Autobiographical Memory Conjunction Errors:

Factors Influencing Memory Accuracy

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Abstract

It has long been recognised that episodic memory representations are stored as constituent features distributed widely across the brain, and that retrieval of a coherent episode requires these fragments to be relocated, reactivated and reintegrated. This reconstructive memory system is subject to a range of distortions, including erroneous incorporation of features from one memory into another, forming what are known as memory conjunction errors. Factors influencing the generation of conjunction errors in autobiographical memory (AM) have thus far received little empirical attention. Understanding the nature of AM conjunction errors affords us the opportunity to identify the circumstances that may facilitate the occurrence of these errors, particularly in situations where memory authenticity is of high priority, such as eyewitness testimony.

The studies in this thesis illuminate several factors influencing the prevalence of AM conjunction errors. *Study 1* demonstrates an imagination inflation effect for AM conjunction errors, whereby generating a highly vivid and plausible simulation at encoding increases the likelihood of a conjunction error later forming. *Study 2* further reveals that the subjective and objective qualities of conjunction events at retrieval are similar to those of authentic memories, in line with a source monitoring account of false memories. In *Studies 3* and *4* the cognitive processes underlying AM conjunction error formation were evaluated through the lens of healthy aging. *Study 3* extends findings of an age-related increase in conjunction errors for simple laboratory stimuli to distinctive and personally-relevant AMs. *Study 4* further demonstrates that declines in inhibition ability may underlie the increased rates of AM conjunction errors with age, and can account for some of the individual variation in conjunction error susceptibility in younger adults. These findings speak towards an overreliance on the familiarity garnered by the individual components of a conjunction lure, as well as a phenomenological dedifferentiation of conjunction events and veridical memories, as contributing to the formation of AM conjunction errors. This research expands our knowledge of the types of memory distortions to which the constructive memory system is prone, and also elucidates some of the mechanisms by which these errors are misattributed as reality.

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Chapter 1: General Introduction

> *"Recovering a memory, therefore, is not like finding a book at a particular single location, but it is more like assembling the pages of a book that may be scattered in different locations in the library"* (Dudai, Moscovitch, Schacter, & Morris, 2007, pp. 19).

It has long been acknowledged that memories are not exact reproductions of past events, but instead are fluid representations which can change over time in accordance with the acquisition of new knowledge about the world (Schlichting & Preston, 2015) and evolving beliefs about the self (Conway, 2005). Episodic memory, or memory for temporally and spatially contextualised events (Tulving, 1972), serves as a personal and richly detailed account of the past, and such memories are stored throughout the cortex as constituent features which must be relocated, reactivated and reintegrated upon retrieval (Bartlett, 1932). This dynamic memory system confers many advantages, such as the ability to flexibly recombine memory details to simulate future events (Schacter, Guerin, & St Jacques, 2011), problem solve (Sheldon, McAndrews, & Moscovitch, 2011) and think creatively (Madore, Addis, & Schacter, 2015). However, the malleability of memory also renders us susceptible to a range of distortions and errors, including the miscombination of memory elements to form a particular type of error known as a memory conjunction error. The aim of this thesis is to further our understanding of the factors that influence conjunction error formation within autobiographical memory (AM), including phenomenological quality, imagination, processing fluency, and executive and mnemonic functions. Moreover, we leverage the neurocognitive changes evidence in healthy aging as a window into how some of these processes underpin AM conjunction errors.

1.1 Autobiographical memory

It is well established that memory is a complex process; many different subsystems have been identified, each recruiting distributed cognitive processes that rely on whole-brain networks (see Schacter & Tulving, 1994). Typically when lay people speak of memory they are referring to long-term declarative memory, or conscious memory for facts and events (see Squire, 1992), as opposed to nondeclarative or implicit memory, which requires no conscious awareness to learn or retrieve. Declarative memory can be further delineated into that which is general (i.e., public) versus that which is autobiographical (i.e., personal). AM is not a discrete memory category in itself, but instead describes memory that is self-referential in nature. AM plays an integral role in the formation of identity (Prebble, Addis, & Tippett, 2013; Wilson & Ross, 2003), social interaction (Alea & Bluck, 2003; Ciaramelli, Bernardi, & Moscovitch, 2013), goal-directed behaviour (Bluck, 2003), problem solving (Goddard, Dritschel, & Burton, 1996; Madore & Schacter, 2014; Sheldon et al., 2011) and navigation (Spreng, Mar, & Kim, 2008). Moreover, many of the applied situations in which memory authenticity is critical involve autobiographical retrieval, such as eyewitness testimonies used in legal cases.

