. This was found for the overall number of episodic details (i.e. internal AI score) and both the vividness and re- or pre-living rating that the participant gave the experience. This correspondence was also evident for the subcategories of the AI and the ratings that participants gave for event/perceptual, spatiotemporal and emotion/thought. These results were found when participants both remembered past events and imagined future experiences. For the latter two subcategories and the re-/pre-living model, there was an interaction with temporal condition. This indicated that the relationship was stronger for future as compared to past events for spatiotemporal details and re-/pre-living. For emotion/thought details, there was a significant relationship for future events but not past events. These results were echoed in the correlations conducted on the summed data. Significant relationships were found between the experimenter-scored content and vividness, pre-living, spatiotemporal and emotion/thought ratings for future episodes. No significant correlations were found for autobiographical memory. Although due to several participant exclusions, this study is underpowered to detect a correlation with a medium effect size.

For the first time, it has been demonstrated in young healthy participants that there is correspondence between their subjective experience and the objective content as rated by an experimenter for both autobiographical memory and future imagining, using mixed-effects modelling. Given the novelty of this finding and the preliminary results highlighting some differences in this relationship between the past and future, a second study was completed with a larger sample to determine if this result would replicate. In this additional study, the valence of the cue words was also manipulated to examine whether the valence of the episode moderates this relationship. In the first study, the events were based on mildly positive or neutral cue words. Yet positive and negative events differ in the amount of episodic detail in which they are described (Ford et al., 2012; Holland & Kensinger, 2010) as well as how they are rated by participants (Arnold et al., 2011; D'Argembeau & Van der Linden, 2004; Kensinger & Schacter, 2006; Rasmussen & Berntsen, 2009). Therefore, valence may impact the degree of correspondence between objective content and subjective ratings. As the effect of valence has not previously been examined in this context, the second study implemented broadly positive and negative cue words. Due to there being no previous research investigating the effect of valence on this relationship, no hypotheses were made about the differences in correspondence between positive and negative events.

2.5 Method – study 2

All methodological details for study two are the same as for study one except as indicated below.

2.5.1 Participants

82 healthy undergraduate students (67 female) who were aged between 18-23 years (mean age = 19) participated in the second study.

2.5.2 Materials

In the second study, the AI scoring system (Levine et al., 2002) and participant ratings were consistent with the first study. However, the cue word paradigm was adapted to include both positive (Birthday, Achievement, Adventurous, School/University, Christmas, Holiday) and negative (Exam, Falling Over, Getting into Trouble, Failing, Embarrassed, Mistake) cue words. The positive cue words overlapped with those given in the first study, but the negative cue words were distinct. Participants completed three events for each valence and condition, with all events of one valence first and then the other (e.g. past positive, future positive, past negative, future negative). The order of valence was counterbalanced across participants.

AI Scoring was completed by the same two raters as in the first study. An intra-class correlation analysis (ICC; two-way random model conducted in IBM SPSS statistics 26) was conducted to evaluate the inter-rater consistency across all AI subcategories. Significant ICCs (all $ps < .01$) were observed for both the broader categories (internal: $r = 0.99$; external: $r = 0.95$) and their subcategories (internal: event $r = 0.99$; time $r = 0.97$; place $r = 0.98$; perceptual $r = 0.93$; emotion/thought $r = 0.99$).

Consistent with study one, the O-LIFE was administered following completion of the cue word paradigm. The O-LIFE is not analysed in this chapter (see Chapter 4 for analysis of the O-LIFE).

2.5.3 Procedure

The second study was also conducted in-person, but two adaptations were made to the procedure. First, participants were presented with six positive and six negative cue words, and explicitly instructed to describe events that were either positive or negative in response to the cues. Second, participants had a time limit of one minute to describe each event. As the participants had to describe some negative events, they watched a short positive mood induction video once all tasks were complete. Otherwise, the procedure was consistent with the first study.

2.5.4 Data analysis

The linear mixed-effects models were conducted as previous but with the addition of valence (positive or negative) as a fixed effect. The two interactions between valence and the AI variables were also examined to determine if valence moderates the relationship (i.e. experimenter-scored objective measure x valence and experimenter-scored objective measure x valence x temporal condition). Due to the additional categorical predictor in these mixed-effects models and Jamovi's implementation of the Satterthwaite method, some of the results have decimal degrees of freedom. For the correlations, separate relationships were assessed for positive and negative events. Otherwise, all aspects of data analysis were consistent with study one.

2.5 Results – study 2

2.5.1 Linear mixed- effects models

As in study one, the mixed-effects models revealed that internal details was a significant predictor of vividness ($b = 0.054$, $SE = 0.008$, $F(1, 792) = 43.75$, $p < .001$) and re-/pre-living ($b = 0.041$, $SE = 0.007$, $F(1, 955) = 29.29$, $p < .001$) ratings, and that the experimenter's scores for event/perceptual ($b = 0.090$, $SE = 0.012$, $F(1, 467.9) = 62.01$, $p < .001$), spatiotemporal (b

= 0.235, SE = 0.036, F(1, 950.7) = 42.48, p < .001), and emotion/thought (b = 0.076, SE = 0.023, F(1, 929.05) = 11.12, p < .001) details were all significant predictors of their subjective, self-report counterparts.

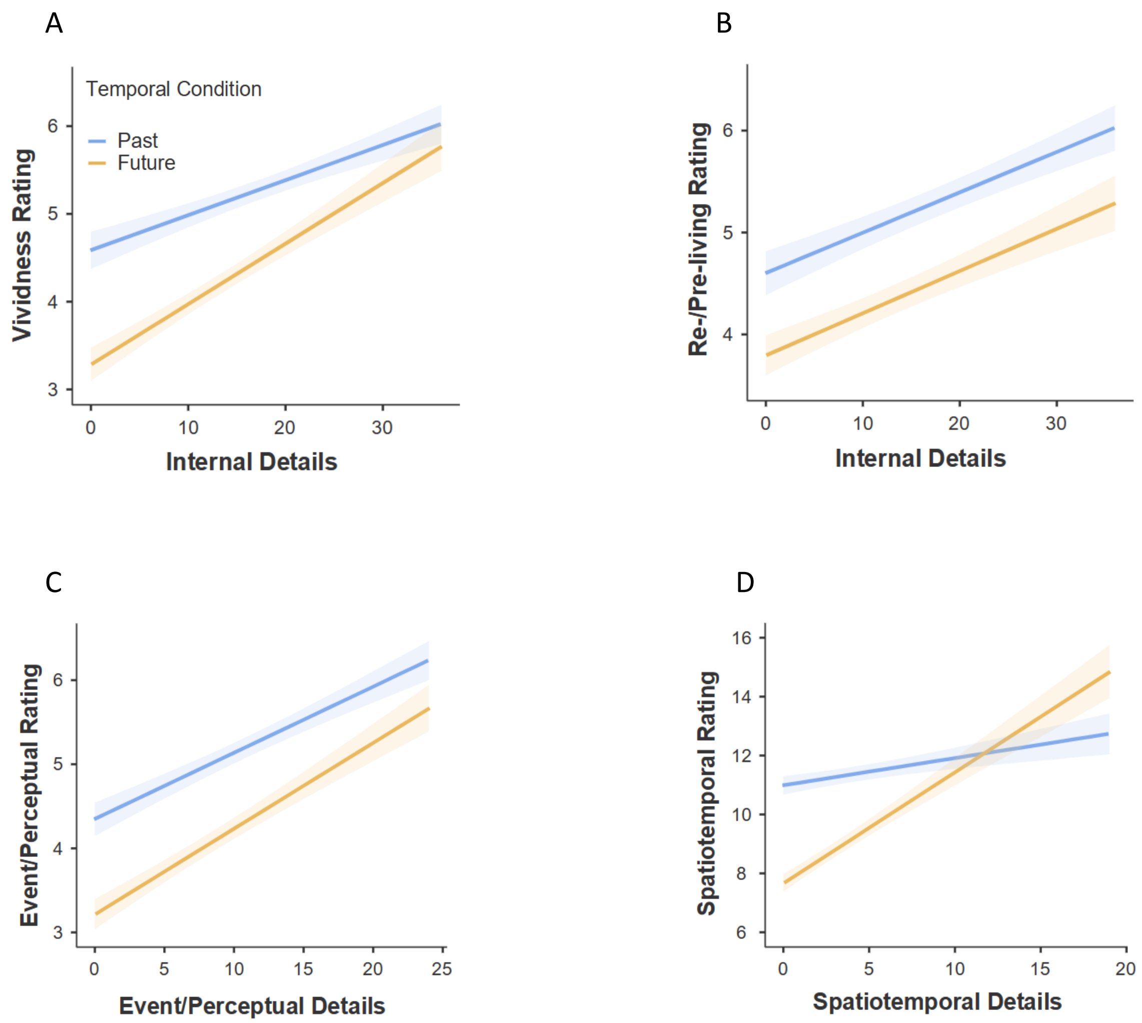
The effect of the internal details x temporal condition interaction (b = 0.029, SE = 0.014, F(1, 921.2) = 4.14, p = .036; see Figure 4A) for vividness ratings, spatiotemporal x temporal condition interaction (b = 0.285, SE = 0.065, F(1, 922.2) = 19.25, p < .001; see Figure 4D), and emotion/thought x temporal condition interaction (b = 0.083, SE = 0.040, F(1, 918.03) = 4.45, p = .035; see Figure 4E) were all significant, but the internal details x temporal condition interaction for re-/pre-living ratings (b = 0.002, SE = 0.012, F(1, 905.9) = 0.02, p = 0.881; see Figure 4B) and the event/perceptual x temporal condition interaction (b = 0.023, SE = 0.020, F(1, 914.4) = 1.35, p = .246; see Figure 4C) were both not significant.

Simple effects analysis was conducted for each temporal condition in the internal-vividness, spatiotemporal, and emotion/thought models. Internal and spatiotemporal details were significant predictors in both conditions but stronger in future events (Internal details: b = 0.069, SE = 0.011, F(1, 905) = 37.1, p < .001; spatiotemporal details: b = 0.318, SE = 0.054, F(1, 953) = 49.72, p < .001) than in past events (Internal details: b = 0.040, SE = 0.010, F(1, 919) = 14.9, p < .001; spatiotemporal details: b = 0.092, SE = 0.043, F(1, 953) = 4.50, p = .034). As was found in study one, emotion/thought details was a significant predictor in future events (b = 0.118, SE = 0.033, F(1, 955) = 12.76, p < .001), but not in past events (b = 0.035, SE = 0.028, F(1, 934) = 1.58, p = .209).

In all models, temporal condition significantly predicted the dependent variable, indicating that higher subjective ratings were reported in past events than in future events (bs = >-2.302, all ps <.001).

2.6.1.1. Effects of valence

For the internal-vividness (ps > .469), internal-re-/pre-living (all ps > .173) and spatiotemporal (ps > .216) models, there were no significant effects involving valence. For the event/perceptual model, valence significantly predicted participants' event/perceptual ratings, indicating that higher event/perceptual ratings were reported for positive events than negative events ($b = -0.353$, $SE = 0.090$, $F(1, 11.1) = 15.44$, $p = .002$) but no other effects involving valence were significant ($ps > .855$). The effect of the experimenter-scored emotion/thought details x temporal condition x valence interaction was significant ($b = 0.173$, $SE = 0.078$, $F(1, 907.52) = 4.98$, $p = .026$). Simple effects analysis for each temporal direction and valence revealed that for positive events, experimenter-scored emotion/thought details was not a significant predictor in past or future events ($ps > .058$; see Figure 4A). For negative events, experimenter-scored emotion/thought details was a significant predictor in future events ($b = 0.169$, $SE = 0.044$, $F(1, 931) = 14.90$, $p < .001$; see Figure 4B), but not in past events ($b = -0.001$, $SE = 0.039$, $F(1, 895) = 0.001$, $p = .972$; see Figure 4B). There were no other significant effects involving valence for the emotion/thought model ($ps > 0.69$).



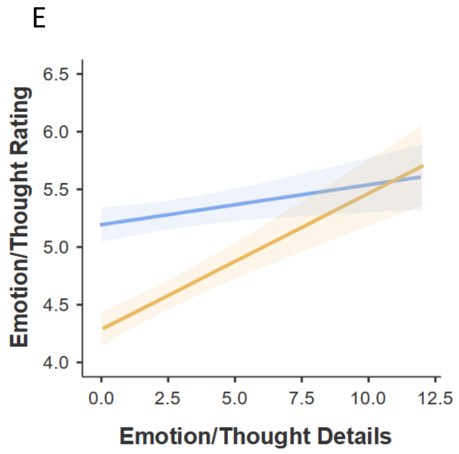


Figure 4. Results of study two's linear mixed-effects models for A) internal details and vividness B) internal details and re-/pre-living C) event/perceptual details D) spatiotemporal details E) emotion/thought details. Objective experimenter-scored details are on the X-axis and participant's subjective ratings on the Y-axis. Regression lines are shown for each temporal condition (past in blue, future in orange). Shaded areas represent the standard error.

3.6.2 Correlations

As previously, Kendall's Tau correlations were calculated. Other than a positive correlation between the emotion/thought measures in positive events, there were no significant relationships between experimenter-scored variables and participant ratings when examining past events (see Table 3). In the positive future condition, there were significant correlations between the broad internal category and vividness ratings as well as spatiotemporal and emotion/thought measures. In the negative future condition, there were significant correlations between the broad internal category and vividness ratings as well as event/perceptual, spatiotemporal, and emotion/thought measures. Descriptive statistics are presented in Appendix B.

Table 3. *Kendall's Tau correlation coefficients between internal details and subjective ratings for past and future events in study two*

	Past				**Future**			
	Positive		**Negative**		**Positive**		**Negative**	
	τ_b	**p**	**τ_b**	**p**	**τ_b**	**p**	**τ_b**	**p**
Internal – Vividness	.13	.06	.08	.16	**.16**	**.02**	**.15**	**.03**
Internal-Re-/Pre-living	.12	.06	-.02	.60	.13	.05	.04	.32
Event/Perceptual	.09	.12	.05	.28	.10	.11	**.15**	**.03**
Spatiotemporal	-.01	.47	.13	.05	**.18**	**.01**	**.26**	**.001**
Emotion/Thought	**.26**	**.001**	.08	.17	.10	.11	**.22**	**.003**

Note. Significant correlations are in bold. P-values can be different for the same correlation coefficients because all values have been rounded to two decimal places. P-values have been rounded to three decimal places if they are <.005.

2.7 Discussion

Does the subjective experience of mental time travel correspond with episodic content scored by the experimenter? The present studies aimed to explore this question by examining the relationship between subjective ratings and the AI scoring system (Levine et al., 2002). Positive relationships were expected between the objective number of episodic details and participants' ratings of remembered and imagined events. Linear mixed-effects models demonstrated that at the trial-level, the number of episodic details was significantly related to the vividness and re-/pre-living ratings provided by the participant in both temporal conditions across two independent studies. Positive relationships were also found in all episodic subcategories (event/perceptual, spatiotemporal, emotion/thought) and their corresponding participant ratings in both studies. Given the marked similarities between remembering the past and imagining the future (Schacter et al., 2012; Szpunar, 2010), objective and subjective measures were expected to be similarly related in both temporal conditions. However, several relationships were stronger, and some were only significant in the future condition. Relationships were stronger in future events for the spatiotemporal and emotion/thought subcategories in both studies as well as for the overall number of internal details and pre-living ratings in study one, and vividness ratings in study two. Similarly, when examined using correlations, significant relationships were revealed in the future condition only (except for the emotion/thought subcategory in positive past events in study two).

The mixed-effects models demonstrated that there is correspondence between the number of episodic details scored by the experimenter and the subjective ratings provided by the participant. As the topic of subjective versus objective measures is a current talking point in the literature (e.g. Clark & Maguire, 2020; Cooper & Ritchey, 2022; Thakral et al., 2020), this finding has important implications. As mental time travel is a complex and multi-faceted process, some have questioned whether these different measures are assessing the same aspects of retrieval (e.g. Clark & Maguire, 2020). However, as the present studies provide compelling evidence that internal details and subjective ratings correspond, it is evident that broadly speaking, subjective and objective measures are not dissociated. Rather, it is more likely that event-based and trait-based measures dissociate (Clark & Maguire, 2020; Palombo et al., 2013). This chapter provides clarification that internal details (Levine et al., 2002) and subjective ratings (vividness and re-/pre-living), two widely adopted measures, are assessing related or overlapping constructs. Namely, the degree of episodic content associated with a given episode. This research demonstrates for the first time that this correspondence extends to distinct episodic details. This provides particularly compelling evidence for the correspondence between objective content and subjective experience, as it shows that correspondence is not limited to broad conceptualisations of mental time travel, but it extends to fine-grained episodic details.

The present studies suggest that in healthy individuals, vividness and re-/pre-living judgements are based at least partially on the level of episodic detail that they can retrieve for a given episode. This indicates that in cases where a disjunction between these ratings and objective detail arises (e.g. posterior parietal cortex lesions: Ciaramelli et al., 2010, 2017; Davidson et al., 2008; Hower et al., 2014; Simons et al., 2010; Ageing; Duarte et al., 2008; Folville et al., 2021; Mark and Rugg, 1998), this is likely due to disruptions in normal functioning. For instance, it has been suggested that amnesic patients exhibit compensatory strategies in which episodic-like details are generated in the absence of re- or pre-experiencing (Palombo et al., 2015) and in ageing, disruptions in metamemory may result in inaccurate subjective judgements related to the quality of one's memories (Folville et al., 2020). In contrast, the present studies suggest in healthy young individuals, the episodic content used to describe an event can be used as a reliable proxy for certain subjective experiences. This provides some insight into the factors which are considered when forming a vividness or re-/pre-living judgement, indicating that to some degree, these ratings are ascribed to the amount of episodic detail which can be retrieved. This is a critical finding for mental time travel research, as understanding the exact constructs each measure is tapping is fundamental to designing an appropriate study to suit the given research question.

Although correspondence was demonstrated across all subcategories, the mixed-effects models indicated that several relationships were stronger in the future in comparison to the past condition. Given the marked parallels between remembering the past and imagining the future, these differences in temporality were rather unexpected. At face value, these temporal differences suggest that the objective measure is tapping subjective experience more so in episodic future thinking than in autobiographical memory. Yet there are several potential explanations for these results.

One factor which might explain these results is differences in the external event details generated between past and future events. If past events contained more external detail than future events this may have weakened relationships in this condition. As the external event subcategory is defined by episodic details belonging to episodes other than the identified main event (Levine et al., 2002), it is plausible that these details informed the participants' ratings. They may have described episodes which exceeded the 24-hour cut off, providing episodic details on events which occurred in the preceding or subsequent days or hours. According to the scoring protocol, these details are scored as external as they fall outside of the identified main event (Levine et al., 2002). As the participant would have included these details despite receiving explicit instructions to describe episodes no longer than 24 hours, this suggests they perceived this content as central to the main event. It is thus likely that that it was taken into consideration when scoring the episode. However, there is typically no difference in the number of external details generated in past and future events (Addis et al., 2008; De Brigard & Giovanello, 2012). Indeed, as can be seen in Appendix C, there is little difference in the number of external details generated between the past and future conditions. As both conditions prompted a similar number of external details, the idea that external content informed subjective ratings is not a viable explanation for the differences in temporality.

An alternative explanation relates to temporal proximity as the recency of events was not examined nor controlled in these studies. In comparison to remote episodes, past and future events that are temporally close tend to contain more specific detail and receive higher phenomenological ratings (Addis et al., 2008; Arnold et al., 2011; D'Argembeau & Van der Linden, 2004; Gamboz et al., 2010; Meléndez et al., 2018). Previous research has shown that on average, future events tend to be more proximal than past events when no recency constraints are imposed on the participant (Anderson et al., 2012). If future events were generally more recent than past events, this might explain why greater correspondence was seen in this condition. As recent events are typically experienced both more vividly and in richer episodic detail, this may lead to a tighter coupling between the objective and subjective assessments. If recency was driving the difference in correspondence between temporal conditions, higher scores would be expected in the future condition. However, as is shown in Tables A1, B1 and B2, past events contained more internal details and received higher subjective ratings. As future events in fact contained less detail and received lower ratings, it is unlikely that they were typically more recent. This suggests that temporal proximity cannot explain the greater correspondence observed in the future condition.

It is notable that event/perceptual was the only category in which correspondence was not stronger in the future condition, as this may provide some insight into the differences in temporality found in other variables. What distinguishes this subcategory is that it is based on two classes of episodic detail that are not normally aggregated. While event details refer to details such as happenings, occurrences, and people present, perceptual details are generally aspects of the recollection which are taken in through the senses, such as sounds, smells, and visual details (Levine et al., 2002). Event details are typically very high, comprising the majority of the overall internal category (Levine et al., 2002), whereas perceptual details are relatively low. It may be that objective event details are driving the results observed in the event/perceptual models, as the number of event details likely outweigh the number of perceptual details. As the subjective rating encompasses both event and perceptual aspects, participants might have allocated more weighting to the perceptual component of this question, basing their judgement more on the sensory aspects of people, objects and surroundings, rather than the presence of these details. Therefore, there is less consistency in the operationalisation of the experimenter-scored and participant-scored variables in this category, so the episodic content used to inform these ratings (i.e. perceptual detail) might not align with the major component of the experimenter's score (i.e. event details). This would explain why this relationship was not stronger in the future condition, as the objective content used to inform this rating was not in total alignment for this category.

Given these notable differences in the event/perceptual category and the lack of validation for alternative explanations, it is proposed that objective content has greater influence over subjective ratings for future events. While correspondence was generally demonstrated in both temporalities which suggests that episodic content informed all ratings to some degree, episodic detail had more influence in the future condition. This indicates that as well as episodic content, there were additional factors that informed past ratings which were not considered for future events. This may be due to one key difference which was outlined in section 1.5; memories are based on events that have taken place whereas future episodes are imaginary novel scenarios.

Future events are characterised by novelty. This distinguishes the future from the past condition, as the latter would have prompted memories of events that have already occurred, undergone encoding, and may have been talked or thought about several times. This is a critical distinction due to the design whereby events were rated immediately after describing them. Because novel future events were imagined and described on the spot, episodic content may have had a greater contribution to these ratings in comparison to ratings of past events. As future scenarios were imagined there and then for the purpose of the task, it is unsurprising that the episodic content provided just prior was the main source when forming subjective judgements. On the contrary, past events were constrained by real life experiences. As these events were retrieved rather than imagined, there might have been additional variables which informed subjective judgments related to memories. Possible factors include how confident the participant is in the accuracy of the memory (Pezdek, 2003), how often it has been talked or thought about since it happened (i.e. rehearsal; Ritchie et al., 2006; Skowronski & Walker, 2005), the participant's mood and cognitive state at the time of encoding (Ellis et al., 1984; Nasby & Yando, 1982), and whether the participant felt they could remember the event or simply knew that it happened (Tulving, 1985, 2002b). These factors are more relevant for the past condition as recounting past events requires the retrieval, reconstruction, and recollection of memories. As ratings of future events were completed seconds after a novel scenario was initially constructed, these additional factors would have been far less prevalent and would have had little Impact over subjective judgements in the future condition. Therefore, it is speculated that episodic content had greater influence over subjective judgements in the future condition, due to these episodes being formulated on the spot. As past events were constrained by real-life experiences, episodic content informed these ratings to a lesser degree, due to there being more additional influences over how memories are perceived.

Not only were there differences in the strength of relationships between temporal conditions, but the emotion/thought measures were not associated in the past, despite being significantly related in the future. As all other relationships were significant in both temporal conditions, this lack of alignment is noteworthy. Socially desirable responding is a critique of self-report ratings (Paulhus & Vazire, 2007) that could be responsible for this disjunction. As thoughts and feelings related to certain memories may be personal, the participant may not have disclosed these details to the experimenter but felt comfortable providing an accurate rating on a generically worded questionnaire (Panattoni & McLean, 2017). Thus, the participants omitted these details when verbally recounting the memory, which the objective scoring is based upon. Yet they took them into account when rating it. This might have only occurred in memories because there is a positivity bias in episodic future thinking where individuals imagine their future as more positive than their past (Berntsen & Bohn, 2010; Berntsen & Jacobsen, 2008; D'Argembeau & Van Der Linden, 2004; Newby-Clark & Ross, 2003; Rasmussen & Berntsen, 2013). As feelings associated with more negative episodes are likely to be more personal, perhaps the participants felt less inclined to describe these details in such cases. Although study two prompted both positive and negative events which should have reduced this effect, it is expected that negative cues prompted future events which were less negative than past events, due to the positivity bias. As positive emotions and thoughts are likely to have been more prevalent in the future condition, participants may have been more willing to disclose these details to the experimenter. The significant three-way interaction found in the emotion/thought model supports this theory as simple effects analysis indicated that for negative events, the experimenter-scored detail was a significant predictor for future, but not past events. This supports the idea that there was a selective disjunction between the detail provided to the experimenter and the participants' ratings in negative memories.

Simple effects analysis also demonstrated that emotion/thought measures were unrelated in positive events occurring in both the past and future. As participants are likely to be more willing to disclose positive emotions, socially desirable responding cannot explain the lack of correspondence in positive episodes. This suggests that while the positivity bias might be driving differences in temporality for negative episodes or events with no explicit valence, there are other factors causing misalignment for positive events in both the past and future. One possible explanation is that there were differences in the operationalisation of the experimenter-scored and participant-scored variables (Panattoni & McLean, 2017). This may have only occurred in the emotion/thought subcategory due to the AI scoring being based on the prevalence of emotion/thought details rather than the intensity of the emotion. For instance, the participant may have stated that they were 'so happy they could cry'. Even though this statement signifies extreme emotion, it would only equate to one emotion/thought detail when scored by the experimenter. When the participants rated their subjective experience of the episode, it is more likely that they based their rating on the intensity of the emotion during the event, rather than the number of different emotions involved. This is a probable explanation, as the question asked the participant to rate the clarity of their emotions and thoughts. It is thus suggested that for the emotion/thought category, subjective judgements were based on the intensity of the feelings experienced, rather than the amount of detail generated about them.

The differences between the mixed-effects models and the correlations are also of note. While mixed-effects modelling found that all measures were robustly related at the trial-level, correlating summed scores masked several of these relationships, revealing significant correlations in the future condition only. The distinguishing feature of the correlations was that rather than examining the relationship in each event, their association was assessed across events. Mixed-effects modelling increased the statistical power of these relationships (Yang et al., 2014), which might explain why certain relationships were not replicated. While the correlations echoed the results presented by the mixed-effects models, only the strongest relationships were significant in this less sensitive approach. If the present studies conducted correlations alone, a different and somewhat inaccurate set of conclusions would have been deduced – that internal details and subjective ratings correspond in the future but not the past. This demonstrates that aggregating data across trials is inappropriate in this context, in which the relationship between two event-based measures is examined. This may explain why previous studies adopting a similar approach failed to find relationships between the number of internal details and vividness ratings of autobiographical memories (Clark & Maguire, 2020) but demonstrated significant correlations in future events (Thakral et al., 2020). As demonstrated in the present studies, the correspondence between objective content and subjective ratings has a lesser effect size in past as compared to future events. As the previous research employed correlations, it is plausible that this less sensitive approach obscured correspondence in past events (Clark & Maguire, 2020) but not in future events (Thakral et al., 2020), where this relationship is stronger. By implementing both approaches, the present studies have illuminated the value of mixed-effects modelling as well as the limitations of summed scores in this area.

It is acknowledged that a limitation of the present studies is the aggregation of the event and perceptual subcategories. It is thus recommended that future research examines event and perceptual details separately, as they refer to distinct episodic details. As previously discussed, a mismatch between the objective and subjective scores might be why no temporal differences were observed in the variable. It is also proposed that future research either dictates the life periods in which events are retrieved or asks participants to rate the temporal distance of each episode. As no such constraints were imposed on the participant, participants might have generally discussed more recent events which may have contributed to the correspondence between the objective content and subjective ratings. As these amendments could provide further clarification on the factors underlying correspondence, they are proposed as recommendations for future studies.

A more novel avenue for future work is neuroimaging. Functional neuroimaging can provide knowledge into the constructs of mental time travel that subjective and objective measures are tapping into, thus providing complementary insights into the relationship between these assessments. One previous functional neuroimaging study found that the subjective vividness and objective content of imagined future events were uniquely sensitive to activity in the hippocampus and the bilateral lateral parietal cortex respectively (Thakral et al., 2020; see section 1.7.3 for more detail). Yet this study only assessed episodic future thinking. Future research should examine both autobiographical memory and episodic future thinking within the same sample. This is necessary to determine whether subjective and objective assessments are associated with common, distinct, or additional regions when remembering the past and imagining the future. This may provide insight into the neural mechanisms driving the differences in temporality in the present study. Given the differing levels of correspondence revealed across past and future events, it is speculated that subjective experience and episodic content might be uniquely sensitive to some additional regions when remembering. Future research can also extend the work conducted by Thakral et al. (2020), by examining the internal subcategories as well as additional subjective ratings. This will determine whether regions of the core network are sensitive to certain subcategories or phenomenological experiences, despite being insensitive to the broad internal category and/or vividness ratings.

As mental time travel is defined by subjective experience, selecting an appropriate measure is challenging. To understand the exact facets each measure is assessing, the relationship between different measures must be established. The present studies suggest that the AI scoring system (Levine et al., 2002) and subjective ratings correspond, and are therefore assessing somewhat overlapping constructs.

Chapter 3: Intra-individual differences in the subjective experience and objective content of mental time travel

3.1 Introduction

Whether mental time travel is stable across different episodes is a critical question with both practical and theoretical implications. Much of the literature is based upon the theoretical assumption that mental time travel is stable. However, if certain measures are not stable this would call into question the common practice of summing or averaging scores across different episodes. As discussed in Chapter 1, there is a considerable lack of knowledge about whether: i) episodic future thinking is stable, and ii) the stability demonstrated in subjective measures of autobiographical memories (Boyacioglu & Akfirat, 2015; Rubin, 2021; Rubin et al., 2003; Sutin & Robins, 2007; Talarico & Rubin, 2003; Vannucci et al., 2020; Vannucci et al., 2021) replicates in objective content. This is despite the widely accepted view that mental time travel is a trait (Palombo et al., 2018). If there is stability, this would suggest that the experience of mental time travel is largely defined by the individual, as opposed to the particular event. Therefore, similar characteristics would apply to all of the individual's memories. This would support the consensus that autobiographical memories are not an exact replica of the past but are re-constructed based on an individual's cognitive constraints and cultural dispositions (Addis, 2018; Hassabis & Maguire, 2007; Schacter & Addis, 2007). This view is supported by evidence that individuals with cognitive deficits such as impaired speech (Brien et al., 2020), diminished imagery (Dawes et al., 2022), and ruminative self-focus (Williams, 1996) have deficient autobiographical memory and that memories are altered to be shared through socially acceptable narratives, which vary substantially depending on one's culture (see section 1.8.1; Bartlett, 1932; Neisser, 1967; Rubin 2021). Thus, a high-level of stability would be anticipated across different autobiographical events. In this case, certain memory characteristics could be viewed as stable intra-individual differences which can be examined at the trait level. If they are unstable, this would suggest that memories should be measured at the event level.

As detailed in section 1.8.1, numerous studies have demonstrated that a vast array of subjective experiences are stable across autobiographical memories. These studies examined the internal consistencies of various phenomenological questionnaires and rating scales (Rubin, 2021; MEQ; Sutin & Robins, 2007; AMCQ; Boyacioglu & Akfirat, 2015; AMQ; Rubin et al., 2003; Talarico & Rubin, 2003; APAM; Vannucci et al., 2020; Vannucci et al., 2021). Many of these studies have assessed internal consistency using Cronbach's alpha (Cronbach, 1951), finding alphas above 0.70 for various memory characteristics. While an alpha of 0.70 or above suggests there is some variation between memories, this would be expected as phenomenological ratings are known to differ, due to factors such as temporality (D'Argembeau & Van der Linden, 2004; 2006), valence (Ford et al., 2012; Kensinger & Schacter, 2006; Rasmussen & Berntsen, 2009), recency (D'Argembeau & Van der Linden, 2004), and arousal (Ford et al., 2012). In fact, a maximum alpha of 0.90 has been recommended as very high alphas may indicate redundancy (Streiner, 2003; Tavakol & Dennick, 2011). Despite some expected variation between memories, as might be anticipated due to the specifics of the memory, this literature indicates that ratings of autobiographical memories are relatively stable.

While numerous studies have demonstrated stability in how participants rate autobiographical memories, there is limited evidence that subjective ratings are stable across future episodes. The existing findings have only examined visual perspective and vividness ratings (see section 1.8.1; Berg et al., 2021; Verhaeghen et al., 2018), whereas the memory literature has examined numerous phenomenological properties. Therefore, it is unclear whether other important characteristics are stable in episodic future thinking. Given their notable cognitive and neural similarities (see section 1.4), it may be expected that future event ratings would demonstrate a similar level of stability. On the other hand, as has been shown in previous research and in Chapter 2, phenomenological ratings differ depending on the temporal direction of the event (D'Argembeau & Van der Linden, 2004; 2006). In this regard, future ratings cannot be viewed as an exact replica of past ratings, and therefore may not mirror the same level of stability. The stability of a wide range of subjective ratings for future events will be explored in this chapter.

The literature discussed thus far is focused on subjective ratings rather than objective measures. Yet it was found in Chapter 2 that, while subjective and objective measures generally correspond, there are variations in the alignment of different temporalities and episodic characteristics. While these measures are broadly assessing the same constructs, there are separable contributions to each of these measures, and thus the stability which has been demonstrated in subjective ratings may not be replicated in objective content. Yet few studies have examined intra-individual variability using objective measures of episodic content.

As detailed in Chapter 1 (see section 1.8.1), only one study has examined whether internal details are stable across different memories in the AI (Lockrow et al., 2023). This study found that internal detail scores were robustly correlated across autobiographical memories from different time periods (childhood, teenage years, early adulthood, middle adulthood, late adulthood). This question has important practical implications. When analysing the AI, it is common practice to sum the number of internal details generated across autobiographical episodes. This calculation creates an internal composite score which is used as a measure of the overall quantity of episodic detail (Miloyan et al., 2019). In certain analyses, the use of composite scores may be masking meaningful results if internal details are unstable across autobiographical episodes. If participants are producing varying levels of episodic detail across events, this nuanced information will be lost once summed. If there is variability between events, the practice of summing internal details across memories may not be appropriate for analyses whereby potential differences between events could bias the results (e.g. the correlations conducted in Chapter 2).

Although Lockrow et al. (2023) have provided preliminary support for the stability of episodic content between autobiographical episodes, there are some significant gaps in this research. Their study only assessed autobiographical memories, not future experiences. It should be highlighted that internal composite scores are the most frequently used measure amongst studies using the adapted AI to assess episodic future thinking (Miloyan et al., 2019). Therefore, whether internal details are stable amongst future episodes is a fundamental question. However, this has not yet been examined. It cannot be assumed that the same level of stability is replicated in episodic future thinking. Furthermore, the analysis by Lockrow et al. (2023) is limited to the broad internal category. Yet the overall number of internal details is derived from various subcategories (event, time, place, perceptual, emotion/thought; Levine et al., 2002) which are often assessed separately and summed in the same manner to the broad internal category. Despite the widespread use of these composite scores, there are no previous studies which have examined the stability of these subcategories across episodes. Alike the overall internal scores, the stability of these subcategories must be established to substantiate the use of these composite scores.

The primary aim of this research is to examine the stability of objective content across both past and future episodes, addressing a largely unexplored question in the field – are internal details stable within healthy individuals? This will be completed using the same methodological procedures which are detailed in Chapter 2 (see section 2.2). This study goes beyond the present literature, by not just examining the broad internal category but also exploring the stability of the subcategories which define internal details (event, perceptual, time, place, emotions/thoughts). There are no previous studies which have done this, despite the multi-faceted nature of mental time travel and the widespread use of composite scores. Based on the findings by Lockrow et al. (2023), as well as indirect support that mental time travel is a trait (Palombo et al., 2018), it is hypothesised that internal details will have robust internal consistencies across both past and future episodes.

Due to the limited phenomenological characteristics which have been examined in future imaginings, the second aim is to explore the stability of subjective ratings. Because there is ambiguity as to whether future event ratings would replicate similar levels of stability to autobiographical memories, internal consistencies are examined for past and future events. As no previous studies have examined the stability of subjective ratings related to the episodic content of future events, the present study implements ratings related to broader subjective experiences (vividness and re-/pre-living) as well as specific episodic details (event/perceptual, spatiotemporal, emotion/thought). It is hypothesised that subjective ratings will have robust internal consistencies across both past and future episodes.

3.2 Method – study 1

3.2.1 Participants

The sample and exclusion criteria for this study are detailed in Chapter 2 (study 1, see section 2.2.1). As a traditional null hypothesis of H0 > 0 yields very small sample sizes in power analyses for Cronbach's alpha, H0 > 0.5 and H1 > 0.7 have been recommended when determining sample size (Bujang et al., 2018). Therefore, a post-hoc power analysis using a web-based sample size calculator (Arifin, 2023; http://wnarifin.github.io) was completed, indicating that a sample of n= 62 was required to achieve a statistical power of 0.8, with k[1]=5, a minimum acceptable Cronbach's alpha (H0) of 0.50, and an expected Cronbach's alpha (H1) of 0.70 (Bonett, 2002). Thus, the original sample of 82 participants was sufficient but 30 participants were excluded due to experimenter error, resulting in a sample of n=52.

As Cronbach's alpha is typically used to test the reliability of questionnaire items, there is a gap between what is hypothesised and what is 'acceptable' (Arifin, 2018; Bonnett, 2022; Bujang et al., 2018). To clarify, the null hypothesis is rejected if $\alpha > .70$ as this is the expected value based on the literature (see Table 4). However, as 0.50 is the minimum acceptable value, $\alpha > .50$ are interpreted as stable despite the null hypothesis being accepted: $\alpha < .50$ are interpreted as unstable and $\alpha > .50$ as stable (see Table 4).

Table 4. *Interpretation of Cronbach's alpha*

α	Interpretation	Hypothesis Testing
0.01 – 0.49	Unstable	Null hypothesis accepted
0.50 – 0.69	Stable (some variation)	Null hypothesis accepted
> 0.70	Stable (robust)	Null hypothesis rejected

3.2.2 Materials and procedure

This analysis used the data which is fully detailed in Chapter 2 (study 1, see section 2.2). The process by which this data was collected (and the process by which the AI scoring was

[1] K denotes the number of trials

performed) is described in the methods section of Chapter 2. In summary, participants were presented with ten cue words and asked to verbally describe an event (5 past, 5 future) in relation to each cue word. These event descriptions were scored according to the AI scoring system (Levine et al., 2002; see section 2.2.2.2) which is analysed in the present study. Participants also completed several subjective ratings following each narration (see section 2.2.2.3). These ratings were also analysed in the present study.

3.2.3 Data analysis

As in the studies from Chapter 2, the AI scores and participant ratings for time and place were aggregated to form a spatiotemporal category. The AI variables examined were event, perceptual, spatiotemporal, and emotion/thought subcategories, as well as the overall internal detail scores. A total of five subjective variables were analysed, which included two ratings related to the individual's general subjective experience (vividness and re-/pre-living ratings) as well as three ratings related to episodic content (event/perceptual, spatiotemporal, and emotion/thought ratings). Cronbach's alpha (Cronbach, 1951) was used to examine these variables' internal consistencies across the five events for each temporal direction. As the power analysis was based on a minimum acceptable alpha of .50 and an expected alpha of .70 (Bujang et al., 2018), variables with α <.50 were interpreted as unstable, α > .50 as stable, and α > .70 was taken as robust evidence for stability. In other words, alphas which fall above 0.50 but below 0.70 are interpreted as relatively stable, but with some evidence of variation between episodes. Yet the null hypothesis is rejected if α < .70 as based on the literature, it is expected that all variables will have α > .70 (see Table 4). It is acknowledged that implementing thresholds to interpret alpha is subject to some limitations (Cortina, 1993; Taber, 2018; Tavakol & Dennick, 2011) and therefore, all results are interpreted on a case-by-case basis. These cut off points are used only as a rule of thumb and values above and below are interpreted individually and not simply as 'satisfactory' or 'unsatisfactory'.

3.3 Results – study 1

Table 5 shows the means, standard deviations, and internal consistencies of the five AI variables for each temporal condition. In the past condition, Cronbach's alpha showed robust levels of stability (α > .70) for the broad internal category as well as the event and spatiotemporal subcategories. The internal consistency of the emotion/thought subcategory fellow below the robust threshold. In the future condition, Cronbach's alpha showed robust levels of stability in the broad internal category. However, the internal consistencies of the spatiotemporal and emotion/thought subcategories were both below the robust threshold. Other than the perceptual subcategory which fell below the acceptable threshold in past and future conditions, all variables had acceptable internal consistencies (α > .50) in both temporal conditions.

Table 5. *Internal consistencies between internal details across past and future events in study one*

	Past			**Future**		
	Mean	**SD**	**α**	**Mean**	**SD**	**α**
Internal	24.9	13.5	.81	16.6	8.36	.75
Event	14.5	10.1	.81	8.35	5.72	.71
Perceptual[2]	1.12	1.67	.11	0.53	0.88	.42
Spatiotemporal	6.82	4.85	.75	4.81	3.32	.65
Emotion/Thought	2.52	2.27	.61	1.17	1.51	.60

Table 6 shows the means, standard deviations, and internal consistencies of the five subjective ratings for each temporal direction. In both the past and future conditions, Cronbach's alpha demonstrated robust internal consistencies (α > .70) for vividness, re-/pre-living, and emotion/thought ratings. The Cronbach's alpha for event/perceptual and spatiotemporal ratings were acceptable (α > .50) but did not meet the robust threshold. Therefore, all the subjective ratings had acceptable internal consistencies in both temporal conditions.

[2] The aggregated event/perceptual subcategory was above the robust threshold in the past (α= .79, M= 15.6, SD= 8.83) and future (α= .73, M= 10.6, SD= 5.89) conditions

Table 6. *Internal consistencies between subjective ratings across past and future events in study one*

	Past			**Future**		
	Mean	**SD**	**α**	**Mean**	**SD**	**α**
Vividness	5.35	1.42	.84	4.37	1.45	.74
Re/Pre-Living	5.57	1.20	.79	4.70	1.34	.74
Event/Perceptual	5.52	1.31	.60	4.57	1.49	.64
Spatiotemporal	11.9	2.15	.53	9.47	2.81	.67
Emotion/Thought	5.28	1.35	.78	4.21	1.54	.78

3.4 Summary

It was hypothesised that all internal details would have robust internal consistencies (α > .70) across past and future episodes. Robust levels of stability were demonstrated in the broad internal category and the event subcategory in both temporal conditions. As the internal category represents the overall amount of episodic detail and event details comprise much of the internal detail count, this suggests that the overall level of episodic detail is robustly stable across different autobiographical episodes. In all but one AI variable, Cronbach's alpha demonstrated acceptable levels of stability (α > .50) across both past and future episodes, indicating that most internal details were relatively stable across different episodes. Despite this, there was evidence of some variation in the more fine-grained episodic subcategories. Spatiotemporal details met the robust threshold in the past condition but not in the future. Additionally, the emotion/thought subcategory fell below this cut-off in both conditions. Furthermore, the perceptual subcategory did not meet the acceptable threshold in either temporal condition, suggesting that these details were unstable. As the perceptual, spatiotemporal, and emotion/thought subcategories appear to be less stable and in some cases unstable, this suggests the stability of episodic content depends on the episodic detail in question.

It was also hypothesised that all subjective variables would have robust internal consistencies (α > .70) in both temporal conditions. The internal consistencies of vividness, re-/pre-living, and emotion/thought ratings appeared to be robustly stable, but event/perceptual and spatiotemporal ratings were somewhat less stable. Yet Cronbach's alpha demonstrated acceptable levels of stability (α > .50) across both past and future episodes in all subjective ratings. Consistent with the autobiographical memory research, this suggests that several phenomenological properties are similarly stable across both remembered and imagined events. With the exception of emotion/thought ratings, it appears that ratings related to the overall subjective experience (i.e. vividness and pre-living) are more stable than those related to episodic content (i.e. event/perceptual and spatiotemporal). However, it should be acknowledged that the internal consistency of emotion/thought ratings was also robust, and all the other episodic ratings were close to the α > 0.70 threshold (apart from spatiotemporal ratings of past events which was < .60). As no previous studies have examined subjective ratings related to the episodic content of future events, it is unclear whether these results reflect meaningful differences between overall experience versus episodic content.

3.5 Study 3: Online cue word paradigm and the Assessment of the Phenomenology of Autobiographical Memories

In study one, the stability of internal details was examined for the first time. Given the i) novelty of this finding, ii) the fact that the first study was underpowered, and iii) the unexpectedly low alphas observed in perceptual details, another study was conducted in a larger sample to establish whether these results replicated. This issue was not examined in study two which was described in section 2.5, because of its valence manipulation. To examine the stability for each valence, internal consistencies would need to be calculated across three trials. This is a relatively low number of trials to reliably assess internal consistencies (Cortina, 1993) and it is less than the typical number of events that is prompted by the traditional AI (Levine et al., 2002). The alternative approach was to examine internal consistencies across six trials by collapsing positive and negative cues for each temporal direction. However, both episodic content (Ford et al., 2012; Holland & Kensinger, 2010) and subjective ratings (Arnold et al., 2011; D'Argembeau & Van der Linden, 2004; Kensinger & Schacter, 2006; Rasmussen & Berntsen, 2009) are known to vary depending on the valence of the episode. Therefore, if the measures were found to be unstable, there would be uncertainty as to whether this reflected a true lack of stability or whether this would be due to either i) a low number of trials or ii) the inconsistencies between positive and negative events. Hence a new study was conducted with a larger sample of participants and a more comprehensive range of subjective questions. In study three, participants completed an online version of the cue word paradigm in which they typed their event descriptions. The Cronbach's alphas were examined to determine whether the internal consistencies in the AI categories from study one replicated.

This second study aims to replicate but also extend what was found in the previous study by examining several additional subjective ratings which assess more fine-grained subsets of subjective experience and episodic details. The previous study examined two ratings related to overall subjective experience and three related to specific episodic details. Although ratings of vividness and pre-living were more stable than ratings of certain episodic details, this is one of the first studies to examine intra-individual differences in future episodes. Therefore, it is unclear whether these differences are replicable. In study three, participants completed the original and an adapted version of the Assessment of the Phenomenology of Autobiographical Memory (APAM; Vannucci et al., 2020; 2021) to examine a vast array of additional subjective ratings. The present study will examine internal consistencies of APAM ratings of past and future events. As the APAM items have previously shown robust levels of internal consistency ($\alpha > .70$) across autobiographical memories (Vannucci et al., 2020; 2021) and study one revealed similar alphas in both temporal conditions, it is hypothesised that these variables will have robust internal consistencies ($\alpha > .70$) in both temporal conditions.

3.6 Method – study 3

3.6.1 Participants

A sample of n= 90 healthy undergraduate students (82 female; aged 18-41; mean age= 19.6, SD= 2.73) took part in the study. All participants were required to be fluent in English and confident in their ability to type written English. Written consent was obtained from all participants prior to testing. Participants received course credit for their time. This research was reviewed and approved by Cardiff University School of Psychology Ethics Committee. No participants were excluded.

A power analysis indicated that n=66 was sufficient to achieve a statistical power of 0.8, with k=4, a minimum acceptable Cronbach's alpha (H0) of 0.5, and an expected Cronbach's alpha (H1) of 0.7 (Arifin, 2018; Bonett, 2002).

3.6.2 Materials

In the second study, the AI scoring system (Levine et al., 2002) was consistent with the first study. However, the cue word paradigm was adapted to be completed online using Zoom. All participants were tested individually using the camera feature on Zoom. The experimenter presented the participant with a series of cue words to prompt both past and future events. Participants then typed a description of an event relating to the cue word via Qualtrics. Each cue word was presented one by one and a time-limit of two minutes per cue word was implemented. A total of eight cue words was used to generate four past and four future events. Participants typed descriptions for four events for one temporal direction (past or future) before beginning the next condition. The order of temporal condition was counterbalanced across participants, resulting in two versions of the task (past then future, future then past). The cue words were divided into two groups (Group A = Memorable Meal, Party, Day Trip, Shopping; Group B = Achievement, Animals/Pets, Birthday, Exam) which were also counterbalanced across past and future conditions. The order in which cue words were presented was consistent in all conditions.