AM itself can be distinguished as either episodic or semantic (Cabeza & St Jacques, 2007; Levine, 2004). Episodic memory represents personal experiences that are temporally and spatially defined, and involve a state of “mental time travel” and conscious re-experience. Semantic memory on the other hand is abstract and context-free encyclopaedic knowledge that exists without reference to a specific time or place (Tulving, 1972, 1985). This dichotomy in conscious memory is supported by cases of amnesic patients who experience differential episodic or semantic deficits. For example, patients with medial temporal lobe (MTL) damage – specifically to the bilateral hippocampus – typically present with episodic amnesia, but spared remote semantic knowledge (Manns, Hopkins, & Squire, 2003). A similar pattern is observed in healthy aging, whereby reductions are observed in episodic memory, but semantic memory is relatively preserved (Light, 1996; Maguire & Frith, 2003; Nilsson, 2003; St Jacques, Rubin, & Cabeza, 2012), and may actually improve with age (Salthouse, 2004). In contrast, patients with semantic dementia – which affects the anterolateral temporal lobe but spares MTL regions – exhibit semantic memory deficits, but can recall episodes from their personal past (Greenberg & Verfaellie, 2010; Kensinger & Giovanello, 2005). This double dissociation indicates that the retrieval of episodic and semantic memory may be underpinned by independent cognitive processes.

The role of the MTL (composed of the dentate gyrus, hippocampus proper, entorhinal, perirhinal, and parahippocampal cortices) in the storage and recall of episodic memories has been hotly debated. The Standard Consolidation Theory (see Squire & Bayley, 2007, for a recent update), posits that consolidation results in the transfer of episodic memory traces to the neocortex, where they can eventually be retrieved without MTL involvement, though the timeframe of this process may be decades long (McClelland, McNaughton, & O'Reilly, 1995). This perspective is supported by patients with MTL damage who exhibit a temporally-graded amnesia, whereby unconsolidated recent episodic memories are impaired, while remote episodes supposedly stored in the neocortex are unaffected (Rempel-Clower, Zola, Squire, & Amaral, 1996; Scoville & Milner, 1957). However, some amnesics with MTL damage present with age-independent episodic deficits. These observations formed the basis of the Multiple Trace Theory (Nadel & Moscovitch, 1997), and later the Transformation Hypothesis (Winocur, Moscovitch, & Bontempi, 2010), which argue that the MTL is critical for episodic memory retrieval for the duration of the memory's life. However, over time some episodic memories may become 'semanticised', losing their contextual quality and becoming functionally independent from the hippocampus (Rosenbaum, Winocur, & Moscovitch, 2001; Yassa & Reagh, 2013). This process accounts for the apparent temporal gradation observed in some cases of episodic amnesia; these patients are recalling decontextualized versions of previously rich episodic memories which are no longer MTL-dependent. Research to date tends to support this latter view of episodic memory (for example, Kim & Cabeza, 2007; Maguire, 2001), though the evidence is far from conclusive.

To further complicate matters, the double dissociation between episodic and semantic memory deficits is not a complete one, as many amnesic patients with MTL damage present with deficits in both types of memory (Bayley & Squire, 2005; Kensinger & Giovanello, 2005). Moreover, the neural networks engaged by semantic and episodic memory share some overlap (Binder, Desai, Graves, & Conant, 2009; Burianová & Grady, 2007; Burianová, McIntosh, & Grady, 2010). Accordingly, rather than being considered two functionally and anatomically separate systems, semantic and episodic memory are best considered as interdependent. Semantic memory may provide a basic scaffold around which an episodic event can be constructed (Irish & Piguet, 2013; Levine, 2004; Svoboda et al., 2006). Reciprocally, the acquisition and retention of semantic memories is more successful if they are embedded within a network of existing episodic memories (Greenberg & Verfaellie, 2010).