Scoring was completed by two raters and all transcripts were double scored. An intra-class correlation analysis (ICC; two-way random model conducted in IBM SPSS statistics 26) was conducted to evaluate the inter-rater consistency across all AI subcategories. Significant ICCs (all ps < .01) were observed for the broad internal category (r= 0.98) and the internal subcategories (event r=0.96; time r= 0.93; place r= 0.98; perceptual r= 0.98; emotion/thought r= 0.99).

3.6.2.1 The Assessment of the Phenomenology of Autobiographical Memory

The Assessment of the Phenomenology of Autobiographical Memory (APAM; Vannucci et al., 2020) is a validated measure of the phenomenological characteristics of autobiographical memory. The original APAM is a 27-item questionnaire in which each item relates to a distinct phenomenological property of memory. As this measure was used in the current study to measure self-report of characteristics for past and future events, only items that participants could answer for both temporal directions were examined. These are outlined in Table 7. Items related to remember/know, confidence in accuracy, emotional reliving, rehearsal, and whether the event was imagined or real were excluded for the future APAM as they were not applicable in this context. The adapted APAM included 19 items related to the phenomenology of imagined future experiences which each had a 7-point Likert scale (see Table 7).

Table 7. *The items used from the Assessment of the Phenomenology of Autobiographical Memory (APAM; Vannucci et al., 2020) with their wording for the past condition (future in italics) and the rating scale*

Item	**Question and Rating**
Clarity	My memory/*imagination* for this event is (1= dim; 7= sharp/clear)
Colour	My memory/*imagination* for this event is (1= black and white; 7= entirely coloured)
Vividness	My memory/*imagination* for this event is (1= vague; 7 = very vivid)
Visual details	My memory/*imagination* for this event involves visual detail (1 = little or none; 7 = a lot)

Sound	My memory/*imagination* for this event involves sound (1 = little or none; 7 = a lot)
Smell	My memory/*imagination* for this event involves smell (1 = little or none; 7 = a lot)
Touch	My memory/*imagination* for this event involves touch (1 = little or none; 7 = a lot)
Taste	My memory/*imagination* for this event involves taste (1 = little or none; 7 = a lot)
Sensory re-/pre-living	As I remember the event, I feel as though I am reliving the original event *As I imagine the event, I feel as though I am there* (1= not at all ; 7 = as clearly as if it were happening right now)
Auditory re-/pre-living	As I remember/*imagine* the event, I can hear it in my mind (1= not at all; 7 = as clearly as if it were happening right now)
Visual re-/pre-living	As I remember/*imagine* the event, I can see it in my mind (1= not at all; 7 = as clearly as if it were happening right now)
Spatial re-/pre-living	As I remember the event, I can recall the setting where it occurred *As I imagine the event, I can envision the setting where it will occur* (1= not at all; 7 = as clearly as if it were happening right now)
Formulation in words	As I remember/*imagine* the event, it comes to me in words (1= completely disagree; 7= completely agree)

Coherence	As I remember/*imagine* the event, it comes to me in words or in pictures as a coherent story or episode and not as an isolated fact, observation, or scene (1= completely disagree; 7= completely agree)
Accessibility	This memory/*event* just sprang to my mind when I was shown the cue word (1= completely disagree; 7= completely agree)
Visual perspective	I view this memory as if I was an observer to the experience *I view this event as if I am an observer to the experience* (1= completely disagree; 7= completely agree)
Emotional intensity	As I remember the event, my feelings are intense *As I imagine the event, my feelings are intense* (1= not at all; 7 = a lot)
Self-distancing	I feel like the person in this memory/*event* is a different person than who I am today (1= completely disagree; 7= completely agree)
Personal importance	This memory/*event* is significant for my life because it imparts an important message for me or represents an anchor, critical juncture, or a turning point (1= completely disagree; 7= completely agree)

3.6.2.2 The Survey of Autobiographical Memory

As detailed in section 1.7.2.2, the SAM is a self-report questionnaire used to measure self-perceived autobiographical memory abilities (Palombo et al., 2013). Prior to completing the cue word paradigm, participants completed the full 26-item version of the SAM. The SAM was administered prior to the cue word paradigm to avoid participants basing their responses to the SAM on their performance from the main task. Rather than rating specific events, the SAM asks participants to rate their general mnemonic abilities according to various statements. These are rated on a five-point Likert scale from 'strongly disagree' to 'strongly agree'. SAM-semantic, SAM-spatial, and SAM-total scores were all calculated according to the original weighting protocol (provided by Brian Levine). The SAM is not analysed in this chapter (see Chapter 4 for analysis of the SAM).

3.6.2.3 The Beck Depression Inventory

The Beck Depression Inventory (BDI-II; Beck et al., 1996) is a 21-item, self-report questionnaire that measures the characteristic attitudes and symptoms of depression. The BDI-II asks participants to rate various experiences on a 4-point Likert from 0 to 3 (e.g. Crying: 0 = I don't cry anymore than I used to; 1 = I cry more than I used to; 2 = I cry over every little thing; 3 = I feel like crying, but I can't). One item related to suicidal thoughts and wishes was not administered due to ethical constraints. The BDI-II (mean score= 14.3, range= 1-35) is not analysed in this chapter (see Chapter 4 for analysis of the BDI-II).

3.6.3 Procedure

Participants completed all tasks in one online session. The O-LIFE, SAM, and BDI questionnaires were first completed via Qualtrics before commencing the cue word paradigm. This online version was largely similar to the paradigms from the first study, but one key adaptation was made to the procedure. Rather than providing verbal descriptions in response to cue words, participants typed their descriptions of autobiographical events into a response box on Qualtrics. As in study one, cue words were presented visually (using cue-cards) and verbally by the experimenter. Participants were informed by the experimenter once they had reached the two-minute time limit and in the instance that a participant finished their response before they had reached the limit, they were probed using a standardised prompt such as 'Are there any other specific details you can think of?'. Once the participant had completed each event description, they completed either the original or adapted version of the APAM (Vannucci et al., 2020). The experimenter and the participant remained on the Zoom call for the entire study session. One and a half hours were scheduled for each participant. Otherwise, the procedure was consistent with the first study.

3.6.4 Data analysis

All aspects of data analysis were identical to study one.

3.7 Results – study 3

Table 8 shows the means, standard deviations, and internal consistencies of the five AI variables for each temporal condition. In both temporal conditions, Cronbach's alpha showed robust levels of stability (α > .70) in the broad internal category and the event subcategory. However, the internal consistencies of the spatiotemporal and emotion/thought subcategories did not meet this threshold in either temporal condition, and the perceptual subcategory met the robust threshold in the future but not the past condition. All variables had acceptable internal consistencies (α > .50) in both temporal conditions.

Table 8. *Internal consistencies between internal details of past and future events in study three*

	Past			Future		
	Mean	**SD**	**α**	**Mean**	**SD**	**α**
Internal	18.1	6.69	.82	15.4	6.45	.84
Event	10.8	4.22	.77	9.32	4.40	.80
Perceptual[3]	1.44	1.88	.62	1.23	1.77	.71
Spatiotemporal	4.75	2.96	.62	3.76	2.73	.57
Emotion/Thought	1.17	1.41	.56	1.15	1.49	.53

[3] The aggregated event/perceptual subcategory was above the robust threshold in the past (α= .79, M= 12.2, SD= 4.97) and future (α= .83, M= 10.5, SD= 4.94) conditions

Table 9 shows the means, standard deviations, and internal consistencies of the nineteen APAM ratings for each temporal condition. In the past condition, Cronbach's alphas were robust (α > .70) for sensory re-living, auditory re-living, visual re-living, formulation in words, coherence, and visual perspective ratings. The internal consistencies of clarity, colour, vividness, visual details, sound, smell, touch, spatial re-living, accessibility, emotional intensity, and personal importance all fell below the robust threshold but were acceptable (α > .50). Taste and self-distancing ratings fell below the acceptable threshold in the past condition (α < .50). In the future condition, Cronbach's alphas were robust (α > .70) for clarity, smell, touch, sensory pre-living, auditory pre-living, visual pre-living, formulation in words, coherence, visual perspective, and emotional intensity ratings. However, the internal consistencies of colour, vividness, visual details, sound, taste, spatial pre-living, accessibility, self-distancing and personal importance all fell below this threshold. All APAM ratings had acceptable internal consistencies (α > .50) in the future condition.

Table 9. *Internal consistencies between subjective ratings of past and future events in study three*

	Past			Future		
	Mean	**SD**	**α**	**Mean**	**SD**	**α**
Clarity	5.42	0.90	.57	4.90	1.50	.71
Colour	6.11	0.88	.65	5.72	1.48	.69
Vividness	5.36	0.97	.60	4.76	1.60	.67
Visual details	5.83	0.85	.65	5.29	1.52	.61
Sound	4.04	1.39	.64	3.73	2.04	.63
Smell	2.67	1.33	.65	2.66	1.91	.70
Touch	3.37	1.46	.69	3.30	2.02	.76
Taste	2.73	1.25	.49	2.71	2.00	.66
Sensory re-/pre-living	4.66	1.15	.72	4.74	1.67	.79
Auditory re-/pre-living	3.88	1.50	.80	3.71	1.87	.74
Visual re-/pre-living	5.51	0.84	.71	5.31	1.36	.74
Spatial re-/pre-living	6.08	0.76	.58	5.41	1.52	.54
Formulation in words	3.66	1.78	.92	3.46	1.84	.90

Coherence	4.94	1.34	.78	4.49	1.81	.76
Accessibility	5.56	1.10	.66	5.07	1.69	.67
Visual perspective	3.58	1.53	.80	3.81	1.90	.75
Emotional intensity	3.73	1.25	.62	3.98	1.78	.71
Self-distancing	4.31	1.32	.42	3.20	1.95	.57
Personal importance	3.55	1.36	.62	3.62	2.02	.58

3.8 Discussion

The present studies aimed to determine whether objective content and subjective ratings are stable across different remembered and imagined episodes. It was hypothesised that both internal details and subjective ratings would have robust internal consistencies in both temporal conditions. Contrary to this hypothesis, not all variables met the threshold for being robust. Yet all but one objective variable and two subjective variables had acceptable levels of stability in both temporal conditions across studies one and three. While the number of perceptual details scored by the experimenter appeared to be unstable in study one, in study three, this subcategory was acceptably stable in past events and robustly stable in future events. Although several internal consistencies were not robust, the overwhelming majority of variables were relatively stable, with evidence of some variation between episodes. While this shows there are some differences in stability amongst characteristics, overall, these results suggest that mental time travel is a stable intra-individual difference which can be examined at the trait level.

It should be highlighted that both objective content and subjective ratings had similar internal consistencies in both temporal conditions across study one and three. This demonstrates that both measures were similarly stable in mental time travel into the past and future, suggesting that the stability which has been previously demonstrated in autobiographical memory (e.g. Lockrow, 2023; Rubin, 2020; Rubin, 2021) is also found in episodic future thinking. This supports the theory that remembering the past and imagining the future rely on the same cognitive mechanisms (Addis, 2018; Hassabis & Maguire, 2007; Schacter & Addis, 2007). Indeed, this indicates that both processes are attributable to one individual difference dimension related to mental time travel, rather than separable dimensions for autobiographical memory and episodic future thinking. For the first time, this shows that both objective content and subjective experience are similarly stable in both forms of mental time travel, adding to the growing body of literature demonstrating similarities between memory and future thinking.

3.8.1 The stability of objective episodic content

For the AI, the pattern which was observed in both studies was that the broad internal category and event subcategory were more stable than the perceptual, spatiotemporal, and emotion/thought subcategories (excepting the spatiotemporal subcategory in the past condition in study one and the perceptual subcategory in the future condition in study two). As event details comprise most of the internal detail score, this suggests that the overall amount of episodic detail is stable whereas the fine-grained content is more variable across episodes. This indicates that specific episodic content is defined more by the episode, whereas the general level of episodic detail is defined by the individual. Nevertheless, for the first time, both studies have demonstrated that all internal details are relatively stable across both remembered and imagined episodes. This suggests that the amount of episodic detail in which events are described remains somewhat consistent, regardless of temporality.

As the broad internal category was robustly stable in both temporal conditions, the use of internal composite scores is supported. As participants are generating similar levels of internal details across events, summing across episodes should provide an accurate measure of the participant's overall quantity of episodic detail. The present studies examined internal detail scores across four to five episodes, which is typical in autobiographical memory research as the traditional AI prompts memories from five different lifetime periods (Levine et al., 2002). As stability was demonstrated across this number of cues, the use of internal composite scores is substantiated for future research that adopts the original protocol or prompts a similar number of episodes. Although it is notable that summing across autobiographical episodes may be less appropriate for the internal subcategories, which differ more from episode to episode. If we take the studies conducted in Chapter 2 as an example, the subcategories' composite scores might be less insightful than the trial-level data because the variation between episodes is not captured.

As it is common practice to examine autobiographical abilities at the event level, this is an important consideration for future research. For instance, it is typical to assess constructs such as specificity (Kopelman et al., 1989; Williams & Broadbent, 1986), valence (e.g. Ford et al., 2012; Wisco & Nolen-Hoeksema, 2010), and linguistics (e.g. Marian & Kaushanskaya, 2007) of remembered and imagined events. If alike Chapter 2, the relationship between these event-based measures and internal subcategories is to be examined, a trial-level analysis is recommended. Yet it should be highlighted that these are considerations for research implementing the internal subcategories only, as the overall internal details were highly stable, substantiating the use of internal composite scores.

It should be highlighted that in study one, the amount of perceptual detail scored by the experimenter was unstable across past and future episodes. While this instability is noteworthy, this finding was not replicated in study three. It could be argued that this resulted from the first study being underpowered or from methodological differences between the two studies, such as descriptions being typed rather than verbalised and adaptations to some cue words. Yet the other internal subcategories did not follow the same pattern. As one would expect internal consistencies of all details to be similarly impacted by these broad methodological differences, it is improbable that this is what was driving the inconsistencies observed in the perceptual scores. This begs the question: what distinguishes perceptual details from the other internal subcategories?

Unlike other episodic details, the perceptual subcategory is defined by sensory characteristics and therefore, is likely to be highly dependent on mental imagery; the ability to construct complex sensory representations in the absence of sensory stimulation (Pearson et al., 2015). Imagery and mental time travel are related (Conti & Irish, 2021; Dawes et al., 2022; Palombo et al., 2018; Sheldon et al., 2016; Vannucci et al., 2020), and imagery itself is stable (Andrade et al., 2014; Blajenkova et al., 2006; McKelvie, 1995). It has been evidenced that imagery is particularly important for perceptual content as aphantasic individuals, who lack the ability to mentally visualise, generate less perceptual details in comparison to healthy controls (Dawes et al., 2022). Interestingly, this reduction in aphantasia was particularly marked for visual details in comparison to other sensory experiences. This indicates that reductions in perceptual content were driven by a lack of visual details, due to a diminished capacity for visual imagery. This suggests that, as visual imagery is a trait, perceptual details that are visual should be stable. However, not only is the perceptual score defined by other sensory experiences (see Table 1), but mental imagery can occur in any sensory modality (Andrade et al., 2014). In this regard, perceptual details pertaining to senses other than vision would require a different modality of imagery, which might not be as stable as visual imagery. Although the stability of different forms of imagery has not been explicitly examined, there is evidence that visual, sound, smell, taste, touch, bodily sensations, and emotion imagery receive different vividness ratings within the same participant (Andrade et al., 2014). This suggests that different modalities of imagery may be less stable than visual imagery. Therefore, perhaps due to the different cue words implemented between the two studies, study three prompted more visual details whereas study one prompted more sound, smell, taste, and touch details. If the perceptual content of study one was more variable and less centred around visual aspects, this may explain the lesser stability found in this particular study.

3.8.2 The stability of subjective ratings

As in the objective measures, there was some variation in the stability of different subjective ratings in both studies. It should be noted that these results are inconsistent with previous research, which found high alphas (> .70) for various characteristics of autobiographical memory (Rubin, 2021; Vannucci et al., 2020). A key difference which may explain these discrepancies is that while the present studies cued four to five episodes, Rubin (2021) cued seven memories and Vannucci et al. (2020) prompted twelve. As Cronbach's alpha is partially based on the number of items analysed (Cronbach, 1951; Cortina, 1993; Tavakol & Dennick, 2011), it could be argued that cases where variables were less stable were due to there being an insufficient number of trials. However, as robust stability (> 0.70) was revealed in several of the present variables, it is unlikely that the lower number of trials was responsible in such cases where this threshold was not met. Yet it may explain why the alphas in the present studies are somewhat lower than those found by previous studies. Indeed, Berg et al. (2021) showed that stability estimates of visual perspective and vividness ratings increased with the number of trials, reaching 'moderate stability' (> .60) when tested across five to seven trials and 'substantial stability' (> .80) across twenty trials. However, as the size of alpha is determined by both the number of trials as well as their inter-item correlations (Cortina, 1993), increasing the number of trials would have inevitably led to increased alphas (Tavakol & Dennick, 2011). This is a conceptual limitation of Cronbach's alpha as there is not a pre-determined number of trials that would be advantageous. As the traditional AI prompts five life periods (Levine et al., 2002), this was an appropriate number for the present studies as it ensures that composite scores are providing an accurate insight into the level of episodic detail one provides. In this regard, examining a higher number of trials would provide little further insight. The low number of trials may explain why the alphas were lower in the present study in comparison to previous research, but it does not explain why there was variation between different variables.

It is more likely that variation arose in the subjective measures simply because certain episodic details vary between episodes. It is arguably unsurprising that measures such as event/perceptual and spatiotemporal ratings, which naturally differ depending on the event, were less stable than vividness and re-/pre-living ratings, which relate more to the participant's general experience. The notion that these broader experiences are more stable is supported by the wider literature on individual differences. One of the core characteristics of HSAM is a self-reported ability to recollect all memories vividly (Ally et al., 2013; Parker et al., 2006). By contrast, people with SDAM provide consistently low vividness ratings (Fuentemilla et al., 2018; Palombo et al., 2015) irrespective of factors such as how recent the memory is (Palombo et al., 2018). This suggests that broad characteristics such as how vividly events are experienced, are defined by the individual's general capacity for mental time travel. The present studies indicate that more specific experiences, such as episodic content, varies more from episode-to-episode. This is a comparable pattern to what was found in the broad internal category versus the internal subcategories. When taken together, these results provide compelling evidence that specific episodic content is defined more by the autobiographical event in question. Moreover, alike the overall amount of episodic detail, broader subjective experience including the vividness in which the event is experienced and the extent to which the participant felt present, is determined more by the individual than the particular episode.

While subjective ratings related to episodic content were generally less stable than the broader ratings related to vividness and re/pre-living in study one, high levels of stability were revealed across the subjective emotion/thought ratings (and the emotional intensity rating in study three); which represent fine-grained episodic detail. What distinguishes these details from the other episodic categories is that they are not tangible, image-based details occurring in the external environment. Emotions and thoughts are internal experiences that are verbalised, conceptual, or reflective (see Andrews-Hanna & Grilli, 2021 for a similar distinction between the 'mind's eye' and the 'mind's mind'). In this regard, emotions and thoughts are rather distinct from other episodic details. The existence of event, perceptual, or spatiotemporal details is often beyond our control. For instance, the sound of a telephone ringing or the presence of a given individual are environmental factors which often cease at their own accord. By contrast, thoughts and feelings are shaped solely by the individual, arising and dissolving in consciousness. It is a common belief that one's sense of self is defined by their thoughts. As famously put by Descartes, "I think, therefore I am" or "Cogito, ergo sum" (Maclean, 2006). As the self is a continuous concept (Conway et al., 2019), it is unsurprising that one's thoughts and feelings received consistent ratings across different autobiographical events. To maintain cohesion between oneself and their thoughts, it is essential that they remain somewhat stable. The other episodic categories (event, perceptual, spatiotemporal) are by contrast, details which vary depending on our environment and external circumstances. These details are affected by the particular scenario more than emotions and thoughts, which are defined by the given individual.

The greater stability observed in the subjective emotion/thought ratings was not mirrored in the objective emotion/thought subcategory, which only met the acceptable threshold. Yet it should be noted that across both studies in Chapter 2, the emotion/thought subcategory was the only episodic detail which did not correspond with its subjective counterpart, specifically in past events. Hence it is unsurprising that the alphas observed in the subjective ratings are not replicas of those found in the objective measure. If we take the view adopted in Chapter 2, perhaps they were more stable in the subjective assessment as this provides a more accurate insight into what was being experienced by the participant. If participants were omitting various details in their descriptions to the experimenter, this could have reduced their stability. Similarly, the difference in the operationalisation of these variables might be responsible for the lesser stability observed in the objective score. If participants were ascribing their ratings to the intensity of their emotion, this might explain why the subjective scores had higher alphas; because emotional intensity is stable (Larsen &

Diener, 1987). As the objective score is based upon the number of different emotions or thoughts that were described, it is unsurprising that this is less stable between different episodes. While such differences may account for why the subjective alphas met the robust threshold and the objective counterpart did not, it should be emphasised that both the subjective rating and objective scores for emotion/thought met the acceptable threshold. This indicates that emotions and thoughts were somewhat stable, regardless of the assessment.

3.8.3 The stability of the Assessment of the Phenomenology of Autobiographical Memory

In study three, past and future events were rated by participants according to a vast array of phenomenological characteristics. Several APAM ratings demonstrated robust stability, but various ratings were less stable. It is notable that for several APAM items, internal consistencies were somewhat lower than those previously found across autobiographical memories (Vannucci et al., 2020). As alphas are comparable across past and future APAM ratings in the present chapter, it is anticipated that differences in study characteristics are driving the lesser consistency observed in this chapter relative to the study by Vannucci et al. (2020). The cue words adopted by Vannucci et al. (2020) are distinct from the words used to prompt mental time travel in this chapter. Many of the words used by Vannucci et al. (2020) were proper nouns (e.g. wine, dress) whereas the words adopted in the present chapter refer to events (e.g. party, day trip, shopping) that were selected to prompt more specific autobiographical episodes. It is speculated that proper nouns elicit general autobiographical events, which contain more consistent phenomenological detail than the specific events probed in this chapter.

The internal consistencies observed in this chapter were also more variable than those found by Vannucci et al. (2020). One possible factor which might underlie these differences is visual imagery. As mental time travel and visual imagery are linked (Conti & Irish, 2021; Dawes et al., 2022; Palombo et al., 2018; Sheldon et al., 2016; Vannucci et al., 2020), perhaps this variation between the APAM ratings was due to the amount of imagery each rating required, with ratings more dependent on visual imagery being more stable. Indeed, several imagery-related ratings such as sensory pre-living, coherence, and visual perspective demonstrated robust stability in both temporal conditions whereas more conceptual characteristics such as self-distancing and personal importance had lower alphas. While it should be noted that colour, vividness, and sensory pre-living ratings are also likely to highly depend on visual imagery, these ratings had alphas which were close to the robust threshold and are thus interpreted as having a high, albeit slightly lower level of stability. Thus, it is speculated that subjective ratings are dependent on visual imagery, leading to lower alphas in more conceptual characteristics and higher alphas in imagery-related variables.

As there is some preliminary evidence that the vividness of different modalities of imagery differs within participants (Andrade et al., 2014), it might be that in contrast to ratings involving a high degree of visual imagery, ratings more reliant on other modalities of imagery are less stable. Therefore, perhaps variation in internal consistencies is due to different levels of reliance on distinct types of imagery. The APAM ratings assessed different sensory experiences, revealing for instance, that taste was less stable than touch. This may be because imagery in certain modalities is less stable, and this rating was naturally more dependent on taste imagery. As mental time travel is dependent on imagery, perhaps modality-related differences in imagery are responsible for the variation observed in the APAM.

It was surprising that in the past condition, two APAM ratings did not meet the threshold for acceptable stability: taste and self-distancing ratings. Yet it should be noted that taste ratings were extremely close to this threshold. This particular rating might have just missed this threshold due to the inclusion of the cue ‘memorable meal’. As this cue is likely to have elicited memories that involve a higher degree of taste details than the other cues, perhaps this cue word is driving the instability of this rating. On the other hand, self-distancing ratings were based on the statement: ‘I feel like the person in this memory is a different person than who I am today’. It is somewhat surprising that this rating was acceptably stable in the future condition but unstable across memories. Yet it is speculated that this temporal difference is due to recency effects. When no time constraints are in place, participants generally select future events that are more recent than past events (Anderson et al., 2012). This is unsurprising as future events were generated for the purpose of the task whereas past events were constrained by real experiences, which are likely to be more variable in temporal proximity. Therefore, it is speculated that varying levels of recency are responsible for the lower alpha observed in this particular rating, which is related to an individual feeling that they are ‘a different person that who they are today’.

It was also unexpected that some APAM ratings did not meet the robust threshold. Visual details only demonstrated moderate stability in both temporalities (>.60; Berg et al., 2021; Shrout, 1998), which was surprising as this rating is likely to have required a high level of visual imagery. Yet this rating might have been less stable because the visual properties of each event varied from episode-to-episode. This rating does not ask the participant to judge the vividness or clarity of the episode, but the amount of visual detail involved (‘1= little or none, 7= a lot’). As the cue words used in this study referred to broader occurrences, the amount of visual detail prompted is likely to have been variable across episodes. Implementing cues that were sensory-rich and high in imageability (e.g. butterfly, rainbow; Anderson et al., 2012) may have elicited more visual detail and led to more consistency in this rating.

Spatial pre-living ratings also had relatively low alphas, which was unexpected based on the result from study one which indicated that general pre-living was robustly stable. This suggests that while certain aspects of pre-living are highly stable (auditory and visual), others are more inconsistent. It is particularly surprising that spatial pre-living differed from visual pre-living, as both ratings probe visual aspects of mental time travel. While visual pre-living is likely to depend heavily on visual imagery, perhaps the spatial pre-living rating is tapping some degree of episodic content as well as visual characteristics. The spatial pre-living rating presented the statement ‘As I imagine the event, I can envision the setting where it will occur’ while the other pre-living ratings refer to the extent to which the participant can ‘see’ or ‘hear’ the event ‘in their mind’. Thus, the spatial pre-living rating references specific characteristics more so than the other pre-living variables. Perhaps this can account for its lesser stability, as setting is an episodic detail which can vary depending on the episode.

It is also noteworthy that the formulation in words rating had a remarkably high alpha in both temporal conditions. As this rating presented the statement ‘As I imagine the event, it comes to me in words’ it is suggested that the involvement of words is especially consistent across both past and future events. Yet the means of this rating are not heavily loaded towards either the upper or lower end of the seven-point scale (see Table 9). This indicates that past and future events were neither solely word-based nor had a complete absence of words. It is likely that most individuals remember and imagine scenarios which are partially comprised of words, but also include image-based content. Given the association between mental imagery and mental time travel (Conti & Irish, 2021; Dawes et al., 2022), it is unsurprising that most participants experienced episodes that were not entirely made up of words. Yet it is notable that the involvement of words is the most stable subjective characteristic across both past and future events.

3.8.4 Future directions and conclusions

While previous studies have examined the stability of subjective ratings across different sessions (Berg et al., 2021; Rubin, 2021) the present studies are limited in that they examine within-session stability only. Therefore, it is unclear whether the within-session stability demonstrated in the present studies extends across sessions. As little previous research has examined internal consistencies in episodic future thinking or the AI, a possible direction for future research is to establish whether these results replicate across different experimental sessions. This would determine whether characteristics of mental time travel remain stable between larger time intervals, providing greater understanding of intra-individual variability in everyday life as opposed to experimental conditions.

To conclude, this chapter has shown that both objective content and subjective experience are stable across remembered and imagined episodes. While there was evidence of some variation in episodic content, this is unsurprising given the multi-faceted nature of mental time travel. More notably, acceptable levels of stability were found in both temporal conditions, aligning with the widely held view that imagining the future relies on the same mechanisms as remembering the past, suggesting that both forms of mental time travel are part of the same individual difference dimension. In summary, the present studies provide compelling evidence that mental time travel is a stable intra-individual difference which manifests at both the objective and subjective level.

Chapter 4: The relationship between schizotypy and mental time travel: are positive and negative schizotypy associated with the subjective experience and objective content of autobiographical memory and future thinking?

4.1 Introduction

As detailed in section 1.8.2.1, there are substantial gaps in the literature on mental time travel in schizophrenia. Due to extremely mixed results, very little is known about how positive and negative symptoms relate to remembering the past and imagining the future. One possible explanation for these inconsistencies relates to the different measures used to assess mental time travel. A recent review found that in schizophrenia, objective measures have found consistent impairments whereas subjective measures have produced variable results in episodic future thinking (Brunette & Schacter, 2021). Therefore, these conflicting findings may be due to the different measures used to examine mental time travel, which may associate with distinct symptoms of schizophrenia.

Various objective measures have demonstrated that in comparison to controls, schizophrenia patients generate less episodic detail in their descriptions of past and future events (Dassing et al., 2020; Gunduz et al., 2020; Nieto et al., 2019; Potheegadoo et al., 2014; Raffard et al., 2010; Yang et al., 2019a; Yang et al., 2019b). Yet most of these studies assessed either autobiographical memory or episodic future thinking separately. As there is a lack of research examining both forms of mental time travel in the same sample, it is unclear whether each temporality relates to different symptoms of schizophrenia. For example, Raffard et al. (2010) found a negative relationship between Experiential Index scores and negative symptoms. As this study examined future thinking only, it is unknown whether this same relationship is replicated in autobiographical memory. To date, no single study has examined the episodic content of both past and future events in relation to the different dimensions of schizophrenia. As Chapter 2 demonstrated some unexpected differences in temporality, it is critical that both forms of mental time travel are assessed. Furthermore, severity of symptoms and duration of illness differ between studies. It is thus unclear whether what is found across studies reflects true distinctions between memory and future thinking or is in fact due to differences in the characteristics of the sample. To address these limitations, the adapted AI (Addis et al., 2008) and its scoring procedure (Levine et al., 2002) will be used to assess both past and future event descriptions in the same sample of participants.

A key strength of the AI scoring (Levine et al., 2002) is its subcategories, which represent the multifaceted nature of mental time travel. Yet only two studies have explored the internal subcategories in relation to schizophrenia (Yang et al., 2018; Yang et al., 2019b). These studies employed an adapted scoring system in which descriptions of future events were scored for time/place, perceptual, and emotion/thought details. This scoring system was different to the standard AI scoring - the richness of these three domains was scored on a three-point scale in which a score of three reflected an episode which was highly rich, whereas events scoring one were general or non-specific (Yang et al., 2018). The authors found that richness of time/place details in positive events was negatively correlated with negative symptoms of schizophrenia, but no relationships were found for emotion/thought or perceptual details (Yang et al., 2018). As a relationship was only found in one subset of episodic details, this suggests that symptoms might be related to specific episodic details, rather than the overall amount of episodic content. However, this is the only study which has examined the internal subcategories in relation to symptom dimensions. It should also be highlighted that it prompted future events only. No previous research has explored the internal subcategories in relation to autobiographical memory and schizophrenia. Although individuals with schizophrenia generate less internal detail in past and future events (Dassing et al., 2020; Gunduz et al., 2020; Potheegadoo et al., 2014; Yang et al., 2019a), it cannot be assumed that the internal subcategories relate to the same symptom dimensions in both forms of mental time travel. As Chapters 2 and 3 both found some distinct results in specific subcategories of episodic content, differences might exist across the internal subcategories. To fully understand how schizophrenia relates to the episodic content of mental time travel, the more fine-grained details must be examined.

In contrast to objective measures, the literature using subjective measures has found variable results demonstrating impairment (Dassing et al., 2020; Painter & Kring, 2016; Raffard et al., 2010; Raffard et al., 2013; Yang et al., 2018; Yang et al., 2019b), enhancements (Raffard et al., 2010), as well as no differences with controls (De Oliveira et al., 2009; Malek et al., 2019; Raffard et al., 2016). One possible explanation for these mixed results relates to the vast array of phenomenological properties assessed across different studies. As different studies examined distinct characteristics, the comparisons that can be drawn between studies are limited. Hence it is unclear whether only certain elements of phenomenology are affected in schizophrenia. These different phenomenological properties may also associate with different dimensions of schizophrenia; certain phenomenological characteristics may be related to positive symptoms such as hallucinatory or delusion-like experience. Yet others might be associated with negative symptoms such as an inability to experience pleasure. However, only a small number of studies have explored the relationship between subjective ratings and symptom dimensions. While one study found a positive relationship between positive symptoms and self-reported sense of presence (Raffard et al., 2010), this relationship was not replicated in a subsequent study (Raffard et al., 2013). Contrary to the research using objective measures, this indicates there may be a positive relationship between subjective measures and positive symptoms. Although not only is this literature conflicting, but alike the AI research (Yang et al., 2018), these studies examined these relationships in episodic future thinking only. How each dimension relates to ratings of autobiographical memory is unclear.

A further gap in this literature is that nearly all the existing research has been conducted on clinical populations. As discussed in Chapter 1, exploring mental time travel in a healthy sample may be advantageous. In this context, assessing schizotypy might be insightful as alike schizophrenia, there are three dimensions of schizotypy: positive schizotypy, negative schizotypy, and disorganisation (Fonseca-Pedrero et al., 2018; Mason & Claridge, 2006; Nelson et al., 2013; for a more complete explanation of schizotypy see Chapter 1). Therefore, examining schizotypy in healthy individuals can provide insight into the relationship between mental time travel and positive versus negative dimensions, without being confounded by epiphenomena. Although, as highlighted in section 1.8.2.2, only a small number of studies have examined mental time travel in relation to schizotypy. One study demonstrated a negative relationship between social anhedonia and emotion/thought details scored by the experimenter (Yang et al., 2018). Yet the studies using subjective measures have demonstrated positive relationships with the positive dimension of schizotypy (Alle et al., 2023; Winfield & Kamboj, 2010). Notably, this aligns with the schizophrenia research which shows that objective measures demonstrate impairment whereas subjective measures produce variable results (Brunette & Schacter, 2021). It should be highlighted however that the research on schizotypy provides a very limited overview of this multi-dimensional construct. Winfield and Kamboj (2010) only assessed positive schizotypy and Yang et al. (2018) examined a specific negative experience. Although Alle et al. (2023) assessed both positive and negative dimensions of schizotypy, these dimensions were only assessed in relation to autobiographical memory and not episodic future thinking. As not a great amount of research has been conducted on this topic, a more comprehensive approach is required.

The aim of this chapter is to explore how different measures of mental time travel relate to positive and negative schizotypy. This will be completed using the same methodological procedures which are detailed in Chapter 2 (see section 2.2). Mental time travel is assessed objectively using the AI scoring system (Levine et al., 2002) and subjectively using phenomenological ratings of vividness and re-/pre-living. For the first time, this research will provide a comprehensive assessment of the relationship between schizotypy and mental time travel in i) subjective and objective measures, ii) autobiographical memory and episodic future thinking, and iii) positive and negative schizotypy dimensions. Based on the schizophrenia literature, it is expected that schizotypy would correlate negatively with the number of internal details generated in past and future events. Negative relationships are also anticipated in each of the internal subcategories. The findings on subjective measures are mixed in terms of whether a relationship will be found with schizotypy and the direction of this possible relationship. Therefore, the relationships between schizotypy and phenomenological ratings are explored, but no specific hypotheses are made. For objective and subjective measures, the research examining symptom dimensions is scarce and those who have assessed these relationships have found conflicting results. Thus, both positive and negative dimensions of schizotypy are examined in relation to these hypotheses to determine whether differential relationships with these dimensions exist.

4.2 Method – study 1

4.2.1 Participants

The sample and exclusion criteria for this study are detailed in Chapter 2 (study 1, see section 2.2.1). The sample size was determined based on a power calculation which showed that for a two-tailed correlation with an alpha of $p < .05$, a sample size of $n= 84$ or greater was needed to achieve statistical power of 0.8 with a medium effect size of 0.3.

4.2.2. Materials and procedure

This analysis used the data which is fully detailed in Chapter 2 (study 1, see sections 2.2.2 and 2.2.3). The process through which this data was collected (and the process by which the AI scoring was performed) is described in the methods section of Chapter 2. In summary, participants were presented with ten cue words. Each participant was given one minute to verbally describe an event (5 past, 5 future) in relation to each cue word. These event descriptions were scored according to the AI scoring system (Levine et al., 2002) which is analysed in the present study. Participants also completed several subjective ratings following each narration (see section 2.2.2.3). Ratings related to vividness and sense of re-/pre-living were examined in this study.

As detailed in section 2.2.2.4, the O-LIFE was administered to provide a validated measure of schizotypy (Mason et al., 1995; Mason & Claridge, 2006). The Unusual Experiences (mean score= 9.13, range= 1-21) and Introvertive Anhedonia (mean score= 5.25, range= 0-16) subscales of the O-LIFE were examined, which map onto the positive and negative symptom dimensions of schizophrenia. The reliability and validity of these subscales are well-established, and the mean scores found in the current study are highly comparable to the normative data for both the Unusual Experiences and Introvertive Anhedonia subscales (Mason & Claridge, 2006).

4.2.3 Data analysis

As in Chapters 2 and 3, the AI scores and participant ratings for time and place were aggregated to form a spatiotemporal category. Internal composite scores were calculated by aggregating the scores for each subcategory across all five events for each temporal direction. For example, a participant's score for internal details in past events was determined by the total number of internal details scored across all five past events. Subjective ratings were also summed in this way. Separate composite scores and analyses were conducted for past and future events.

Normality was analysed using Shapiro-Wilk tests. As several AI (Ws= .82-.94, all ps<.05), participant ratings (Ws= .91-.95, all ps<.05), and O-LIFE (Introvertive Anhedonia: W= .93, p= .004) variables violated normality, two-tailed Kendall's Tau correlation coefficients were used to determine whether internal details and/or participant ratings were significantly correlated with Unusual Experiences and Introvertive Anhedonia scores. Correlations with an alpha of p<.05 were interpreted as significant. However, significant correlations were only considered robust if they replicated in the subsequent studies. For all results, Bayes factors were computed using the jsq package implemented in Jamovi software to establish the strength of evidence for the alternative hypothesis (Dienes, 2014). Bayes factors of <1 were interpreted as evidence for the null hypothesis (see Table 10).

Table 10. *Interpretation of Bayes factors taken from Lee and Wagenmakers (2013)*

BF10	**Interpretation**
>100	Extreme evidence for H1
30-100	Very strong evidence for H1
10-30	Strong evidence for H1
3-10	Moderate evidence for H1
1-3	Anecdotal evidence for H1
1	No evidence
0.33-1	Anecdotal evidence for H0
0.33-0.1	Moderate evidence for H0
0.1-0.03	Strong evidence for H0
0.03-0.01	Very strong evidence for H0
<0.01	Extreme evidence for H0

4.3 Results – study 1

The Unusual Experiences and Introvertive Anhedonia sub-scores of the O-LIFE were not significantly correlated with most internal details for past or future events. Significant positive correlations were found between i) Unusual Experiences and event details in future events and ii) Introvertive Anhedonia and perceptual details in past events (see Table 11). These significant correlations are plotted in Figure 5. The Bayes factors for these significant relationships indicated anecdotal evidence for the alternative hypothesis. However, all other Bayes factors gave anecdotal to moderate evidence for the null hypothesis.

Table 11. *Kendall's tau correlation coefficients and Bayes factors between the O-LIFE and internal details in study one*

	Past			Future		
	τ_b	**p**	**BF10**	**τ_b**	**p**	**BF10**
Unusual Experiences						
Internal	.05	.58	0.21	.12	.23	0.39
Event	.12	.24	0.37	**.21**	**.03**	2.11
Perceptual	-.06	.58	0.21	.03	.76	0.19
Spatiotemporal	-.07	.46	0.24	.01	.94	0.18
Emotion/Thought	.03	.76	0.19	.01	.92	0.18
Introvertive Anhedonia						
Internal	-.02	.83	0.19	.03	.79	0.19
Event	-.06	.56	0.22	.02	.82	0.19
Perceptual	**.22**	**.04**	2.26	-.05	.65	0.20
Spatiotemporal	-.04	.66	0.20	.06	.54	0.22
Emotion/Thought	.02	.82	0.19	-.03	.78	0.19

Note. Significant correlations are in bold.

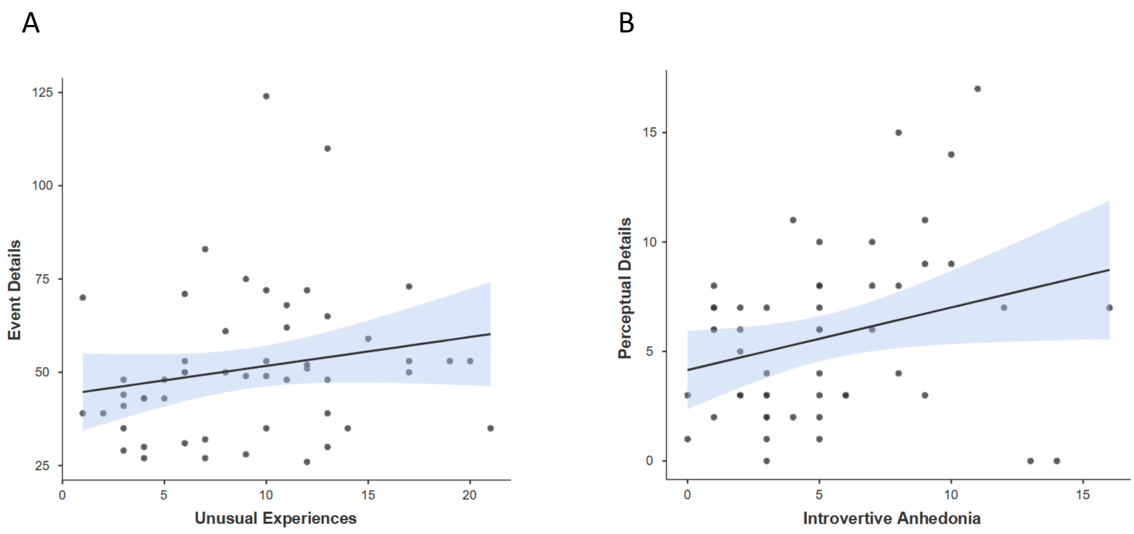


Figure 5. Scatterplots of the correlations from study one between A) Unusual Experiences scores and event details in future events and B) Introvertive Anhedonia scores and perceptual details in past events. The line of best fit is shown for these correlations. Shaded areas represent the standard error.

Correlations were also conducted between the Unusual Experiences and Introvertive Anhedonia dimensions of the O-LIFE and the subjective ratings that participants gave for vividness and re-/pre-living. None of these were significant, as can be seen in Table 12. All the Bayes factors indicated anecdotal to moderate evidence for the null hypothesis.

Table 12. *Kendall's tau correlation coefficients and Bayes factors between the O-LIFE and subjective ratings in study one*

		Past			**Future**	
	τ_b	**p**	**BF10**	τ_b	**p**	**BF10**
Unusual Experiences						
Vividness	.13	.20	0.45	.15	.12	0.64
Re-/Pre-living	.08	.45	0.25	.12	.25	0.37
Introvertive Anhedonia						
Vividness	-.03	.80	0.19	-.05	.61	0.21
Re-/Pre-living	-.01	.96	0.18	-.08	.42	0.26

4.4 Summary – study 1

It was hypothesised that schizotypy would negatively correlate with the overall number of internal details generated for past and future events. However, no significant correlations were found between the broad internal category and positive or negative schizotypy scores. Additionally, most correlations for the internal subcategories were not significant apart from two positive relationships: event details of future events were correlated with positive schizotypy scores, and perceptual details of past events were correlated with negative schizotypy scores. There were no significant correlations between the subjective ratings and either dimension of schizotypy. Furthermore, all Bayes factors for non-significant relationships provided evidence for the null hypothesis, most of which indicated moderate evidence. Overall, this suggests that positive and negative schizotypy are unrelated to the episodic content and phenomenological experience of past and future events. However, it should be highlighted that this study was underpowered due to there being several participant exclusions.

4.5 Study 2: Positive and negative events

In study one, the cued events were based on mildly positive or neutral words. Yet emotional valence is a factor known to impact the amount of episodic detail in which autobiographical events are described (Ford et al., 2012; Holland & Kensinger, 2010). As the number of internal details may increase or decrease depending on the valence of the event, it is critical that episodes of different emotional valence are examined as this may give rise to different patterns of results. Furthermore, schizophrenia studies have shown that the relationship between symptom dimensions and episodic detail can differ depending on the valence of the event (Yang et al., 2018). It is vital that valence is manipulated as this could result in relationships with schizotypy which were not found in study one. As study one examined neutral and mildly positive events, it is particularly important that these relationships are re-examined in negative episodes. Therefore, in study two, both positive and negative events were cued in an appropriately powered sample. Very little research has examined the effect of valence over internal detail production in schizophrenia or schizotypy. Although Yang et al. (2018) prompted positive and negative events, this generated some mixed results. Positive associations were found between i) social anhedonia and the richness of time/place details in positive events and ii) anticipatory pleasure and the richness of emotion/thought details in positive events. Yet a negative relationship was found between negative symptoms and the richness of time/place details in positive events. These findings provide no clear indication as to how valence might affect these relationships. Therefore, no specific hypotheses were made regarding the differences in correlations between positive and negative episodes.

4.6 Method – study 2

4.6.1 Participants

The sample (n=82) and exclusion criteria for this study are detailed in Chapter 2 (study 2, see section 2.5.1). The sample size was determined by the same power calculation conducted in study one (see section 4.2.1).

4.6.2 Materials and procedure

This analysis used the data which is described in Chapter 2 (study 2, see sections 2.5.2 and 2.5.3). To summarise, participants were presented with six positive and six negative cue words and explicitly instructed to describe events that were either positive or negative. This study implemented a time limit of one minute per cue word. Otherwise, the procedure was consistent with the first study. As in study one, the autobiographical interview data and ratings of vividness and re-/pre-living are analysed in relation to the Unusual Experiences and Introvertive Anhedonia subscales of the O-LIFE in the present study. The O-LIFE scores in the current study are highly comparable to the normative data for both the Unusual Experiences (mean score= 8.30, range= 0-28) and Introvertive Anhedonia (mean score= 5.30, range= 0-18) subscales (Mason & Claridge, 2006).

4.6.3 Data analysis

The analysis follows the procedures outlined for study one except internal details and subjective ratings for positive and negative events were analysed separately. Participants' scores for each subcategory were aggregated across all three events for each temporal direction and valence. For instance, a participant's score for internal details of positive past events was determined by the total number of internal details scored across all three positive past events. Separate analyses were conducted for positive past events, positive future events, negative past events, and negative future events. As was found in study one, several AI (Ws= .80-.97, all ps<.05), participant rated (Ws= .92-.97, all ps<.05), and O-LIFE (Ws= .91-96, all ps<.01) variables violated normality. Thus, Kendall's Tau correlation coefficients were used to examine these relationships.

4.7 Results – study 2

As is shown in Tables 13 and 14, significant negative correlations were found between i) Introvertive Anhedonia and emotion/thought details in negative past events and ii) Introvertive Anhedonia and event details in positive past events (see Figure 6). The Bayes factors for these relationships both provided anecdotal evidence for the alternative hypothesis. The Unusual Experiences and Introvertive Anhedonia dimensions of the O-LIFE were not significantly correlated with any other internal details for positive or negative events in the past or future. All the Bayes factors for these relationships provided anecdotal to moderate evidence for the null hypothesis other than two which indicated anecdotal evidence for the alternative hypothesis (see Tables 13 and 14).