Episodic AM is thought to be distinct from episodic memory for laboratory-based events, in which one learns lists of stimuli that have little personal significance (Koriat, Goldsmith, & Pansky, 2000). Memory for laboratory-based and autobiographical events have been treated in the literature as relatively interchangeable; memory for lists are thought to comprise 'mini-events', recruiting core memory processes that can inform our knowledge of the processes underlying memory for personal life events. Using list memory in research gives the advantage of greater experimenter control, but at the detriment of ecological validity (Koriat & Goldsmith, 1996). Episodic AMs, in contrast, are complex, in that they are spatially, temporally, perceptually and emotionally rich with high personal significance, and these idiosyncrasies may not be captured well by memory for simple words or pictures. AM also operates on a longer time scale, on the order of years or even decades, whereas episodic memory for items in a list is typically measured in minutes to days or sometimes weeks (Conway & Pleydell-Pearce, 2000). Moreover, these two types of memory display differing developmental trajectories, in that older children perform at adult levels on memory tests involving an autobiographical component, but have lower performance for tasks relying on episodic memory with no personal relevance (Pathman, Samson, Dugas, Cabeza, & Bauer, 2011). Similarly, memory deficits in older adults are typically observed when using laboratory stimuli, but are not as striking when using naturalistic or autobiographical settings (Rendell & Craik, 2000).

The multifaceted nature of episodic AM, which incorporates sensory, emotional, semantic and spatiotemporal elements (Svoboda et al., 2006; Cabeza & St Jacques, 2007; Levine, 2004), activates a widely distributed network of brain regions, including the prefrontal cortex (PFC), specifically the ventromedial and ventrolateral PFC, as well as retrosplenial and posterior cingulate cortices, temporal pole, temporoparietal junction, cerebellum and MTL areas (Cabeza & St Jacques, 2007; Maguire, 2001; Svoboda et al., 2006). This episodic AM network bears many similarities to the default mode network that is activated when the brain is in a resting state, (which often involves thinking about one's own past and future; Andrews-Hanna, Reidler, Huang, & Buckner, 2010; Andrews-Hanna, 2012), and deactivated during participation in external, stimulus-driven tasks (Buckner, Andrews-Hanna, & Schacter, 2008).

Although episodic memory for autobiographical and laboratory-based events recruit similar brain areas, including the MTL and PFC (Burianova & Grady, 2007; Burianova et al., 2010; Cabeza et al., 2004), differences in the underlying neural substrates between the two memory types are also prominent. AM recruits regions associated with self-relevant processing (medial PFC), recollection (hippocampus) and visual-spatial memory (parahippocampal and occipital cortices) to a greater degree than controlled laboratory events (Cabeza et al., 2004; Gilboa, 2004). In comparison, memory for laboratory events activates the dorsolateral PFC, which may reflect the engagement of more fine-grained retrieval monitoring processes (Gilboa, 2004; McDermott, Szpunar, & Christ, 2009). As such, while work on conjunction errors for simple stimuli like words can inform our understanding of conjunction errors occurring in AM, the differences in both phenomenology and underlying neural substrates mean that caution is advised when extrapolating results from laboratory memory tasks to memory of our personal history.

1.2 Episodic AM encoding and retrieval

Bartlett (1932) was one of the first to theorise that memory is an actively constructive process, rather than a literal recording of the past. He suggested that it is unnecessary and uneconomical to store every episode precisely as it occurred, and instead far more efficient to extrapolate the specifics of an event based on a schema or framework that holds the essence of the memory (see also Neisser, 1986). Considerable evidence now exists to demonstrate that memory is mutable and can be strongly influenced by the schemata we have built about ourselves and the world (Barclay, 1986).