Table 13. *Kendall's tau correlation coefficients and Bayes factors between the O-LIFE and internal details for positive events in study two*

	Past			Future		
	τ_b	**p**	**BF10**	τ_b	**p**	**BF10**
Unusual Experiences						
Internal	-.02	.77	0.15	.06	.43	0.20
Event	.05	.50	0.18	.08	.32	0.25
Perceptual	-.02	.80	0.15	-.10	.23	0.35
Spatiotemporal	-.07	.39	0.22	-.00	.98	0.14

Emotion/Thought	-.09	.25	0.30	.03	.71	0.16
Introvertive Anhedonia						
Internal	-.15	.06	0.98	-.16	.05	1.16
Event	**-.17**	**.03**	1.68	-.09	.24	0.31
Perceptual	-.09	.29	0.29	-.13	.13	0.62
Spatiotemporal	-.11	.17	0.42	-.12	.13	0.53
Emotion/Thought	.01	.86	0.15	-.06	.44	0.20

Note. Significant correlations are in bold.

Table 14. *Kendall's tau correlation coefficients and Bayes factors between the O-LIFE and internal details for negative events in study two*

	Past			Future		
	τ_b	**p**	**BF10**	τ_b	**p**	**BF10**
Unusual Experiences						
Internal	-.11	.17	0.39	.02	.80	0.15
Event	-.10	.22	0.32	-.02	.85	0.15
Perceptual	-.03	.71	0.16	-.05	.55	0.18
Spatiotemporal	-.16	.05	1.26	.06	.44	0.20
Emotion/Thought	-.03	.73	0.15	-.02	.85	0.15
Introvertive Anhedonia						
Internal	-.13	.11	0.58	.05	.51	0.18
Event	-.13	.10	0.66	.07	.40	0.21
Perceptual	-.10	.24	0.34	-.01	.88	0.15
Spatiotemporal	.01	.92	0.15	.04	.61	0.17
Emotion/Thought	**-.18**	**.03**	2.18	-.08	.33	0.25

Note. Significant correlations are in bold.

A B

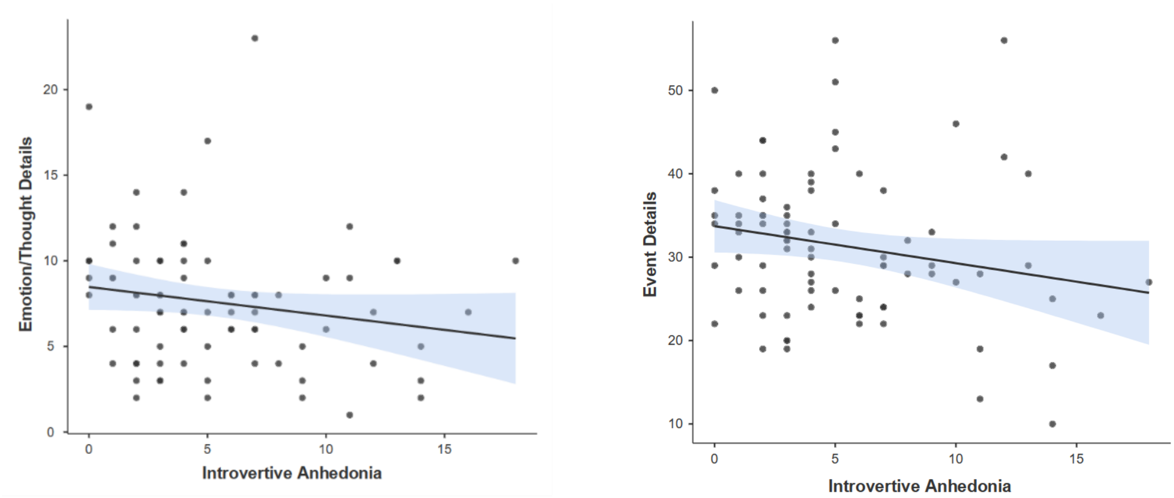


Figure 6. Scatterplots of the correlations from study two between A) Introvertive Anhedonia and emotion/thought details in negative past events and B) Introvertive Anhedonia and event details in positive past events. The line of best fit is shown for these correlations. Shaded areas represent the standard error.

For the subjective ratings, a significant negative correlation was found between Introvertive Anhedonia and vividness ratings for past positive events (see Figure 7). The Bayes factor for this relationship provided moderate evidence for the alternative hypothesis. No significant other correlations were found for participant ratings of positive and negative events. All the Bayes factors for these relationships provided anecdotal to moderate evidence for the null hypothesis (see Tables 15 and 16).

Table 15. *Kendall's tau correlation coefficients and Bayes factors between the O-LIFE and subjective ratings for positive events in study two*

	Past			Future		
	τ_b	**p**	**BF10**	τ_b	**p**	**BF10**
Unusual Experiences						
Vividness	.01	.92	0.15	.12	.12	0.55
Re-/Pre-living	.03	.71	0.16	.14	.07	0.87
Introvertive Anhedonia						
Vividness	**-.19**	**.02**	3.19	-.09	.27	0.29
Re-/Pre-living	-.14	.10	0.71	-.03	.69	0.16

Note. Significant correlations are in bold.

Table 16. *Kendall's tau correlation coefficients and Bayes factors between the O-LIFE and subjective ratings for negative events in study two*

	Past			Future		
	τ_b	**p**	**BF10**	τ_b	**p**	**BF10**
Unusual Experiences						
Vividness	.14	.08	0.81	.02	.85	0.15
Re-/Pre-living	.08	.33	0.24	.11	.17	0.41
Introvertive Anhedonia						
Vividness	-.13	.12	0.59	-.06	.43	0.21
Re-/Pre-living	-.07	.38	0.22	-.06	.45	0.20

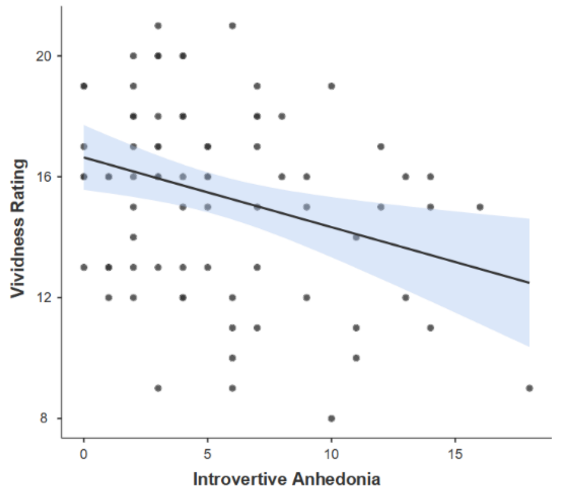


Figure 7. Scatterplot of the correlation from study two between Introvertive Anhedonia and vividness ratings in positive past events. The line of best fit is shown for this correlation. Shaded areas represent the standard error.

4.8 Summary – study 2

No significant relationships were found between the AI and positive or negative schizotypy scores, other than negative relationships between Introvertive Anhedonia and event details in positive past events and emotion/thought details in negative past events. For the subjective ratings, all relationships were null other than a negative correlation between vividness ratings of positive past events and Introvertive Anhedonia. However, these relationships did not replicate across the two studies. As in study one, most Bayes factors for non-significant relationships provided evidence for the null hypothesis, the majority of which provided moderate evidence. Overall, this indicates that positive and negative schizotypy are not associated with the amount of episodic detail scored by the experimenter or vividness and re/pre-living ratings provided by the participant.

4.9 Study 3: The Assessment of the Phenomenology of Autobiographical Memory and the Survey of Autobiographical Memory

Studies one and two provide little evidence that there is any relationship between either dimension of schizotypy and self-reported vividness and re-/pre-living. Yet this does not necessarily mean there is no relationship with all subjective characteristics. It was speculated in section 4.1 that the previous research implementing subjective measures might present inconsistent results due to the vast array of phenomenological characteristics that have been examined between different studies. Therefore, a comprehensive measure of self-reported phenomenology is implemented in study three: The APAM (Vannucci et al., 2020). The aim is to examine the relationship between a much broader range of subjective characteristics and positive and negative schizotypy.

In addition to examining more phenomenological ratings, a trait-based questionnaire will also be implemented to extend our understanding of the relationship between schizotypy and subjective assessments of mental time travel. While the previous two studies examined subjective measures relating to the phenomenology of specific events, it has been argued that measures which assess trait-based mental time travel are a more efficient way of determining relationships with other individual differences (Berntsen et al., 2019). As Chapter 3 demonstrated that mental time travel is relatively stable across different episodes, this suggests that autobiographical memory and episodic future thinking can be reliably assessed at the trait level. This alternative approach might clarify broader relationships between schizotypy dimensions and the general ability for mental time travel, rather than focusing on specific phenomenological characteristics. Therefore, in study three, participants completed a trait-based questionnaire. There is only one previous study which has done this. Alle et al. (2023) used the Autobiographical Recollection Test (Berntsen et al., 2019; see section 1.7.1 for a description of this measure). It was found that the total score on this measure was associated with positive schizotypy and, specifically, hallucinatory-like experiences. In the present study, the Survey of Autobiographical Memory (SAM; Palombo et al., 2013) will be administered and its relationship with positive and negative schizotypy scores is examined. Based on the results found by Alle et al. (2023), it is hypothesised that there will be a positive correlation between the positive dimension of schizotypy and the episodic and future dimensions of the SAM.

Relationships between schizotypy and internal details were also examined to determine if any of the significant relationships found in studies one and two replicated.

4.10 Methods – study 3

4.10.1 Participants

The sample (n=90) and exclusion criteria for this study are described in Chapter 3 (study 3, see section 3.6.1). The sample size was determined by the same power calculation conducted in study one (see section 4.2.1).

4.10.2 Materials

This analysis used the AI, APAM, SAM, O-LIFE and BDI data which is described in detail in Chapter 3 (study 3, see sections 3.6.2 and 3.6.3). To summarise, the cue word paradigm was adapted to be completed online. In this online version of the task, participants were presented with eight cue words (four past, four future) via Zoom before typing a description of an event relating to the given cue word using Qualtrics. As including positive and negative cues resulted in no notable differences in study two, this study did not provide participants with any instruction regarding the valence of events. The cues for this study generally concerned neutral or mildly positive events. This study had a time-limit of two minutes per cue word. The AI and APAM data for each temporal condition is analysed in the present study. As the present study was concerned with mental time travel, only SAM-episodic (mean score= 98.5, range= 76.5-137 e.g. “Specific events are difficult for me to recall”) and SAM-future (mean score= 94.2, range= 78-126 e.g. “When I imagine an events in the future, the event generates vivid mental images that are specific in time and place”) scores were analysed. The mean and range for both SAM subscales were comparable to that of previous studies (Setton et al., 2021) and the O-LIFE scores were comparable to the normative data for both the Unusual Experiences (mean score= 11.6, range= 0-27) and Introvertive Anhedonia (mean score= 6.57, range= 0-17) subscales (Mason & Claridge, 2006).

4.10.3 Data analysis

Kendall's Tau correlation coefficient was used to explore whether the O-LIFE sub-scores were significantly correlated with the self-report questions derived from the APAM (Vannucci et al., 2020). As a substantially higher number of correlations were conducted between the APAM and the schizotypy dimensions, which can increase the familywise error, a correction was implemented to help avoid false positives. The Benjamini-Hochberg (1995) correction was used with a false discovery rate of 0.05. Relationships were also examined between the SAM subscales (SAM-episodic and SAM-future) and the schizotypy dimensions. As there is considerable overlap between the characteristics of negative schizotypy and depression, the relationship between Introvertive Anhedonia and BDI-II scores was examined. As a significant positive correlation was found between these measures ($\tau b = .23$, $p = .002$), mediation analysis will be performed on any significant relationships between Introvertive Anhedonia and measures of mental time travel, to determine the influence of depression on this relationship. All other aspects of data analysis were identical to study one. Several AI (Ws= .83-.95, all ps<.001), O-LIFE (Ws= .96-.97, all ps<.05), and SAM (SAM future: W= .89, p<.001) variables violated normality.

4.11 Results – study 3

Consistent with the general pattern found in studies one and two, neither of the O-LIFE sub-scores correlated with internal details in past and future events (see Table 17). All the Bayes factors for these relationships provided anecdotal to moderate evidence for the null hypothesis (see Table 17).

Table 17. *Kendall's tau correlation coefficients and Bayes factors between the O-LIFE and internal details in study three*

	Past			Future		
	τ_b	**p**	**BF10**	**τ_b**	**p**	**BF10**
Unusual Experiences						
Internal	.04	.63	0.16	-.07	.33	0.23
Event	.05	.53	0.17	-.07	.34	0.22
Perceptual	.01	.89	0.14	.03	.68	0.15
Spatiotemporal	.02	.77	0.14	-.14	.06	0.92
Emotion/Thought	-.06	.46	0.19	-.01	.86	0.14
Introvertive Anhedonia						
Internal	-.09	.23	0.29	.07	.35	0.22
Event	-.07	.37	0.21	-.04	.58	0.16
Perceptual	-.02	.76	0.15	-.00	.99	0.14
Spatiotemporal	-.12	.11	0.57	-.06	.43	0.19
Emotion/Thought	.08	.28	0.27	-.06	.47	0.19

For the APAM, there were significant positive correlations between Unusual Experiences and several ratings of past and future events. This included those related to sensory experiences (sound, smell, touch) and reliving (sensory reliving, auditory reliving). As seen in Table 18, there were also several additional positive correlations in the future condition. Unusual Experiences was significantly correlated with clarity, vividness, visual details, accessibility, perspective, emotional intensity, self-distancing, and personal importance ratings of future events. The Bayes factors for these significant relationships provided moderate to strong evidence for the alternative hypothesis (see Table 18). There were no significant correlations between Introvertive Anhedonia and any of the subjective ratings for autobiographical memory or future thinking (see Table 19).

Table 18. *Kendall's tau correlation coefficients and Bayes factors between the Unusual Experiences dimension of the O-LIFE and the APAM*

	Past			**Future**		
	τb	**p**	**BF10**	**τb**	**p**	**BF10**
Unusual Experiences						
Clarity	0.05	.48	0.18	**0.22***	.004	14.31
Colour	0.07	.38	0.21	0.09	.24	0.30
Vividness	0.09	.25	0.28	**0.18***	.02	2.59
Visual details	0.14	.07	0.88	**0.19***	.01	5.10
Sound	**0.22***	.004	12.66	**0.21***	.004	11.29
Smell	**0.26***	<.001	72.78	**0.24***	.002	31.76
Touch	**0.31***	<.001	1411.51	**0.27***	<.001	126.22
Taste	**0.22***	.004	11.58	0.09	.24	0.30
Sensory reliving	**0.25***	<.001	48.59	**0.18***	.01	3.55
Auditory reliving	**0.21***	.01	10.03	**0.21***	.004	11.34
Visual reliving	0.17	.03	1.91	**0.23***	.002	22.32
Spatial reliving	0.03	.71	0.15	0.10	.20	0.34
Formulation in words	-0.01	.93	0.14	0.07	.33	0.23
Coherence	0.07	.36	0.22	0.14	.06	0.93
Accessibility	0.15	.04	1.33	**0.25***	.001	47.18
Visual perspective	0.05	.50	0.18	**0.25***	.001	44.38
Emotional intensity	0.08	.31	0.24	**0.23***	.002	19.41
Self-distancing	0.08	.27	0.27	**0.17***	.02	2.20
Personal importance	0.11	.13	0.48	**0.25***	<.001	48.98

Note. Some p-values are rounded to three decimal places because they are <.005.

*Correlations which were significant after application of the Benjamini-Hochberg correction.

Table 19. *Kendall's tau correlation coefficients and Bayes factors between the Introvertive Anhedonia dimension of the O-LIFE and the APAM*

	Past			Future		
	τb	**p**	**BF10**	**τb**	**p**	**BF10**
Introvertive Anhedonia						
Clarity						
Colour	-0.04	.63	0.16	-0.08	.27	0.27
Vividness	-0.07	.37	0.22	-0.05	.47	0.18
Visual details	-0.14	.07	0.93	-0.10	.20	0.35
Sound	-0.11	.16	0.42	-0.13	.08	0.71
Smell	-0.10	.19	0.36	-0.04	.62	0.16
Touch	-0.07	.38	0.21	-0.12	.12	0.52
Taste	-0.06	.41	0.20	-0.17	.02	2.51
Sensory reliving	-0.05	.54	0.17	-0.02	.77	0.14
Auditory reliving	-0.16	.03	1.64	-0.12	.12	0.52
Visual reliving	-0.10	.21	0.34	-0.12	.13	0.51
Spatial reliving	-0.10	.21	0.34	-0.10	.19	0.37
Formulation in words	-0.11	.15	0.42	-0.08	.29	0.26
Coherence	-0.06	.47	0.18	-0.08	.30	0.25
Accessibility	-0.05	.51	0.18	-0.08	.29	0.25
Visual perspective	0.03	.66	0.15	0.10	.17	0.39
Emotional intensity	-0.17	.03	1.88	-0.09	.24	0.30
Self-distancing	0	.98	0.14	0	.97	0.14
Personal importance	0.01	.93	0.14	-0.02	.84	0.14

For the SAM, positive correlations were found between Unusual Experiences and SAM episodic and SAM future scores (see Figure 8). The Bayes factors provided anecdotal (SAM episodic) to extreme (SAM future) evidence for the alternative hypothesis. No significant correlations were found between the SAM subscales and Introvertive Anhedonia (see Table 20). The Bayes factors for these relationships provided anecdotal (SAM episodic) to moderate (SAM future) evidence for the null hypothesis.

Table 20. *Kendall's tau correlation coefficients and Bayes factors between the O-LIFE and the SAM*

	τ_b	p	BF10
Unusual Experiences			
SAM Episodic	**.17**	**.02**	2.15
SAM Future	**.27**	**<.001**	140.65
Introvertive Anhedonia			
SAM Episodic	-.11	.14	0.44
SAM Future	-.05	.48	0.18

Note. Significant correlations are in bold.

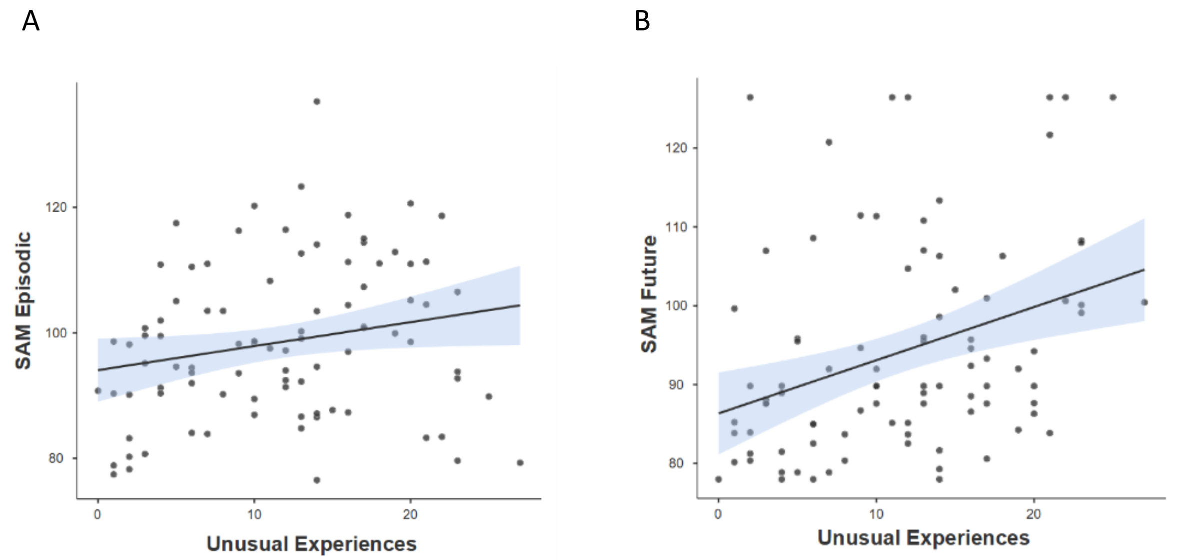


Figure 8. Scatterplots of the correlations from study three between Unusual Experiences scores and the SAM subscales from study three. The line of best fit is shown for SAM Episodic and SAM Future

scores. Shaded areas represent the standard error.

4.12 Discussion

The aim of this chapter was to examine the relationship between positive and negative dimensions of schizotypy and different measures of mental time travel. As separate lines of research have demonstrated mixed results, the present studies provide a comprehensive examination of how different dimensions of schizotypy relate to experimenter-scored and participant-scored measures of mental time travel. Based on the schizophrenia literature, it was expected that the number of internal details generated in past and future events would negatively correlate with schizotypy scores. While there were some significant relationships in studies one and two, these correlations did not replicate in the third study. Contrary to the hypothesis, the overwhelming majority of relationships were not significant, with Bayes factors providing anecdotal to moderate support for the null hypothesis. Therefore, across three studies, no robust relationships were found between any of the objective content measures and either dimension of schizotypy.

The first two studies only examined two subjective characteristics: vividness and sense of re-/pre-living. One significant negative correlation was found between negative schizotypy and vividness ratings of positive past events in study two. Yet when a more comprehensive subjective assessment was implemented in study three, this revealed several positive relationships between the positive dimension of schizotypy and various phenomenological characteristics of past and future events. In both temporal conditions, significant relationships were observed in ratings related to sensory characteristics (sound, smell, touch) as well as a sense of reliving (sensory reliving, auditory reliving). In the future condition, several additional correlations were observed. Participants high in positive schizotypy seemed to imagine their future as more vivid, accessible, emotionally intense, self-distancing, personally relevant and experienced more as an observer. Aligning with these findings, positive schizotypy scores were also positively and significantly correlated with SAM episodic and SAM future scores. This supports the hypothesis that the positive dimension would positively correlate with this trait-based measure of mental time travel. Across both types of subjective measure, the Bayes factors for significant relationships provided anecdotal to extreme evidence for the alternative hypothesis. This presents substantial evidence of a positive relationship between subjective assessments of mental time travel and positive schizotypy.

4.12.1 Objective episodic content is not correlated with positive or negative schizotypy

The three studies conducted in this chapter present compelling evidence that there is no relationship between the level of episodic detail in which past and future events are described and positive or negative schizotypy. This result was unexpected based on the robust impairment found in people with schizophrenia (Berna et al., 2016; Hallford et al., 2018; Ricarte et al., 2017; Zhang et al., 2019). Schizotypy is also associated with impaired performance on episodic memory tasks (Sahakyan & Kwapil, 2016; 2018; 2019) and the study by Yang et al. (2018) demonstrated deficits in a future thinking task with the emotion/thought category. Therefore, the absence of relationships does not appear to be due to schizotypy lacking validity as a dimensional correlate of schizophrenia.

It should be noted that in the present studies, the negative schizotypy scales have relatively low averages. While it is evident that participants provided a range of responses, the range does not extend to the maximum point of the Introvertive Anhedonia scale in any of the three datasets. While the means of the negative schizotypy dimension in the present studies are highly comparable to extended norms derived from 1926 participants (Mason & Claridge, 2006) and are thus typical for schizotypy research conducted on a healthy cohort, it is possible that relationships were not detected in the current studies due to the samples not being inclusive of the upper end of the Introvertive Anhedonia scale. It must be highlighted that in the Yang et al. (2018) study, they screened nearly 3000 participants and selected just over 1% of them to form the high schizotypy group. It is thus possible that deficits in experimenter-scored indices of mental time travel may be very subtle and only observed at the extreme end of the schizotypy continuum. This might explain why no robust relationships were found with the negative dimension of schizotypy, as the present samples did not include individuals scoring at the extreme end of this schizotypy continuum. Yet this explanation does not address the lack of relationship between objective content and the positive dimension of schizotypy.

As the cognitive deficits found in schizotypy are similar to, but less severe than those found in schizophrenia (Park et al., 1995), one possible explanation is that the paradigm and scoring system adopted did not detect the modest impairment which would be expected in schizotypy. The AI scoring includes a 'benefit of the doubt rule', whereby any detail that could reasonably be considered episodic should be scored as internal (Levine et al., 2002). While this rule was originally included to avoid false positives when classifying memory impairments (Levine et al., 2002), the liberal scoring system may have obscured the subtle deficit which would be expected in healthy participants high in schizotypy.

Another factor which could have contributed is the cue word approach, which contrasts with the original AI administration where participants are asked to recover memories from certain life periods. These two methods differ in their retrieval requirements. The cue word method is more of an associative bottom-up search process (Crovitz & Schiffman, 1974), whereas life periods are likely to require more of a strategic top-down search. Research indicates that giving people with schizophrenia more specific cues enhances the number and richness of detail in autobiographical memory (Potheegadoo et al., 2014). Events elicited by the cue word method are also expected to be more recent, as these events are most likely to come to mind first (Janssen et al., 2005). Therefore, when the participant narrates past and future events, this represents not their general ability; but one of their more recent or salient events. In this regard, perhaps the paradigm in which less strategic search was required and more accessible events were elicited, lessened the possibility of finding relationships between objective content and schizotypy.

Another possible explanation is that comorbidities, known to be prevalent in schizophrenia (Fenton, 2001), are responsible for the deficits which have been found in patient groups. One of the advantages of examining schizotypy is that it allowed for exploration of positive and negative dimensions without epiphenomena such as comorbid disorders. As impairment in episodic detail generation were not replicated in schizotypy, it is possible that these deficits are associated with other confounding factors, as opposed to being a symptom of schizophrenia itself. Psychiatric comorbidities such as depression, bipolar disorder, and post-traumatic stress disorder are common in patients with schizophrenia (Buckley et al., 2009). There is also considerable evidence that these psychiatric disorders are associated with deficits in autobiographical memory (Mansell &

Lam, 2004; McNally et al., 1994; Park et al., 2002) and episodic future thinking (Hallford et al, 2018). As the deficits in objective content found in schizophrenia patients were not replicated, it is possible that impairments in mental time travel are a by-product of these comorbidities.

4.12.2 Subjective measures are positively correlated with positive schizotypy

What was found in the subjective ratings aligns with the schizotypy literature, which has demonstrated positive relationships between the positive dimension and self-report measures of mental time travel (Alle et al., 2023; Winfield & Kamboj, 2010). This mirrors Winfield and Kamboj's (2010) finding that positive schizotypy was positively associated with autonoetic consciousness and olfactory detail ratings, despite various additional correlations all generating null results. Akin to the present studies, this suggests that only certain phenomenological experiences are implicated in positive schizotypy. Study three replicated these relationships as both olfaction and various re/pre-living ratings were correlated with the positive dimension of schizotypy. Yet several additional relationships were demonstrated that were not present in Winfield and Kamboj's (2010) study. The results from this chapter align more closely with the study by Alle et al. (2023), which found that the positive dimension was associated with increases in additional ratings related to olfactory detail, intensity of emotion, personal importance, and accessibility. The present studies extend this work, as investigating a wider range of characteristics demonstrated that positive associations are also present in characteristics such as vividness, sensory experiences, and the feeling of re– or pre-living. Considered alongside each other, this provides compelling evidence that the positive dimension of schizotypy is associated with enhanced experiences in some phenomenological characteristics of mental time travel. As this positive relationship is only observed in certain properties, this suggests that the inconsistencies in the previous research are due to different subjective ratings being implemented across studies.

One possible explanation for the relationships found with subjective measures is that positive schizotypy is associated with heightened mental imagery, which enhances mental time travel. As discussed in Chapter 3, mental imagery is associated with more specific (Anderson et al., 2012; Williams et al., 1999; Williams et al., 2007) and detailed (Palombo et al., 2018) episodic content, as well as higher phenomenological ratings (Vannucci et al., 2020). Object imagery also predicts various APAM ratings, including those related to sensory experiences, feelings of re-living, seeing the event in one's mind, and emotional aspects (Vannucci et al., 2020). Given that positive schizotypy is associated with magical beliefs and unusual perceptual experiences (Kwapil & Barrantes-Vidal, 2015) which engender imagination and creativity (Claridge, 1997, Folley & Park, 2005), it has been speculated that this dimension is associated with enhanced mental imagery (Winfield & Kamboj, 2010). Indeed, not only is schizotypy strongly correlated with mental imagery vividness (Aleman et al., 2000; Oertel et al., 2009) but individuals high in positive schizotypy experience involuntary memories more vividly (Holmes & Steel, 2004; Marzillier & Steel, 2007). If imagery is indeed driving this relationship, this could explain why certain relationships were significant in the APAM. Correlations were found with various ratings that are likely to require a high level of mental imagery. For example, clarity, vividness, visual details, sound, smell, touch, taste, re/pre-living (sensory, auditory, visual), and perspective ratings were all related to positive schizotypy. These particular experiences might be heightened in individuals high in positive schizotypy as a result of an enhanced capacity for mental imagery.

Positive schizotypy was also positively and significantly correlated with SAM episodic and SAM future scores (Palombo et al., 2013). This suggests that individuals who report hallucinatory or delusion-like experiences have a better general capacity for both forms of mental time travel. Therefore, the results from this measure align with the event-based ratings. Unlike the APAM which assesses fine-grained characteristics, trait-based assessments measure broader concepts to assess everyday mental time travel and capture a wide-ranging understanding of the participant's abilities. As the SAM encompasses various characteristics in one score, it is unsurprising that this broader assessment detected a similar relationship to what was found between certain phenomenological characteristics and the positive dimension of schizotypy. These findings might also be linked to enhanced mental imagery in those high in Unusual Experiences. Setton et al. (2021) speculated that rather than assessing autobiographical abilities, the SAM is tapping into different aspects of imagery. This is based on various lines of research, including evidence that aphantasic individuals have low future SAM scores (Dawes et al., 2020), and that individuals with HSAM have higher episodic SAM scores than controls (Sheldon et al., 2016). There is also a relationship between SAM episodic and object imagery scores (Fan et al., 2021) and both the episodic and future SAM subscales predict imagery ability on the scene construction task (Clark & Maguire, 2020). This indicates that the relationship between positive schizotypy and the SAM might also be mediated by imagery.

Positive schizotypy was associated with several additional APAM ratings in the future condition compared to the memory condition, and more strongly related to SAM future than SAM episodic scores. This supports the theory that mental imagery is driving the relationship between subjective measures and positive schizotypy, as imagining future scenarios relies more heavily on mental imagery (Conti & Irish, 2021; Dawes et al., 2022). Several studies have found that those in the schizophrenia spectrum, including those with a diagnosis of schizophrenia, their first-degree relatives and those high in schizotypy, have higher mental imagery vividness (Aleman et al., 2000; Mintz & Alpert, 1972; Oertel et al., 2009). The enhanced capacity for mental imagery is likely to support both forms of mental time travel; but it may have a more pronounced impact on the ability to envision the future.

It is notable that there was a remarkably strong effect with touch ratings, which have not been examined previously. Individuals higher on the positive dimension of schizotypy reported that past and future events involved far more tactile details. There is some evidence that people with schizophrenia and schizotypy have impaired tactile acuity (Lenzenweger, 2000; Michael & Park, 2016), which does not align with this result. However, these tasks typically ask participants to discriminate between external stimulations. Other researchers have examined tactile sensations which involve distinguishing between the self and other. People with schizophrenia and those high in schizotypy are more prone to the rubber hand illusion; they have the sense that their own hand is being stroked when it is in fact a rubber hand (Germine et al., 2013; Peled et al., 2000; Thakkar et al., 2011). This is particularly marked in individuals with positive symptoms and schizotypal experiences. These same individuals also experience self-generated touch, which is generally perceived as weaker than externally generated touch, more intensely than control participants (Asimakidou, et al., 2022; Blakemore et al., 2000). Such examples highlight that individuals who have hallucinatory and delusional experiences can experience an enhanced sense of touch when this involves a self-other boundary. These perceptual phenomena might explain why touch ratings were exceptionally stronger in those scoring higher on Unusual Experiences.

It might seem inconsistent that positive schizotypy was correlated with vividness and re/pre-living in study three but that these relationships were not found in studies one and two. A likely explanation for this is differences in the ratings and their response options between studies. For example, relationships may have been found with various re- and pre-living ratings in study three as contrary to the broader ratings in studies one and two, they measure distinct facets of re- or pre-living. This is especially true for the auditory and visual re/pre-living ratings as they ask the participant to rate the extent to which they can 'see' or 'hear' the event. Although, it is notable that the spatial re/pre-living rating was positively associated in study three, because this question is highly similar to the statement presented in studies one and two: 'As I imagine the event, I feel as though I am there'. Yet these ratings differ in their rating scales. The ratings used in the first two studies range from 'not at all' to 'It felt like I was really there' whereas in study three the upper end of the scale stated, 'as clearly as if it were happening right now'. The latter statement is slightly more conceivable than the former. As alterations in re-living are likely to be modest in healthy individuals, perhaps the idea of feeling as if one was really there was too implausible. Therefore, this rating might have been less likely to detect this relationship.

4.12.3 Explaining the subjective-objective disjunction

The present studies suggest that there is no relationship between objective episodic content and positive or negative schizotypy, but that subjective measures of mental time travel are related to the positive dimension of schizotypy. This demonstrates an interesting disjunction between subjective and objective measures whereby distinct patterns of results are presented. One distinguishing characteristic of internal details is that they are an index exclusively related to episodic content, because semantic information is scored under external detail. However, episodic and semantic aspects could not be separated in the subjective assessments. Although Chapter 2 indicates that subjective judgements are based on the amount of episodic content that can be retrieved, individuals with deficits in episodic memory, such as those scoring high in positive schizotypy (Sahakyan & Kwapil, 2016, 2018, 2019), might allocate more weighting to semantic content. Indeed, despite having impairments in episodic memory, semantic memory performance does not differ between high and low schizotypy scorers (Tan et al., 2020). As it appears that semantic memory remains intact, it could be somewhat heightened to compensate for subtle decreases in episodic detail. If individuals high in positive schizotypy are generating increased semantic content, it is plausible that this information informed their self-report. This might explain why these participants regarded mental time travel as enhanced. As their deficits in episodic memory are likely to be modest, they may believe that their mental time travel is greater than average, due to a potentially pronounced ability for semantic memory.

It must be noted that the discrepancy found between objective and subjective measures aligns with the finding that individuals scoring high in schizotypy report severe cognitive deficits despite demonstrating unremarkable functioning when tested objectively (Cohen et al., 2017). The present studies demonstrate a similar ‘subjective-objective disjunction’. Although differences in semantic content may underlie the present results, this does not provide an explanation for the overall phenomena. Moreover, while it is speculated that heightened imagery might contribute to the positive relationships found in the positive dimension, it also does not provide a complete explanation. It fails to account for significant associations which were found with characteristics like accessibility, self-distancing, and personal importance, which are likely to require little to no imagery.

An alternative, more complete explanation relates to metacognition or “thinking about thinking” (Moritz & Lysaker, 2018); an ability which is known to be affected in schizophrenia (Lysaker & Hasson-Ohayon, 2014). Not only are autobiographical memory and metacognitive deficits inter-related in schizophrenia (Dimaggio et al., 2012; Mediavilla et al., 2021), but several studies have demonstrated a link between schizotypy and poor metacognition using the Metacognitions Questionnaire (Barkus et al., 2010; Chan et al., 2016; Stirling et al., 2007). Indeed, the use of subjective measures for testing schizotypal individuals has been critiqued. This is because they are susceptible to item over-endorsement (Merckelbach & Van de Ven, 2001); an effect which is not replicated in objective measures (Cohen et al., 2017). Therefore, some studies have examined task-based indices of metacognition indexed via trial-by-trial confidence ratings. Evans et al. (2019) administered an episodic memory task and found that individuals high in the positive dimension of schizotypy had more false memories and a tendency to give highly confident responses across all item types. This indicates that these individuals have a liberal response bias, whereby less evidence is needed before they are willing to designate an item as 'old'. It might be that a similar response bias was in operation here, and that the ratings provided were not an accurate portrayal of true abilities. They were due to a deficit in understanding and judging one's own experiences. Disruptions in metacognitive functioning seem to be a more likely cause than enhanced imagery. If the latter were true, a somewhat comparable result would be expected in the objective indices, given the correspondence demonstrated between these two measures in Chapter 2.

In contrast to the phenomenological ratings which generated some variable results, positive schizotypy was robustly correlated with the episodic and future subscales of the SAM. This is unsurprising because metacognition is particularly important for trait-based questionnaires; as the participant is required to generalise their abilities across different autobiographical episodes, rating their mental time travel in general as opposed to rating a particular event. Not only is this more cognitively demanding than forming a metacognitive judgement about one episode, but the SAM required participants to rate their mental time travel in general. For instance, questions such as "Specific events are difficult for me to recall" (SAM episodic; Palombo et al., 2013) and "When I imagine an event in the future, the event generates vivid mental images that are specific in time and place" (SAM future; Palombo et al., 2013) depend heavily on the individual's ability to introspect and form judgements regarding their everyday abilities. As individuals scoring high in schizotypy are likely to experience disruptions to their metacognition (Barkus et al., 2010; Chan et al., 2016; Stirling et al., 2007), their responses to the SAM might be more susceptible to error than those provided for the event-based measures. It is recommended that future research examines the role of metacognition and its association with self-report assessments in schizotypy more closely (see section 5.5 for a detailed discussion).

It must be noted that a recent psychometric evaluation of the SAM has identified various limitations of this measure (Setton et al., 2021). The authors found that when correlated with various measures including performance-based assessments of memory, the most robust association was with a measure of self-efficacy (Setton et al., 2021). This led to the speculation that SAM episodic scores might be tapping into confidence more so than true mnemonic abilities. This supports the idea that disruptions to metacognition are driving the positive relationships found with the SAM. If the SAM is measuring an individual's belief or confidence in their mnemonic abilities as opposed to their actual capacities, it is probable that deficient metacognition would lead to highly pronounced scores, regardless of one's mental time travel abilities. It should also be highlighted that based on various issues regarding validity, Setton et al. (2021) concluded that the SAM is not a psychometrically valid measure and urge caution when using this questionnaire. This is based upon the association between the SAM episodic subscale and measures of imagery and memory confidence, as well as evidence that the episodic and semantic subscales might not be independent or specific. While the limited psychometric validity identified by Setton et al. (2021) is a concern that should be acknowledged, this work supports the theory that either enhanced mental imagery or disruptions to metacognition underlie the positive association between subjective measures and positive schizotypy.

4.12.4 Conclusion

The empirical work in this chapter has provided an extensive examination of the relationship between mental time travel and schizotypy. Contrary to expectations, the results provide compelling evidence that both positive and negative schizotypy are not related to objective episodic content. This presents a notable dissimilarity with the schizophrenia research, suggesting that deficits in mental time travel do not extend to non-clinical individuals and that the capacity to generate episodic detail varies across the schizophrenia spectrum. However, these studies also provide considerable evidence that positive schizotypy is associated with heightened subjective ratings at both the event and trait level. This provides important insights into how different dimensions of schizotypy relate to mental time travel and presents an interesting discrepancy between subjective and objective measurement.

Chapter 5: General discussion

5.1 Overview of the thesis

Remembering the past and imagining the future are the cornerstones of mental time travel (Tulving, 1985, 2002b, 2005). This bidirectionality enables re-experiencing of our autobiographical past as well as projection into our hypothetical future. The commonalities between remembering and imagining are indisputable (Schacter et al., 2012; Szpunar, 2010), yet there are separable aspects to each process (Schacter et al., 2012). While there is disagreement regarding the extent to which these systems are functionally distinct, there is a general understanding that both are attributable to an overarching principle – mental time travel. Mental time travel has intrigued the greatest minds for millennia; as put by Aristotle, "memory is the scribe of the soul". This famous quote highlights the personal and subjective nature of memory. Centuries later, Tulving's seminal work reiterated the importance of subjective experience, emphasizing that this elusive aspect of mental time travel is the fundamental component which should be strived to be understood (Tulving, 1983). While we have learnt a great deal in recent years, the subjective experience of mental time travel is something we are still trying to understand (Simons, 2022). This thesis aims to further this knowledge, elucidating both the subjective experience and objective content of mental time travel into the past and future.

This thesis used both subjective and objective measures, providing a holistic examination of mental time travel. This was achieved using the AI scoring system (Levine et al., 2002), various participant ratings including those taken from the APAM (Vannucci et al., 2020), and a self-report questionnaire of trait mnemonics (the SAM; Palombo et al., 2013). This combined approach extends much of the literature, which has assessed mental time travel with either experimenter-scored or self-report techniques. By implementing various measurements, a more complete understanding of mental time travel is presented, encompassing both the participant's subjective experience as well as their objective performance. This approach is advantageous for the study of autobiographical abilities. As both remembering the past and imagining the future are idiosyncratic and multi-faceted in nature, adopting one form of measurement can be limited. We can lose sight of what is true for the individual, inferring their subjective experience according to our well-established testing procedures. However, through approaching research from both a participant and an experimenter perspective, this lessens the possibility of drawing non-representative conclusions which only address one facet of mental time travel. This thesis achieved this by implementing a combination of performance-based and self-report measures to address the multiple constructs which characterise mental time travel.

Another important aspect of this thesis is its examination of mental time travel into the future, as well as the past. This was achieved using the adapted AI (Addis et al., 2008) which assessed remembered and imagined events using identical procedures as well as implementing a common scoring system (Levine et al., 2002). The same phenomenological characteristics were rated by the participant for past and future episodes, which was achieved by using standardised ratings (e.g. vividness) as well as developing and employing a novel adaptation of the APAM (Vannucci et al., 2020) which allowed for this measure to be applied to episodic future thinking. Finally, mental time travel was examined at the trait level by opting for a self-report questionnaire which assessed trait mnemonics in different domains, differentiating between autobiographical memory and future thinking (the SAM; Palombo et al., 2013) as opposed to alternatives which only measure remembering (e.g. the ART; Berntsen et al., 2019). A bidirectional approach was adopted to determine whether results found for one temporality were replicated in the other. The rationale for this was based upon the various differences between autobiographical memory and future thinking (see section 1.5; see Schacter et al., 2012 for a review), despite their undeniable similarities. Several of the topics explored in this thesis had also been more extensively researched in autobiographical memory in comparison to episodic future thinking. When compared to memory, future thinking is a relatively recent area of study. Thus, all studies included in this thesis have examined both forms of mental time travel in each sample. This provides a clearer indication of whether results are truly replicated across each temporal direction, rather than reflecting differences in experimental or sample characteristics.

5.2 Summary of findings

5.2.1 The relationship between the subjective experience of mental time travel and objective content

As noted above, it is common practice to employ either subjective or objective measures to assess mental time travel. Despite the widespread and interchangeable implementation of both classes of measure, very little is known about their relationship. Some research has indicated that episodic content and self-reported trait mnemonics are dissociated (Clark & Maguire, 2020; Palombo et al., 2013; Setton et al., 2021), but only a small number of studies have examined the relationship between subjective and objective measures which are both at the event level. The studies which have done this have analysed one temporality or relied on summed scores (Clark & Maguire, 2020; Lockrow et al., 2023; Thakral et al., 2020).

Chapter 2 aimed to examine the correspondence between subjective and objective measures by analysing the relationship between internal details scored using the AI protocol (Levine et al., 2002) and self-reported phenomenology such as vividness ratings. This chapter aimed to extend the previous literature in two ways: by examining content in a more nuanced manner and using a more powerful statistical analysis. While previous studies have looked at the relationship between the broad internal category and vividness ratings, various episodic subcategories (event/perceptual, spatiotemporal, emotion/thought) and re-/-pre-living ratings were examined in this thesis. These relationships were analysed on a trial-by-trial basis, providing a direct comparison between the participants' ratings and the amount of objective episodic content at the event level. This is a novel and more sensitive approach to answering this question. Positive relationships were expected between the participants' subjective experiences and the corresponding objective content score.

Overall, the results obtained across two studies indicate that the amount of episodic detail scored by the experimenter corresponds with the subjective rating provided by the participant. This suggests that these measures are assessing somewhat overlapping constructs and that participants base their subjective judgements on the amount of episodic detail which can be retrieved. Yet an unexpected effect of temporality was observed whereby several relationships were stronger in the future condition. This was inferred from significant interactions between the objective predictors and the temporal condition. As the literature traditionally emphasises the similarities between remembering and imagining (Schacter et al., 2012; Szpunar, 2010), the differences observed in this chapter are notable. There are several factors which might account for these results. For instance, the difference between retrieving a memory to constructing a novel event, potential differences in the recency of past as compared to future episodes, socially desirable responding, and the operationalisation of variables. Another notable finding is the differences in results presented by two statistical approaches. As has already been discussed, linear mixed-effects modelling provided robust evidence of correspondence in both temporal conditions. On the contrary, correlations revealed significant relationships in the future condition only; echoing the temporal differences demonstrated using mixed-effects modelling. This chapter therefore provides compelling evidence that the subjective experience of the participant corresponds with objective content and highlights the utility of using a statistical method where correspondence can be examined at the event level.

5.2.2 Intra-individual differences in the subjective experience and objective content of mental time travel

This next chapter explored a fundamental yet under-researched question: is mental time travel a stable intra-individual difference? The widely held view is that mental time travel is a trait which remains relatively consistent across autobiographical episodes within a given individual (Palombo et al., 2013; Palombo et al., 2018; Sheldon et al., 2016). Empirical support for this notion is largely limited to subjective assessments of memories. Only one study has examined the stability of internal details (Lockrow et al., 2023) and the research which has examined consistency across future events is limited to vividness and perspective ratings (Berg et al., 2021; Verhaeghen et al., 2018). Yet both subjective ratings and internal details are commonly summed across events. These summed scores are used as an index of mental time travel. If either measure is unstable across events, this would not only call the use of summed scores into question but would also challenge the idea that mental time travel is a trait.

Across two studies, the internal consistencies of participant ratings and internal details were analysed using Cronbach's alpha (Cronbach, 1951). This added to the present literature in several ways. The stability of the overall internal category and its subcategories (event, perceptual, spatiotemporal, emotion/thought) were examined, extending the very limited research which has looked at the broad internal category only (Lockrow et al., 2023). In addition to past events, the stability of internal details was examined across future events. As the previous work had just looked at autobiographical memory (Lockrow et al., 2023), this is the first study to have done this. Participants also provided vividness, re/pre-living, event, perceptual, spatiotemporal, and emotion/thought ratings for past and future events in study one and rated past and future episodes according to a vast array of characteristics in study two. This work extends and builds upon the previous research which had only examined the stability of vividness and perspective ratings in relation to future thinking (Berg et al., 2021; Verhaeghen et al., 2018). Based on the findings by Lockrow et al. (2023) and indirect support from the wider literature (Palombo et al., 2018), it was hypothesised that internal details would have robust internal consistencies (>.70) across both past and future events. It was also anticipated that subjective ratings would have robust internal consistencies (>.70) across both past and future events.

Although not all variables had robust internal consistencies, the overwhelming majority of objective content and subjective ratings (except for objective perceptual details in study one as well as taste and self-distancing ratings in study three) had acceptable internal consistencies (>.50) across both past and future events. These findings support the theory that mental time travel is a trait (Palombo et al., 2018) and that memories are reconstructed based on individual dispositions (Addis, 2018; Hassabis & Maguire, 2007; Schacter & Addis, 2007). In addition to these theoretical implications, on a practical level, these findings substantiate both trait-based questionnaires (e.g. ART; Berntsen et al., 2019; SAM; Palombo et al., 2013) and composite scores. While all variables were relatively stable, a similar pattern was observed in subjective and objective measures whereby broader experiences (e.g. overall internal details and vividness ratings) were more stable than fine-grained episodic content (e.g. spatiotemporal). This is thought to reflect variation due to factors such as valence (Ford et al., 2012; Kensinger & Schacter, 2006; Rasmussen & Berntsen, 2009), recency (D’Argembeau & Van der Linden, 2004) and arousal (Ford et al., 2012). There was also some variation in the internal consistencies of the nineteen APAM ratings provided for past and future episodes, as not all characteristics met the threshold for robust stability and two fell below the acceptable threshold. It was speculated that the involvement of imagery might be driving stability in these ratings, as ratings which are likely to have required a higher level of visual imagery had higher internal consistencies than more conceptual ratings. Despite evidence of some variation, the vast majority of variables met the acceptable threshold, indicating that both episodic content and subjective experience are stable intra-individual differences.

5.2.3 The relationship between schizotypy and mental time travel: are positive and negative schizotypy associated with the subjective experience and objective content of autobiographical memory and future thinking?