It was further theorised by Neisser (1986) that episodic memory is inherently nested in structure, with smaller details and events embedded within larger memory units. To use his example, pressing the individual keys on a keyboard are discrete details that form part of the current writing episode, which itself is a lower level event in the grander scheme of writing a thesis. These different units of experience are linked in memory, so that retrieval of details at one level will activate recall of upward or downward levels. A similar idea was put forward by Conway & Pleydell-Pearce (2000), who proposed that the autobiographical knowledge base is organised in a hierarchical manner, with varying levels of specificity. Constituent memory features are organised by event-specific knowledge at the lowest level, which can be themselves grouped into generalised event clusters (e.g., ‘writing a thesis’) and further in semanticised lifetime periods (e.g., ‘when I was at university’).

In line with the notion that episodic retrieval is constructive, there is evidence to suggest that the constituent features of an episode (e.g., perceptual, emotional and visuospatial details) are not stored in a unitised manner, but are distributed widely across the brain. For instance, the cortical reinstatement (Woodruff, Johnson, Uncapher, & Rugg, 2005) and sensory reactivation (Nyberg, Habib, McIntosh, & Tulving, 2000; Wheeler, Petersen, & Buckner, 2000) hypotheses posit that brain regions engaged during the encoding of an item or elements of an event are necessarily reactivated during retrieval of that event. Evidence that the modality of studied items determines the neural regions involved in the retrieval of those items supports this notion. For instance, visual and auditory cortical areas are engaged during retrieval of visual and auditory stimuli, respectively (Vaidya, Zhao, Desmond, & Gabrieli, 2002; Wheeler et al., 2000), and similar findings have been reported for emotional stimuli, mental imagery, and motor enactment (for reviews, see Danker & Anderson, 2010; Rugg, Johnson, Park, & Uncapher, 2008). As such, no single brain area retains a complete representation of a multifaceted episode (McClelland et al., 1995; Squire, 1992a). As Greenberg and Rubin (2003) eloquently state: "searching for a single neural location of memory is a fool's errand. Memory is stored everywhere, and at every level of analysis" (pp. 690).

Despite the fact that episodic memories are stored in a distributed content-dependent fashion, converging evidence from both lesion and neuroimaging studies have identified the MTL and PFC as brain structures crucial to the encoding and retrieval of any episodic memory, regardless of its specific content. For instance, healthy aging is typically associated with structural declines in MTL (particularly the hippocampus; Buckner, Head, & Lustig, 2006; Raz et al., 2005; Tisserand et al., 2004) and PFC areas (Raz et al., 2005; Tisserand et al., 2004; West, 1996). These structral changes contribute to age-related reductions in episodic memory ability (Leube et al., 2008; Levine, 2004; Moscovitch & Winocur, 1995; Persson et al., 2006; Schacter, Savage, Alpert, Rauch, & Albert, 1996; Sexton et al., 2010; St Jacques et al., 2012; Stuss, Craik, Sayer, Franchi, & Alexander, 1996) and episodic AM in particular (St Jacques et al., 2012). Similarly, frontal damage is associated with the decreased generation of episodic detail when recalling AMs (Levine, 2004).

An interactive and collaborative relationship between the MTL and PFC exists in order to successfully store and recall an episode from memory (McClelland et al., 1995; Preston & Eichenbaum, 2013; Schlichting & Preston, 2015; Simons & Spiers, 2003). Indeed, reduced connectivity between these regions is observed with healthy aging, contributing to age-related declines in episodic memory (Andrews-Hanna et al., 2007; Gutchess et al., 2005; St Jacques et al., 2012). The MTL has extensive connections to the rest of the brain, which are structured in a bidirectional hierarchy of associativity, whereby the integration of information increases in complexity from the neocortex, through perirhinal and parahippocampal cortices, into the entorhinal cortex, and finally to the hippocampus (Lavenex & Amaral, 2000). As such, the hippocampus is thought to act as an episodic index for the constituent features of an episode dispersed across the neocortex (Lavenex & Amaral, 2000; McClelland et al., 1995; Squire, 1992b; Yassa & Reagh, 2013). Yet the MTL system is thought to be reflexive, in that it encodes and retrieves without much measure of control over the input or organisation of information. In the Working with Memory model, Moscovitch and Winocur (2002) implicate the frontal cortex in playing a supervisory role over the MTL, controlling the delivery and organisation of information, guiding search attempts, and monitoring recalled information. The lateral and medial PFC subregions involved in episodic memory processing have reciprocal structural and functional connections to the majority the brain (Pandya & Barnes, 1987; Pandya, Yeterian, Fleminger, & Dunnett, 1996; see Stuss & Knight, 2013 for an update), particularly the hippocampus (Nauta, 1973), meaning the PFC is anatomically well-placed to implement cognitive control processes critical to successful episodic encoding and retrieval.