This final chapter addressed an area which at present, has shown extremely mixed results – the relationship between mental time travel and schizotypy. This chapter examined whether schizotypy is associated with differences in mental time travel as well as which dimensions of schizotypy might be critical. As the previous chapter substantiated the view that mental time travel is a trait, the use of trait-based questionnaires and summing of both internal details and subjective ratings across trials was supported. Thus, all three of these measures were used to address this question. This allowed for exploration of how schizotypy related to both subjective and objective measures. Both forms of measurement were implemented as it was speculated that the use of different measures across studies might be accountable for the mixed findings in the preceding literature.

This research aimed to examine how positive and negative dimensions of schizotypy relate to objective content, phenomenological ratings, and trait-based assessments of mental time travel in both temporal directions. Across three studies, healthy volunteers completed the O-LIFE (Mason et al., 1995; Mason & Claridge, 2006) and described and rated past and future events which were scored according to the AI (Levine et al., 2002). In the final study of this chapter, participants also completed the APAM (Vannucci et al., 2020) and the SAM (Palombo et al., 2013). This is the first research to look at the relationship between schizotypy and mental time travel in i) both the past and future and ii) using subjective and objective measures. Furthermore, this research extends a recent study which for the first time, used a trait-based questionnaire (The ART; Berntsen et al., 2019) to examine the relationship between schizotypy and autobiographical memory (Alle et al., 2023). The SAM

(Palombo et al., 2013) was used to examine trait mnemonics in both the past and future in relation to positive and negative schizotypy. This chapter presents a comprehensive assessment of the relationship between schizotypy and mental time travel. Its aim was to disentangle the previous literature and elucidate the reasons why the findings are mixed. It was hypothesised that schizotypy would negatively correlate with internal details and positively correlate with SAM scores. Due to conflicting findings using phenomenological ratings, no directional hypotheses were made regarding the event-based subjective measure.

Across three studies there was little evidence of any significant relationships between the objective content scored by the experimenter and positive or negative schizotypy. In studies one and two, there was also little evidence of any significant associations between vividness and re/pre-living ratings provided by the participant and either dimension of schizotypy. However, when a more comprehensive assessment was implemented in study three (the APAM; Vanucci et al., 2020), several positive correlations were observed between various subjective ratings of past and future events and the positive dimension of schizotypy. In this final study, positive schizotypy was also positively and significantly correlated with the past and future subscales of a trait-based questionnaire (the SAM; Palombo et al., 2013). These findings present a notable disjunction between objective and subjective measures. On the one hand, there is compelling evidence that schizotypy is not associated with the objective content scored by the experimenter. However, there is also substantial evidence that positive schizotypy is associated with enhanced subjective experience. This presents an interesting discrepancy between objective and subjective measures which adds to the literature demonstrating a subjective-objective disjunction in schizotypal individuals (Cohen et al., 2017).

5.3 Overall contribution

5.3.1 The subjective-objective and event-trait distinction

The first key finding of this thesis was the significant relationship between the episodic content scored by the experimenter and subjective ratings provided by the participant. This indicates that there is correspondence between objective content and subjective ratings and challenges speculations that objective measures do not reflect the individual's subjective experience of mental time travel (Clark & Maguire, 2020). This is a critical finding for mental time travel research, as it suggests that the measures implemented in Chapter 2 are assessing overlapping or related facets of mental time travel. Yet it does not align with some of the existing literature.

One key justification for speculation that subjective and objective measures may be assessing different facets of mental time travel, was that several studies demonstrated a dissociation between the number of internal details scored by the AI and SAM episodic scores (Clark & Maguire, 2020; Palombo et al., 2013) which indeed, indicates a disjunction between these objective and subjective assessments. However, given the findings from Chapter 2, it is unlikely that the subjective-objective distinction is driving the dissociation between the SAM and the AI. There is a further distinction between these two measures; the AI scoring is event-based whereas the SAM is trait-based. Trait-based assessments are distinct from internal detail production as the AI measures a select subset of autobiographical events whereas the SAM assesses everyday mnemonic abilities. As Chapter 2 implemented event-based ratings as the subjective measure, both the subjective and objective measures were assessing mental time travel at the event level. This is likely the reason why these measures were significantly related in Chapter 2, despite compelling evidence that internal details and the SAM are dissociated (Clark & Maguire, 2020; Palombo et al., 2013). This finding was then echoed in Chapter 3, which found comparable levels of stability across internal details and event-based subjective ratings. Taken together, this indicates that the dissociation between internal details and the SAM is due to the distinction between event-based and trait-based approaches. Going forward, this is an important distinction which should be acknowledged. While the matter of subjective versus objective measures is a rapidly growing area of research (e.g. Clark & Maguire, 2020; Cooper & Ritchey, 2022; Thakral et al., 2020), the differences between event-based and trait-based measurement should also be acknowledged.

While subjective-objective and event-trait are both important distinctions to consider, the differences between these measures are more nuanced than simple binary distinctions. Some studies have found positive relationships between internal details and the SAM (Armson et al., 2021; Setton et al., 2021) and event-based and trait-based assessments seem to correspond when both measures are subjective. Two studies have demonstrated significant correlations between the SAM and vividness ratings (Clark & Maguire, 2020; Setton et al., 2021), and the ART has shown to robustly correlate with event-based ratings that correspond to its seven components (vividness, coherence, reliving, rehearsal, scene, visual imagery, life story; Gehrt et al., 2022). These subjective measures appear to be tapping overlapping constructs, despite one adopting an event-based approach and the other measuring broad abilities at the trait level. Chapter 4 also indicated some correspondence between event-based and trait-based subjective measures. Comparable relationships were found between positive schizotypy and both the SAM and APAM, but there was a lack of association with objective content. It was speculated that positive associations were seen in both the event-based and trait-based subjective measures due to disruptions in metacognitive functioning, which are known to be prevalent in schizotypy (Barkus et al., 2010; Chan et al., 2016; Stirling et al., 2007; see section 4.12). This suggests that in addition to distinct constructs such as retrievable episodic detail and trait mnemonics, both these subjective measures draw on metacognition which might account for their correspondence.

It is noteworthy that Chapter 4 revealed a disjunction between both forms of subjective measure in comparison to objective episodic content. Positive associations were found in event-based and trait-based subjective measures whereas no internal details were robustly correlated with positive schizotypy. Given the correspondence demonstrated in Chapter 2, this discrepancy between subjective and objective measures is likely to be a factor of schizotypal experiences. Indeed, this finding aligns with the wider schizotypy literature which has demonstrated a 'subjective-objective disjunction' (Cohen et al., 2017). As discussed in section 4.12.3, this disjunction in schizotypy might be due to disruptions to metacognitive functioning (Barkus et al., 2010; Chan et al., 2016; Stirling et al., 2007). Due to deficiencies in introspective abilities, one's own experiences may be judged inaccurately. This seems a more probable explanation than heightened subjective experiences. Given the correspondence between subjective ratings and objective content found in Chapter 2, it would be expected that enhanced subjective experience would feed into the objective scores to some degree. This proposition aligns with the literature on ageing. When describing past and future events, older adults tend to produce significantly fewer internal details than younger adults despite providing statistically equivalent or sometimes higher vividness ratings (Addis et al., 2010; Addis et al., 2011b). This effect has been ascribed to age-related differences in metacognition whereby older adults retrieve less episodic detail but cannot recalibrate their subjective ratings to this lower number of details (St Laurent et al., 2014; Wong et al., 2012). Taken together, this suggests that intact metacognition is a pre-requisite for subjective assessments as to some degree, this type of measure is tapping into metacognitive ability. This highlights an important distinction between objective and subjective measures, as internal details which are a performance-based index would not necessitate metacognition.

To summarise, this thesis provides compelling evidence that the subjective ratings provided by the participant correspond with the amount of episodic detail scored by the experimenter. This is a fundamental finding as it indicates that these measures are assessing related or overlapping constructs. This in turn suggests that previous research failed to demonstrate correspondence between the AI scoring and the SAM due to their different, event-based and trait-based approaches rather than their objective and subjective qualities. As mental time travel is multi-faceted and complex, neither the event-trait nor subjective-objective distinction is a 'one fits all' rule. To ensure each measure is being used appropriately, it is important to understand the exact facets each measure is assessing. This is a notable hurdle in the literature, which this thesis has helped to illuminate.

5.3.2 What constructs are different measures of mental time travel assessing?

The measurement of mental time travel is challenging and deciphering the facets each measure is tapping into is not always a simple matter of event versus trait or subjective versus objective. While Chapter 2 revealed that objective content and phenomenological ratings correspond, this does not mean that one is a duplication of the other or that they are assessing identical facets. There is some variation in their alignment; they are measuring overlapping rather than interchangeable constructs. This is evidenced by the higher level of correspondence observed in the future condition in Chapter 2 as well as engagement of different neural regions such as the lateral parietal cortex when describing an episode, and the hippocampus when rating it (Thakral et al., 2020). As mental time travel is multi-faceted and highly complex, some variation in the constructs each measure is assessing is to be expected. While some measures have considerable overlap and only discrete differences in what they are assessing, others might be measuring more distinct constructs. This thesis has illuminated some of these differences.

The AI scoring system (Levine et al., 2002) is a measure of episodic content that is limited to a select number of events. The events selected by the participant are likely to be those which are salient, recent, and generally accessible. Internal details provide an index of the amount of episodic detail which can be retrieved about certain episodes, which reflects one's best possible performance. This proposition is supported by the dissociation between internal details and the SAM (Clark & Maguire, 2020; Palombo et al., 2013) which suggests the AI scoring does not provide a broad scope of everyday abilities but that it measures performance on a subset of autobiographical events. This measure is also exclusively related to episodic content as the AI scoring separates episodic from semantic information (Levine et al., 2002). As semantic information is scored under external details, internal details are an index of episodic content that is not confounded by semantic content. This distinguishes internal details from other event-based indices that do not control for semantic memory.

Alike the AI scoring system (Levine et al., 2002), phenomenological ratings measure a given subset of autobiographical episodes. Yet there are critical ways in which these measures diverge. For example, phenomenological ratings do not control for semantic information. This is a key difference that was of relevance in Chapter 4 because the involvement of semantic memory might have been driving the selective association between subjective measures and positive schizotypy. This is an important distinction to consider when opting for either measure or when drawing comparisons between their results. As phenomenological ratings do not control for semantic information, they are likely to be based upon semantic as well as episodic content. Although episodic and semantic memory are typically inter-dependent (Renoult & Rugg, 2020; Tulving, 1983), there are several cases whereby one is deficient and the other is functional (e.g. semantic dementia; Hodges & Patterson, 2007; Pick; 1892). This is a particularly important consideration for testing samples where episodic and semantic memory diverge.

Another defining characteristic of phenomenological ratings is that they are an index of subjective experience. These subjective ratings provide insight into how the event is experienced by the individual rather than how they perform on an objective task. Given the correspondence between phenomenological ratings and internal details revealed in Chapter 2, it is likely that to some extent, participants are basing their ratings upon the amount of retrievable episodic detail for a given episode. The more episodic detail that can be retrieved, the higher the self-reported rating. The notion that episodic content contributes to subjective decisions is supported by one previous study. Cooper and Ritchey (2022) found strong correspondence between gist information (names of objects, people, and places) and vividness ratings. As in Chapter 2, this suggests that the objective content of the memory informs vividness judgements. This is an important finding for memory research as what constitutes the subjective experience of remembering is a partially unanswered yet pressing question in the field (Simons et al., 2020; Simons et al., 2022). Facets such as multisensory experiencing, the self, and first-person perspective have been identified as likely contributors (Simons et al., 2022) but little research has examined what informs participants subjective decisions when rating phenomenological characteristics (Cooper & Ritchey, 2022). However, this thesis has provided compelling evidence that episodic content is feeding self-reported subjective experiences.

Trait-based questionnaires are also an index of subjective experience. Rather than measuring specific episodes, these questionnaires provide a broader scope of mnemonic abilities, assessing one's capacity for mental time travel in general. The dissociation between internal details and the SAM indicates that in contrast to phenomenological ratings, trait-based measures are not gauging the amount of retrievable episodic detail for certain episodes. On the other hand, the positive relationship between trait-based questionnaires and phenomenological ratings (Clark & Maguire, 2020; Gehrt et al., 2022; Setton et al., 2021) suggests that trait level responses are based on the subjective experience of certain episodes. The level of vividness in which events are recounted seems to inform how participants regard their overall mnemonic abilities (Clark & Maguire, 2020; Setton et al., 2021).

The association between these different forms of subjective measure also indicates that metacognitive factors are involved in both types of measurement, as was speculated in Chapter 4. This suggests that in addition to subjective experience, both measures are assessing metacognitive abilities. Therefore, intact metacognition is a pre-requisite for subjective assessments due to these measures' dependency on introspective abilities. This is an important consideration for the literature as subjective assessments are commonly used to gauge the idiosyncratic experience that characterises mental time travel. In healthy individuals who are likely to have intact and reliable metacognition, these assessments should provide a more accurate indication of subjective experience. In individuals with deficits in metacognitive functioning (e.g. people with eating disorders, generalised anxiety disorder, major depressive disorder, obsessive compulsive disorder, and schizophrenia; Sun et al., 2017) however, these measures might be less reliable due to their dependence on metamemory (Folville et al., 2020). This is an important consideration for future research as in certain samples, these measures might be confounded by metacognition. In these instances, a holistic approach should be adopted through implementing objective and subjective assessments. This will allow for comparison between these measures, establishing whether metacognition is a confound of subjective measurements.

Understanding the constructs each measure is assessing has some fundamental implications for research practice. While each approach has its strengths and limitations, the most appropriate measurement should be determined by the research question at hand. If examining features of the specific autobiographical episodes, such as their valence or level of arousal, or the differences in these characteristics between episodes, an event-based approach would be most suitable. This would allow either the experimenter or the participant to rate the given properties of these episodes, allowing for examination of different event-related variables. In inter-individual differences research however, a trait-based approach might be more appropriate. In this context, trait-based questionnaires such as the SAM (Palombo et al., 2013) and the ART (Berntsen et al., 2019) present an efficient way of investigating potential relationships between individual differences and mental time travel. For instance, experiences can be assessed in healthy individuals by implementing questionnaires which adopt a continuum approach (e.g. OLIFE; Mason et al., 1995; Mason & Claridge, 2006; Beck Depression Inventory; Beck et al., 1996). If it is hypothesised that mental time travel is associated with a given individual difference dimension, this relationship can be examined straightforwardly using the trait-based approach. Although, researchers are encouraged to view these measures as complementary and where feasible, a holistic approach should be adopted. Different levels of measurements should be used to capture the multiple facets of mental time travel.

5.3.3 Differences between mental time travel into the past and future

As noted previously, one of the critical contributions of this thesis was its examination of both forms of mental time travel. The aim of adopting this approach was to provide direct evidence for any similarities and differences in temporality, as opposed to inferring whether results would replicate in a distinct form of mental time travel based on the wider literature. In the first instance, Chapter 2 revealed some unexpected and interesting differences in correspondence between objective content and subjective experience. This was demonstrated by several significant two-way interactions between the objective predictors and temporal condition. Moreover, temporal condition significantly predicted the dependent variable in all models, indicating that higher subjective ratings were reported in past events than in future events. Chapter 3 demonstrated similarities in intra-individual variability and Chapter 4 showed largely comparable relationships with schizotypy. Yet Chapter 4 also revealed additional and subtly stronger relationships in the future condition. Overall, these findings add to the vast literature demonstrating commonalities between remembering and imagining (Schacter et al., 2012; Szpunar, 2010) but have also elucidated some noteworthy differences.

To date, the semantic scaffolding hypothesis (Irish & Piguet, 2012a, 2012b, 2013) is the only influential theory which emphasises differences between mental time travel into the past and future. This theory proposes that imagining the future is more reliant on semantic memory (Irish & Piguet, 2012a, 2012b, 2013; see section 1.6.4 for a detailed description of this theory), which might provide a potential explanation for the differences in temporality found in Chapter 4. It was speculated in section 4.12.3 that the involvement of semantic memory in the subjective assessments might have been responsible for the positive relationships found between these measures and positive schizotypy. As semantic information would have been classed as external detail when scored using the AI (Levine et al., 2002), perhaps this was why positive relationships were not found with this objective measure (see section 4.12.3 for a detailed explanation). If schizotypal individuals are indeed using semantic memory as a compensatory strategy, this may also explain why the relationships were stronger when imagining the future. According to the semantic scaffolding hypothesis, future thinking is more dependent on semantic memory. While semantic information is likely to have contributed to the subjective ratings in both temporal conditions, it would have provided more support for imagining future scenarios, which are highly reliant on general knowledge. This greater involvement of semantic memory may have led to the subjective ratings of future events being higher than those provided to autobiographical memories, which rely more on the retrieval of episodic details than semantic information. In this sense, failure to retrieve episodic content is likely to have impacted the subjective ratings more so in the past condition, where this is more critical.

The semantic scaffolding hypothesis (Irish & Piguet, 2012a, 2012b, 2013) provides limited insight into the differences in correspondence found in Chapter 2, as semantic information was coded using the AI scoring system (Levine et al., 2002) but was not included in the analysis. As it was not possible to make the same adjustment for the subjective measure, it is likely that participants based their ratings on both episodic and semantic aspects of mental time travel. Because the semantic scaffolding hypothesis suggests that imagining the future is more dependent on semantic memory, we would expect semantic information to make a stronger contribution to the participants' ratings in the future condition. If this were true, it would in fact lead to higher misalignment in the future condition. Yet the opposite result was observed. As a higher reliance on semantic detail cannot explain these results, this suggests that in addition to different dependencies on semantic memory, there are further distinctions between remembering and imagining. While the semantic scaffolding theory can provide a potential explanation for the temporal differences found in Chapter 4, it provides little insight into why different levels of correspondence were revealed in Chapter 2. Therefore, alternative theoretical perspectives are discussed.

The constructive episodic simulation hypothesis interprets differences between remembering and imagining as a reflection of the greater constructive processes and novel associations which take place when simulating a novel scenario (Schacter & Addis, 2007). In this regard, the differences in temporality observed in Chapters 2 and 4 might be due to the different levels of construction required in each condition. According to this theory, imagined events would have been most reliant on constructive processes whereas past events would be more dependent on the retrieval of episodic details. Because imagining the future is less reliant on retrieving specific details, perhaps it was easier to provide introspective ratings in cases where construction was predominant. As remembering involves retrieving accurate and detailed pieces of information, this might have led to greater misalignment in the past condition which could have arisen from various factors. The participant may have rated details that: did occur but were not included in their description, were retrieved after the time limit had passed, or were prompted by the subjective ratings themselves. In other words, the participant may have rated the overall memory rather than the snapshot which was provided to the experimenter. These factors would be less prevalent in the future condition as these events were constructed for the purpose of the task. It is unlikely that future events involved additional episodic details which influenced the subjective ratings, that were not detailed to the experimenter. The constructive episodic simulation hypothesis might also provide an explanation for why positive schizotypy was more robustly correlated with subjective assessments related to the future. As the Unusual Experiences dimension of the O-LIFE engenders imagination and creativity (Claridge, 1997; Folley & Park, 2005), the process of construction involved in imagining the future might be less demanding than the retrieval of episodic details, which is known to be impaired in schizotypy (Sahakyan & Kwapil, 2016, 2018, 2019). The proposition that imagining the future engenders greater constructive processes thus presents a potential explanation for the stronger relationships observed in the future condition of both Chapters 2 and 4.

A critical element of the constructive episodic simulation hypothesis is the notion that imagining the future is reliant on the episodic memory system. If this were true, it would be expected that the past and future conditions would have comparable levels of correspondence, with the future condition mirroring the pattern observed in the past. If episodic future thinking were in fact reliant on the memory system, then we might even expect the correspondence to be higher in the past, as this is the core system. In a similar sense, we would expect relationships with schizotypy to be stronger in the past. Yet in both chapters relationships were stronger in the future condition, indicating that episodic future thinking is not entirely reliant on the episodic memory system. While this theory has provided some insight into the potential mechanism driving temporal differences, this thesis provides limited support for one of its fundamental ideas – that episodic future thinking is reliant on the episodic memory system (Schacter & Addis, 2007).

Contrary to the traditional constructive episodic simulation hypothesis (Schacter & Addis, 2007), the updated theory proposes that both forms of mental time travel are reliant on common cognitive mechanisms (Addis, 2018). This notion was supported by Chapter 3. This chapter found that past and future events were similarly stable within individuals, suggesting that both processes belong to one individual difference dimension. As this indicates that both forms of mental time travel are derived from a common dimension, this supports the theory that memory and future thinking rely on the same processes, as opposed to one being dependent on the other. Therefore, the present findings appear to align more so with this updated theory (Addis, 2018) than the traditional constructive episodic simulation hypothesis (Schacter & Addis, 2007).

In further contrast from the previous theory, Addis (2018) ascribes differences in temporality to different dependencies on schemas. It is proposed that future thinking is more reliant on schemas, as imagining a future scenario is more dependent on cognitive frameworks and conceptual understanding. The notion that imagining the future is more reliant on schemas may provide some explanation for the results found in Chapter 2. Despite cue words being counterbalanced across temporal conditions, it is anticipated that future scenarios contained broader references to schemas whereas memories elicited more precise episodic content. Perhaps higher levels of correspondence were observed in the future scenarios as it was easier to rate events related to broader themes and generic schemas than memories which are known to contain more specific episodic details (Addis et al., 2008; Addis et al., 2009a; Addis et al., 2010; Williams et al., 2020); an effect which was replicated here (see Tables A1, B1, and B3). The role of schemas might also provide some insight into the differences in Chapter 4. As discussed above, individuals scoring high in schizotypy might have been highly dependent on semantic memory to compensate for deficits in episodic memory. Schemas are a defining feature of semantic memory (Tulving, 1983), and therefore, might be the driving factor for the heightened relationships in the future. The notion that schemas are responsible for differences in temporality provides a potential interpretation of the differences in temporality found in this thesis.

To summarise, all the theories discussed can provide some degree of insight into the temporal differences observed in this thesis as well as the mechanisms which might be driving them. There are several potential explanations, ranging from different dependence on semantic memory (Irish & Piguet, 2013), construction (Schacter & Addis, 2007), and schemas (Addis et al., 2018). As the assumptions of these different theories were not explicitly examined in this thesis, it is unsurprising that the present findings do not provide overwhelming support for any one of these theories. Rather, different factors have been drawn from each of them to provide a holistic explanation of the results. The semantic scaffolding hypothesis (Irish & Piguet, 2013) suggests that different dependencies on semantic memory underpin why schizotypy was more robustly correlated with subjective measures in the future condition. Yet the constructive episodic simulation hypotheses indicate that greater reliance on construction (Schacter & Addis, 2007) and schemas (Addis, 2018) might have contributed to the stronger relationships found in the future conditions of Chapters 2 and 4.

5.3.4 The relationship between mental imagery and mental time travel

The well-established association between mental imagery and mental time travel (Conti & Irish, 2021; Dawes et al., 2022; Palombo et al., 2018; Sheldon et al., 2016; Vannucci et al., 2020) informed the interpretation of various results across chapters. For example, imagery was proposed as a potential explanation for higher levels of stability found in Chapter 3. It was speculated that the involvement of imagery was responsible for greater internal consistencies in certain imagery-dependent variables as compared to more conceptual characteristics. A better propensity for mental imagery was also proposed as the driving mechanism underlying the relationship between positive schizotypy and self-report assessments of mental time travel. This highlights the importance of imagery for both remembering the past and imagining the future, as it was repeatedly identified as a factor which might have been influencing the results. This view aligns with the scene construction theory (Hassabis & Maguire, 2007) as the involvement of mental imagery would suggest that autobiographical events are viewed in the mind's eye in a scene-like format, which substantiates the importance of scene construction.

In addition to explaining broader findings, the link between imagery and mental time travel was used to interpret differences in temporality. This was based on prior research which evidenced that mental time travel into the future appears to be more dependent on mental imagery (Conti & Irish, 2021; Dawes et al., 2022). This is a key mechanistic difference between remembering the past and imagining the future. While this difference is not regarded as critical by any of the prominent theories outlined in Chapter 1, disparate dependencies on imagery provided probable explanations for the results in this thesis. This was used as an explanation for more robust relationships between positive schizotypy and self-report measures in the future condition. As imagery presented a viable explanation, this has highlighted an important difference between remembering and imagining that should be considered in subsequent research.