1.2.1 *Encoding*

In order to be successfully encoded, a stimuli must first pass through the lens of attention, which is directed and maintained by the dorsolateral PFC (Cabeza et al., 2003; Iidaka, Anderson, Kapur, Cabeza, & Craik, 2000; MacDonald, Cohen, Stenger, & Carter, 2000; Moscovitch & Winocur, 2002; Uncapher & Rugg, 2005). Age-related declines in memory may in part be attributable to deficits in attention direction and conservation associated with frontal deterioration, meaning that certain stimuli never enter the encoding process. Indeed, younger adults encoding items under conditions of divided attention perform at similar levels on subsequent memory tests as older adults utilising full attention (Attali & Dalla Barba, 2012; Castel & Craik, 2003; Craik & Byrd, 1982; Jennings & Jacoby, 1993; but see Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994).

Once attention has been appropriately directed, the features comprising a single memory trace must be bound together, so that activation of a subset of features comprising an event at retrieval will spread to activate the remaining components (Schacter, Norman, & Koutstaal, 1998). The perirhinal cortex has been implicated in the encoding of individual features, while the hippocampus plays a role in the pattern formation process (Davachi, Mitchell, & Wagner, 2003; Kirwan & Stark, 2004; Ranganath, 2010), with help from executive processes of the PFC (Moscovitch & Winocur, 2002). The ability to form, encode and retrieve bonds between memory elements declines with age (Naveh-Benjamin, 2000), as a result of reduced hippocampal recruitment (Giovanello, Kensinger, Wong, & Schacter, 2010; Mitchell, Johnson, Raye, & D'Esposito, 2000), coupled with deficits in PFC-mediated strategic encoding of relational information (Naveh-Benjamin, Brav, & Levy, 2007; Naveh-Benjamin, 2000).

Not only are the individual features constituting a memory representation bound at encoding, links are also formed between different memory traces that share common features. The medial PFC reactivates associated memories during encoding, in order to integrate a new experience into the existing relational memory network (Eichenbaum, 2004; Schlichting & Preston, 2015). In order for features belonging to one episode to be discriminated from others at retrieval, the incoming information must be encoded in a distinctive manner, in a pattern separation process supervised by the ventrolateral PFC (Parkin, Ward, Bindschaedler, Squires, & Powell, 1999; Schacter, Norman, et al., 1998). Indeed, ventrolateral PFC dysfunction has been linked to impairments in relational encoding in older adults (Addis, Giovanello, Vu, & Schacter, 2014). The dorsolateral PFC further contributes to the organisation of memory traces during encoding, specifically in maintaining temporal order and relations within and between episodes (Blumenfeld, Parks, Yonelinas, & Ranganath, 2011).

1.2.2 Retrieval

When presented with a memory cue, an active and iterative search ensues throughout the memory hierarchy in order to identify and reinstate a specific episode (Burgess & Shallice, 1996; Conway & Pleydell-Pearce, 2000; Moscovitch, 1992; for a review, see Schacter, Norman, & Koutstaal, 1998). Failure at any retrieval step restarts the iterative process of cue specification, memory retrieval and evaluation.

The dorsolateral PFC is thought to supervise the initial stage of setting of a retrieval goal and strategy (Lepage, Ghaffar, Nyberg, & Tulving, 2000; Moscovitch & Winocur, 2002). Lateral PFC activation is also observed during memory search in response to a generic retrieval cue (i.e., one that does not directly prompt recovery of a specific memory trace; Addis, Musicaro, Pan, & Schacter, 2010; Daselaar et al., 2008; Ford, Addis, & Giovanello, 2011; St. Jacques, Kragel, & Rubin, 2011). Because a generic cue may correspond to many different stored episodes, a refined cue description must be generated to allow more directed retrieval; the ventrolateral PFC initiates a strategic search through stored memory representations in order to specify distinctive retrieval cues (Moscovitch & Winocur, 2002). Presentation of a direct cue can bypass this search cycle and allow direct access to a specific memory (for example, Addis, Knapp, Roberts, & Schacter, 2012). Impairments in memory performance as a consequence of age-related executive declines (Angel, Fay, Bouazzaoui, & Isingrini, 2010) are reduced when individuals are provided with retrieval cues to support these frontally-mediated search processes (Earles, Smith, & Park, 1996; Smith, 1977), in further support of a vital role of the PFC in the early stages of retrieval.

A specified cue is then conveyed to the MTL, which initiates a pattern completion process. Activation of a subset of the features comprising an event spreads to activate the remaining features indexed by the hippocampus (McClelland et al., 1995; Schacter, Norman, et al., 1998; Teyler & Rudy, 2007), which plays an integral role in retrieving relations between memory components (e.g., Giovanello et al., 2010; Nakazawa et al., 2002; see Mayes, Montaldi, & Migo, 2007, for a review). The PFC monitors and evaluates activated memory representations with regards to appropriateness to the search criteria, and fulfilment of retrieval goals, inhibiting those representations that do not meet search criteria. In particular, the ventromedial PFC contributes to an early and rapid rejection or endorsement of a memory trace as complying with the goals of the memory task (Moscovitch & Winocur, 2002).

Finally, the origin of retrieved episodes must be established, which includes determining whether the individual features pertain to the episode of interest, as well as whether the event as a whole was internally-derived or externally-experienced (Schacter, Norman, et al., 1998). The source monitoring framework postulates that specific characteristics of a mental experience are used to make an online judgment about the source of that experience at retrieval, based on the tendency for memories of different origins to have different characteristics (Johnson, Foley, Suengas, & Raye, 1988; Johnson, Hashtroudi, & Lindsay, 1993). For example, veridical events are typically rated higher in perceptual, emotional, temporal and spatial detail, while imagined events usually contain information about the cognitive operations involved in their generation (Johnson, Foley, Suengas, & Raye, 1988; Justice, Morrison, & Conway, 2013; McGinnis & Roberts, 1996). The dorsolateral PFC is involved in monitoring the source of retrieved memory representations (Blumenfeld et al., 2011; Henson, Shallice, & Dolan, 1999); as such, lateral PFC damage often results in impairments in source determination (Simons et al., 2002).

Brain regions outside the MTL and PFC are also involved in AM retrieval. The lateral and anterior temporal lobes are activated during both AM and semantic retrieval, further demonstrating that AM is reliant upon episodic and semantic components (Binder & Desai, 2011; Graham, Lee, Brett, & Patterson, 2003). Posterior parietal areas, including posterior cingulate cortex (PCC) and retrosplenial cortex, have strong anatomical connections to the hippocampus (Sugar, Witter, van Strien, & Cappaert, 2011; Vogt, Finch, & Olson, 1992), and are functionally connected with the hippocampus during memory tasks (Vincent et al., 2006; Zhou et al., 2008). The PCC has further extensive connectivity across the brain, and may be a cortical hub involved in the integration of a variety of evaluative processes (Hagmann et al., 2008). The retrosplenial cortex forms an intermediate region between the PCC and MTL, potentially mediating the construction of scenes that form the basis of episodic AM (Vann, Aggleton, & Maguire, 2009). Moreover, the precuneus – a major association area with widespread connections – is particularly implicated in the visuospatial imagery and self-processing that allows for re-experiencing of an AM (Cavanna & Trimble, 2006).