It must be noted that across studies, imagery appeared to be more pertinent for results obtained with subjective measures compared to the objective assessment. For instance, as significant relationships were only observed between positive schizotypy and subjective measures, the imagery explanation noted above is only applicable to subjective experiences. The idea that subjective assessments are related to imagery is supported by the positive associations between imagery-related measures and both the APAM and the SAM (Setton et al., 2021; Vannucci et al., 2020; see Chapter 4 for detail). This suggests that mental imagery may influence subjective experiences more than narrative content. As the AI is a language-based assessment (Levine et al., 2002), this measure may not tap into all the sensory aspects that are viewed in the mind's eye during mental time travel.

Imagery was also identified as a potential contributor for the higher internal consistencies found in APAM ratings in Chapter 3. Given this interpretation, it was surprising that objective perceptual detail was the only unstable variable, as this subcategory is highly dependent on imagery. It was speculated that this finding was due to the recruitment of imagery in different sensory modalities, which may not be as stable as the visual domain (Andrade et al., 2014). Perhaps this was in fact due to the recruitment of different types of imagery when describing as compared to rating an event. Aydin (2018) has demonstrated that object imagery is positively related to phenomenological ratings of past and future events, whereas spatial imagery is positively associated with internal details in both temporalities. This indicates that different forms of imagery are supporting each index of mental time travel. Object imagery refers to the ability to vividly imagine pictorial details and mental images of objects, whereas spatial imagery is the ability to imagine spatial relations (Blajenkova et al., 2006). Based on Aydin's (2018) finding, it is speculated that greater object imagery engenders richer subjective experiences when remembering the past and imagining the future. Indeed, SAM episodic and object imagery scores are significantly associated (Fan et al., 2021). As mental imagery was generally used to explain findings obtained with subjective measures, these interpretations pertain to object imagery and not spatial imagery. Yet spatial imagery might be more critical for the objective assessment, as relational processing would ensure the coordination and integration of different episodic details (Sheldon et al., 2016). This presents a further distinction between the constructs supporting each measure of mental time travel.

5.3.5 The value of mixed-effects modelling in mental time travel research

A further contribution of this thesis is that it has demonstrated the value of using trial-level analyses in autobiographical research. Although linear mixed-effects modelling and multi-level modelling have previously been identified as appropriate statistical techniques in this field (Armson et al., 2021; Folville et al., 2020; Ford et al., 2012; Wright, 1998), this remains under-utilised as several studies have used correlational approaches in contexts where multi-level modelling would be advantageous (e.g. Clark & Maguire, 2020; Noël et al., 2022; Thakral et al., 2020). By implementing both linear mixed-effects modelling and correlations of summed scores to address the same research question in Chapter 2, the strengths of trial-by-trial analyses were exemplified. This more sensitive approach identified significant relationships which were in some cases, masked by the correlations. This demonstrates an important consideration for future research. If correlations alone were implemented in Chapter 2, a different set of conclusions would have been inferred. It would have appeared that internal details and subjective ratings were significantly associated in future but not past events. By implementing both approaches, it is evident that these measures are associated in both forms of mental time travel but to a higher degree in future thinking. Similarly, the use of composite scores might have been responsible for previous dissociations, which led to speculation over the constructs each measure is assessing (Clark & Maguire, 2020). This demonstrates the value of using a trial-level approach over correlations where possible and appropriate. As mixed-effects modelling is the more sensitive method, adopting this statistical approach will lessen the possibility of inaccurate conclusions, which might have occurred if this thesis used summed scores only.

While Chapter 2 demonstrates that mixed-effects modelling is the more sensitive approach, Chapter 3 evidenced why this trial-by-trial approach is more appropriate for autobiographical research. Although this chapter indicated that mental time travel of a given individual remains somewhat consistent across different memories and imaginings, it also showed the more fine-grained episodic content varies depending on the context of the episode. This was reflected in the internal consistencies of different variables, as not all met the threshold for being robust. It was speculated that some variables were less stable because given the nature of mental time travel, more specific content will naturally differ from episode-to-episode. For example, the spatiotemporal detail might be clearer for an episode that took place in a setting which we are familiar with, such as our home or place of work, but less rich for an event at a location which was only visited this one time. Similarly, a highly emotional event would be expected to contain more emotion/thought details and be rated higher for emotional intensity in comparison to a mundane scenario. This may explain why the summed scores implemented in Chapter 2 were less sensitive than a trial-level approach. By totalling scores across events, this variability between events is partially lost, thus reducing the likelihood of finding the significant association which was observed at the event level. This not only provides insight into the results observed in Chapter 2, but it is an important consideration for future research.

It should be highlighted that Chapter 3 also substantiated the use of summed scores, as most objective content and subjective ratings had acceptable internal consistencies across both past and future events. Taken together, these results suggest that a trial-level approach is advantageous when exploring relationships between event-based measures. Yet composite scores are appropriate for assessing relationships with individual differences, as well as comparing scores between groups such as younger and older adults or clinical samples and healthy controls. For example, if a researcher wanted to determine whether individuals with depression provided lower ratings than healthy controls, a summed score which captures their experiences across events would provide an accurate indication of whether there are any significant differences between these samples. A summed score is appropriate in this instance, as the research aims to understand how these populations experience mental time travel in general. Indeed, this approach was implemented in Chapter 4 to examine the relationship between mental time travel and schizotypy. This was an appropriate approach for this chapter, as the aim was to determine how schizotypal individuals experienced mental time travel in general. The idiosyncrasies between different episodes were irrelevant in this context. In Chapter 2 however, the idiosyncrasies between each event created noise in the correlations, as the aim was to determine whether there was correspondence between the experimenter's and the participant's scores. For this research question, mixed-effects modelling was the advantageous approach. Both statistical approaches are justifiable, given that they are carefully selected based on the research question.

5.4 Limitations of the cue word paradigm

All the studies conducted as part of this thesis used a cue word paradigm (Crovitz & Schiffman, 1974) and the traditional AI scoring procedure (Levine et al., 2002). As outlined in section 1.7.1, this approach was selected over alternatives based on its various advantages, making it the gold standard of autobiographical memory measurement. Although there are many strengths of this approach, it is not without its disadvantages. As this procedure was adopted for all empirical chapters, its limitations are discussed.

One disadvantage of adopting a cue word paradigm (Crovitz & Schiffman, 1974) over the traditional AI (Levine et al., 2002) was that events were not prompted from pre-determined life periods. As the traditional AI prompts events from early childhood, adolescence, early adulthood, middle ages, and the previous year (Levine et al., 2002), temporal proximity is controlled for. As more recent events typically contain more episodic detail and receive higher subjective ratings (Addis et al., 2008; Arnold et al., 2011; D'Argembeau & Van der Linden, 2004; Gamboz et al., 2010; Melendez et al., 2018), proximity is a factor which might have biased the present findings. This is a limitation of the overall thesis as recency effects were not examined nor controlled for across all studies. Although this approach was adopted because cue words are recommended over life periods to avoid overly rehearsed events (Palombo et al., 2015), it is possible that more recent events were generally selected which might have confounded some results. For instance, if more recent events were described this might have led to i) stronger correspondence between subjective experience and objective content, ii) higher internal consistencies across events, and may have iii) obscured the subtle impairment that would be expected in individuals high in schizotypy. Overall, the results presented might be specific to more recent episodes. To determine whether the present findings extend to more proximal events, future research should prompt events from pre-determined life periods.

A second limitation of the cue word paradigm (Crovitz & Schiffman, 1974) is that it has limited ecological validity. While this paradigm is considered a naturalistic approach (Levine et al., 2002), it still requires participants to recount autobiographical episodes to the experimenter in a situation that would not occur outside of the laboratory. In comparison to more naturalistic procedures such as staged events (see section 5.5 for a detailed description of the staged event paradigm), the cue word paradigm has less ecological validity (Sheldon et al., 2018). This is because the situation in which a word is used to prompt recall, a verbal description is required, and a time limit is imposed, is not one that would occur outside of experimental research. This raises the question, are we really measuring what is true for the individual or are we testing what we believe is true based on our experimental procedures? While a valid concern which should be acknowledged, ecological validity is extremely difficult to control for in autobiographical research (Sheldon et al., 2018). The AI scoring controls for these factors, as unlike measures such as the Autobiographical Memory Interview (Kopelman et al., 1989) which separates episodic from semantic by conducting separate interviews, the AI allows participants to switch between categories of information in naturalistic discourse. Therefore, although there are limits to its ecological validity, this approach also has its advantages.

A further limitation of the cue word paradigm is the inability to experimentally control the encoding context of the memories selected by the participant (Sheldon et al., 2018). When presented with various cue words, the participant selects autobiographical episodes retrospectively. Due to this lack of experimental control, it is uncertain whether differences at retrieval are in fact due to variation in the encoding of different episodes. It has already been discussed that the cue word paradigm engenders participants' best possible performance, as they are tested based on a small subset of self-selected episodes. This highlights the disadvantage of having no experimental control over the episodes which are recounted. If the episodes were pre-determined by the experimenter, this would ensure that the most accessible, well-rehearsed, or prominent events were not being selected. This could be achieved by adopting a staged event paradigm (Armson et al., 2021; Diamond & Levine, 2020; Diamond et al., 2020) whereby the encoding context is controlled, and several target items are implemented, thus pre-determining events to prompt at recall (N.B. this approach will be discussed in detail in section 5.5). This would provide a more accurate picture of how a given individual remembers everyday situations.

It is noteworthy that adopting a staged event paradigm (Armson et al., 2021; Diamond & Levine, 2020; Diamond et al., 2020) would address limitations related to temporal proximity, ecological validity, and controlling encoding for autobiographical memories. However, it is not applicable for the study of episodic future thinking. As one of the overarching aims of this thesis was to examine both forms of mental time travel using consistent procedures, these factors were not prioritised, and a staged event paradigm was not appropriate. Nevertheless, a staged event paradigm is one way in which ecological validity and experimental control can be increased. Despite this approach not being suitable for this thesis, it is a valuable method for the study of autobiographical memory which addresses several of the limitations of outlined in this section. Hence this is a potential avenue for autobiographical memory research which is discussed in the following section.

5.5 Future directions

As discussed in the previous section, all the present studies used the same cue word paradigm which is subject to various limitations. Therefore, the staged event paradigm (Armson et al., 2021; Diamond & Levine, 2020; Diamond et al., 2020) is proposed for future autobiographical memory research. This approach has been used in a previous study where participants carried out an immersive audio-guided walking tour featuring various target items (Armson et al., 2021; Diamond & Levine, 2020; Diamond et al., 2020). Participants then returned to the lab after two days and freely recalled their experience of the tour. Their responses were then scored according to the AI scoring protocol (Levine et al., 2002). Not only is this approach more naturalistic, but it controls the content that is encoded and subsequently retrieved. By using a similar strategy in future research, this may provide a more typical picture of an individual's autobiographical abilities. Words or pictures of target items could be used to prompt several different autobiographical memories when participants return to the lab. Akin to the studies in this thesis, these events would be described to the experimenter before subsequently completing various phenomenological ratings. This would enable the research questions investigated in this thesis to be examined in more naturalistic autobiographical memories. As has been discussed, the cue word paradigm is likely to prompt memories which are accessible and well-rehearsed, representing the individual's best possible performance rather than their overall mnemonic abilities. This is a limitation of the overall thesis as this procedure was implemented in all the included studies. Therefore, the conclusions presented in this thesis might be specific to the paradigm used. If subsequent studies adopt this guided tour procedure, this will establish whether the results presented here are replicable in a paradigm which engenders autobiographical memories with different characteristics. The content of memories would be controlled, providing a more accurate picture of their capacities rather than a snapshot of their most accessible or marked events. A further advantage of using this approach is that temporal proximity is also controlled. If all content is encoded on the same date, temporal distance would no longer be a potential confound. However, it must be highlighted that this approach can only extend our knowledge of these topics in autobiographical memory. It is not a viable paradigm for bidirectional or future thinking research. Yet adopting a staged event paradigm would build upon some of the work presented in this thesis, addressing the limitations of the cue word paradigm (Crovitz & Schiffman, 1974) which were outlined in section 5.4.

Another avenue for future research is to examine the event-trait distinction further. The distinction between event-based and trait-based measures has been discussed in detail. Yet this thesis provides a limited overview of the potential differences between these measurements. Neuroimaging is one complementary approach which could extend this work. This thesis examined different forms of measurement at the behavioural level, demonstrating both similarities and differences. Now these differences should be examined at the neural level. Functional MRI has been used to examine the neural substrates of both internal details (Addis et al., 2011a; Thakral et al., 2020) and vividness ratings (Addis & Schacter, 2008; Thakral et al., 2020), revealing activity in several overlapping networks but also some distinct regions. However, there has been little research conducted into the neural correlates of trait-based measures. Only one study has examined the neural correlates of the

SAM (Palombo et al., 2013). Sheldon et al. (2016) did this by examining patterns of medial temporal connectivity obtained from resting-state functional MRI scans. This revealed that the episodic subscale of the SAM was associated with medial temporal lobe connectivity to posterior occipital and parietal cortices. Petrican et al. (2020) then re-examined this sample using an alternative analysis, revealing that SAM episodic scores were related to a similar pattern of brain activity associated with a visual memory task. This indicates that the SAM and event remembering are dependent on some common mechanisms, which is unsurprising given that both are expected to rely on the core network (Benoit & Schacter, 2015). As internal detail production and vividness ratings each correlate with activity in distinct brain regions (Thakral et al., 2020), it is anticipated that the SAM also recruits some distinct regions. Yet it is currently unclear whether the SAM is associated with activity in additional brain regions, as the existing research has only examined one specific network. As this provides a limited indication as to what regions might associate with the SAM, a data-driven network analysis would be a viable option. This approach would allow for a comparison of whole brain and default mode networks.

A further rationale for adopting a network analysis approach is that the existing literature has predominantly employed functional neuroimaging. In addition to functional measurements, structural measurements could be used to elucidate the structural attributes of the brain that correlate with performance on the SAM. These structural measurements would complement the picture painted by the functional measurements, providing a more comprehensive understanding of the mechanisms associated with the SAM. This approach could analyse graph theoretical metrics to determine which measures of the topological organisation of the brain correlate with the different SAM subscales. By examining the neural correlates of the SAM, the degree of overlap with the correlates of the AI and vividness ratings would indicate the extent to which these measures are gauging distinct constructs; providing complementary evidence to the arguments presented in this thesis. It would also provide further insights into the mechanisms supporting each measure. Along with the previous research, this would provide more holistic understanding of the different or overlapping mechanisms each measure depends on.

A more specific recommendation for future research is to examine the influence of metacognition and in particular, its contribution toward the significant relationship between subjective measures and positive schizotypy. It was speculated that metacognition might be driving the results from Chapter 4 where subjective and objective measures presented distinct patterns of results in relation to positive schizotypy. As discussed in section 4.12.3, this finding indicated that in certain samples, subjective measures are tapping into metacognitive abilities more so than mental time travel. This aligns with the finding that the SAM was strongly associated with a measure of self-efficacy (Setton et al., 2021), which suggests that metacognition is a confounding factor when opting for subjective assessments. While this is an important avenue for further exploration, measuring metacognition is not a simple task. Although questionnaires are one of the most frequently used measures of metacognition (Akturk & Sahin, 2011), this technique has limitations. The reliability of questionnaires depends on metacognition itself and are therefore not recommended. Interestingly, metacognition is often assessed by examining the degree of correspondence between an objective, performance-based measure and subjective assessments (Seow et al., 2021). While this exact question was addressed in Chapter 2, this provides little insight into the metacognition of individuals who score high in positive schizotypy. Indeed, this approach is more effective where a specific population of individuals is assessed (e.g. patient groups). Alternatively, it has been suggested that metacognition can be quantified by examining the degree of association between accuracy and confidence at the trial-level (Fleming & Lau, 2014). As discussed in Chapter 4, some research has adopted a similar approach to examine metamemory in schizotypy. Evans et al. (2019) administered an episodic memory task and found that individuals scoring high in positive schizotypy were more likely to state that 'new' items were 'old' but also gave high confidence ratings across all items, even when they were false memories related to lure items. A similar task could be implemented to assess whether metacognition has a mediating effect over the relationships presented in this thesis. The correlation between positive schizotypy and confidence ratings for false memories (i.e. 'new' items given an 'old' response) would provide a quantitative index of metacognition. A mediation analysis could then be performed to determine whether this quantified measure of metacognition mediates the relationship between positive schizotypy and subjective assessments of mental time travel. This would determine whether this relationship is due to attenuated metacognition or other variables such as heightened capacities for mental imagery.

5.6 Conclusion

Tulving first stated that the subjective experience that accompanies mental time travel "should be the ultimate object of interest, the central aspect of remembering that is to be explained and understood" (Tulving, 1983, p. 184). Yet given its subjective nature, the assessment of mental time travel is an ongoing challenge in this literature. While it is common practice to adopt either subjective measures that are scored by the participant or objective measures that are scored by the experimenter, there remains gaps in our knowledge regarding the exact constructs each measure is assessing. Much of the previous research has adopted either one type of measure or examined one form of mental time travel. This thesis has demonstrated that a holistic approach whereby both types of measurement are used to examine both forms of mental time travel, is a viable and valuable approach for future research. The relationship between subjective and objective assessments was established, providing novel insights into the facets of mental time travel each measure is assessing. Direct support was provided for the widely accepted view that mental time travel is a trait. For the first time, it was demonstrated that this extends to both subjective and objective assessments, as well as both temporalities of mental time travel. Hence there is compelling evidence that remembering the past and imagining the future belong to one individual difference dimension. A comprehensive evaluation of the relationship between mental time travel and schizotypy was also conducted. By doing so, an interesting disjunction was revealed between objective and subjective measures and how they relate to positive schizotypy. In contrast to the correspondence demonstrated in Chapter 2, this evidenced that subjective and objective measures can be disjunctive in individuals with certain personality characteristics and experiences. This provided further insight into the facets of mental time travel each measure is assessing, as the disjunction in these individuals illuminated the importance of metacognition for subjective assessments. There are several ways in which future studies can build upon this research, by examining further approaches to measurement. For instance, using a staged event paradigm (Armson et al., 2021; Diamond & Levine, 2020; Diamond et al., 2020) or extending the work on trait-based assessment. The latter can be achieved by adopting a neuroimaging approach, thus determining any mechanistic differences with other types of measure. This thesis has provided a basis for these proposed research avenues which alike this thesis, will further our knowledge of the subjective experience of mental time travel.

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Appendix A: Descriptive statistics of internal details and subjective ratings for study one

Table A1. *Means, minimum (Min) and maximum (Max) scores for summed internal details in study one*

	Past			Future		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
Event/Perceptual	80.09	34.00	209.00	55.15	28.00	129.00
Spatiotemporal	34.67	12.00	100.00	24.77	6.00	57.00
Emotion/Thought	12.73	1.00	33.00	6.02	0.00	22.00
Internal	127.50	64.00	307.00	85.94	44.00	174.00

Table A2. *Means, minimum (Min) and maximum (Max) scores for summed subjective ratings in study one*

	Past			Future		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
Event/Perceptual	27.58	18.00	35.00	22.81	9.00	31.00
Spatiotemporal	59.73	46.00	70.00	47.31	25.00	69.00
Emotion/Thought	26.40	13.00	35.00	21.02	8.00	31.00
Vividness	26.77	8.00	35.00	21.79	8.00	32.00
Re-/Pre-Living	27.85	17.00	35.00	23.44	10.00	33.00

Appendix B: Descriptive statistics of internal details and subjective ratings for study two

Table B1. *Means, minimum (Min) and maximum (Max) scores for summed internal details in positive events in study two*

	Past			Future		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
Event/Perceptual	33.63	10.00	62.00	26.21	10.00	52.00
Spatiotemporal	14.91	5.00	31.00	9.66	0.00	24.00
Emotion/Thought	8.56	0.00	18.00	6.20	0.00	21.00
Internal	57.11	17.00	101.00	42.18	13.00	74.00

Table B2. *Means, minimum (Min) and maximum (Max) scores for summed internal details in negative events in study two*

	Past			Future		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
Event/Perceptual	30.23	10.00	51.00	24.15	6.00	45.00
Spatiotemporal	10.67	2.00	29.00	7.45	0.00	22.00
Emotion/Thought	7.59	1.00	23.00	7.13	0.00	17.00
Internal	48.48	15.00	85.00	38.73	9.00	76.00

Table B3. *Means, minimum (Min) and maximum (Max) scores for summed subjective ratings in positive events in study two*

	Past			Future		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
Event/Perceptual	15.93	8.00	21.00	13.12	5.00	20.00
Spatiotemporal	34.67	17.00	42.00	27.40	8.00	42.00
Emotion/Thought	15.80	8.00	21.00	13.56	4.00	21.00
Vividness	15.41	8.00	21.00	12.96	4.00	21.00
Re-/Pre-Living	15.67	5.00	21.00	13.40	4.00	19.00

Table B4. *Means, minimum (Min) and maximum (Max) scores for summed subjective ratings in negative events in study two*

	Past			Future		
	Mean	**Min**	**Max**	**Mean**	**Min**	**Max**
Event/Perceptual	15.15	5.00	21.00	11.32	3.00	21.00
Spatiotemporal	33.59	14.00	42.00	24.99	7.00	40.00
Emotion/Thought	15.95	5.00	21.00	13.78	5.00	21.00
Vividness	16.23	7.00	21.00	12.28	3.00	19.00
Re-/Pre-Living	16.09	5.00	21.00	12.71	4.00	20.00

Appendix C: Violin plots of external details in studies one and two

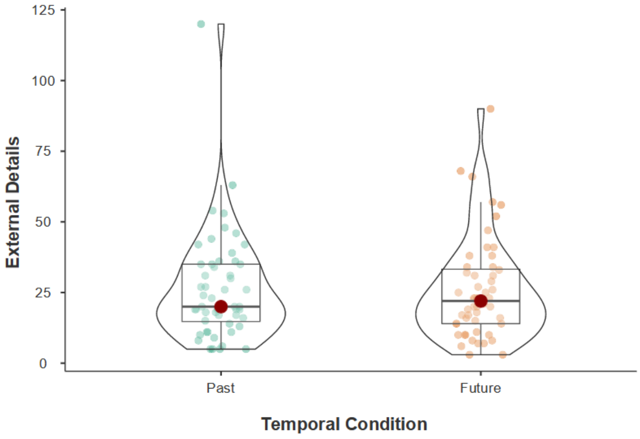

Figure C1. Violin plot of external details in study one.

A

B

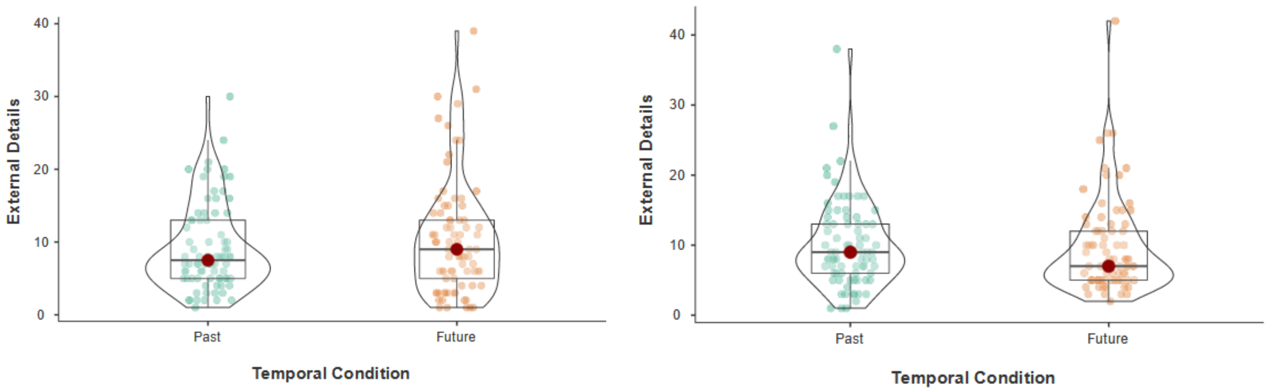

Figure C2. Violin plots of external details in study two in A) positive events and B) negative events.