In some cases of retrieval, this re-experiential process may be bypassed altogether. The dual processing account theorises two separable processes underlying recognition memory: familiarity and recollection (Hintzman & Curran, 1994; Jacoby, 1991). While recollection is an effortful retrieval of specific memory details, familiarity is a rapid process involving no conscious retrieval of context. Yonelinas (1994) builds on this model by suggesting that recollection is an all-or-none process, while familiarity occurs on a continuum. If retrieval pressures are high, rather than recollecting a specific episode, a stimulus may instead be evaluated with regards to the overall strength of familiarity it evokes; whereby a strong sense of familiarity is attributed as evidence that the stimulus has been previously encountered. The hippocampus plays a vital role in in recollection, while the parahippocampal and perirhinal cortices are recruited for familiarity-based decisions (Aggleton & Brown, 1999; Ranganath et al., 2004; Yonelinas, Otten, Shaw, & Rugg, 2005; for reviews, see Yonelinas, 2002; Skinner & Fernandes, 2007). Consistent with these findings, aging is associated with impairments in recollective processes, and sparing of familiarity-based processing (Dennis, Bowman, & Peterson, 2014), corresponding to neural declines in the hippocampus and preservation in the rhinal cortices (Daselaar, Fleck, Dobbins, Madden, & Cabeza, 2006; Dennis, Kim, & Cabeza, 2008; Insausti et al., 1998; Yonelinas et al., 2007).

1.3 Adaptive functions of the constructive memory system

Such a wide range of cortical regions and cognitive functions are necessarily recruited during AM encoding and retrieval due to the inherently constructive nature of memory. Because it is neither essential nor economical to retain every detail about each episode we experience, a reconstructive memory system that approximates the past is beneficial over an inflexible yet perfect record of what has been (Schacter et al., 2011). One of the main advantages of the flexibility in memory is the ability to imagine future events which have not yet transpired. The Constructive Episodic Simulation Hypothesis (Schacter & Addis, 2007) theorises that we draw upon and reassemble stored autobiographical details in novel ways to simulate episodes that might occur in the future. One of the first cases to highlight this relationship between remembering the past and imagining the future was that of K.C., who suffered episodic memory loss after substantial damage to the MTL (Rosenbaum et al., 2005). When posed the question *"what will you be doing tomorrow?"*, K.C. was unable to come up with an answer, instead describing a *"kind of blankness"* (Tulving, 1985, pp. 4). This lead Tulving to suggest that episodic memory is vital not only for our ability to relive the past, but also to imagine the future. In support of this view, healthy older adults report fewer episodic details than younger adults when recalling past events and imagining future scenarios (Addis et al., 2010, 2008; see also Cole, Morrison, & Conway, 2012; De Beni et al., 2013; Gaesser, Sacchetti, Addis, & Schacter, 2011; Schacter, Gaesser & Addis, 2013; Rendell et al., 2012). This episodic reduction occurs over and above any influence of change in narrative style with age (Gaesser et al., 2011; Madore & Schacter, 2014; Race, Keane, & Verfaellie, 2011).

Interestingly, although patient K.C. could not imagine future episodes, he was still able to engage in future-oriented thinking on the basis of semantic memory (Craver, Kwan, Steindam, & Rosenbaum, 2014; see also Klein, Loftus, & Kihlstrom, 2002). In contrast, semantic dementia patients can retrieve past events to the same quality as controls, yet have difficulty imagining the future in detail, despite having access to episodic details (Irish, Addis, Hodges, & Piguet, 2012). Together these findings suggest that, in addition to episodic memory, semantic memory plays a role in future simulation, perhaps via the provision of an organisational framework upon which an imagined event can be constructed using episodic details. However, although necessary, semantic memory is not sufficient for the imagination of rich future episodes, as simulations based on semantic memory are devoid of personal context (Klein et al., 2002; Race et al., 2011), and do not recruit the core network to the same degree as simulations drawing from episodic experiences (Arnold, McDermott, & Szpunar, 2011; Szpunar, Chan, & McDermott, 2009).

Neuroimaging studies reveal a striking overlap in the neural networks recruited during memory and imagination, including medial and lateral PFC, MTL, lateral temporal and posterior parietal regions (Addis, Pan, Vu, Laiser, & Schacter, 2009; Addis, Wong, & Schacter, 2007; Okuda et al., 2003), providing further evidence for an interplay between these two processes (see Schacter, Addis, & Buckner, 2007; Schacter, Chamberlain, Gaesser, & Gerlach, 2012 for reviews). The hippocampus in particular is believed to play an integral role in the ability to imagine the future, specifically in recombining disparate memory details into an integrated event (Addis & Schacter, 2012). For example, patients with damage restricted to the bilateral hippocampus imagine less detailed and cohesive future events than controls (Hassabis, Kumaran, Vann, & Maguire, 2007; Race et al., 2011).

By simulating the future, we can plan for upcoming events, anticipate consequences, and make effective decisions without having to engage in the actual behaviour (Benoit, Gilbert, & Burgess, 2011; Boyer, 2008; Taylor, Pham, Rivkin, & Armor, 1998; Taylor & Schneider, 1989). Recombining elements from past events in novel ways also allows us to creatively solve problems (Addis, Pan, Musicaro, & Schacter, 2014; Howe, Garner, Charlesworth, & Knott, 2011; Sheldon et al., 2011). Recent work has also explored the adaptive value of counterfactual thinking, where alternative outcomes for *past* events are simulated (De Brigard, Addis, Ford, Schacter, & Giovanello, 2013; Gerlach, Dornblaser, &

Schacter, 2013). Imagining poorer outcomes for positive events provides comfort in the thought of what might have transpired (Roese, 1997), while thinking about how a negative episode may have had a better outcome can prepare one to improve similar future scenarios (Nasco & Marsh, 1999; Roese, 1994).

1.4 Memory distortions

While the flexibility inherent in a reconstructive memory system provides many adaptive benefits, such a system also comes with a downside in that its mutability is error-prone and renders us vulnerable to memory distortions (Schacter, 2001). Such errors can be made at many points along the encoding and retrieval "pipeline", meaning that we are subject to a diverse range of memory distortions (Johnson et al., 1993; Schacter et al., 1998; Schacter, 2001; Straube, 2012; see Figure 1). Exploring the fallibility of memory deepens our understanding of the underlying mechanisms of the memory system, in the same way that examining visual illusions can aid understanding of the visual system (Roediger, 1996). In recent years neuroimaging methods have permitted the exploration of the underlying neural substrates supporting false memories, revealing a large overlap in the brain areas evoked during the encoding (Baym & Gonsalves, 2012) and recognition (Garoff-Eaton, Kensinger, & Schacter, 2007; Gutchess & Schacter, 2012; Schacter et al., 1996; Slotnick & Schacter, 2004) of both true and false memories. Such evidence suggests similar cognitive processes mediate memories irrespective of their veracity, and provides evidence that memory distortions are a consequence of normal memory processes (Schacter et al., 2011; Schacter & Slotnick, 2004).

No memories or individuals are impervious to memory distortions. Even flashbulb memories – incredibly rich and persistent memories of highly salient public events, which used to be considered exceptionally accurate (Brown & Kulik, 1977) – are prone to errors. For example, Neisser & Harsch (1992) examined individuals' memories for the space shuttle Challenger explosion immediately after the incident and for a number of years following, and found marked alterations in the memory reports over time, despite the individuals' continued confidence in the veracity of these memories (see also Greenberg, 2004; Schmolck, Buffalo, & Squire, 2000). It is now thought that flashbulb memories do not differ from everyday memories in their objective accuracy, only in their perceived accuracy by the memory holder (Talarico & Rubin, 2003). In a related vein, individuals identified as having highly superior AM, who show extraordinary memory ability for even trivial past details, are equally as vulnerable to memory distortions as those with average memory abilities (Patihis et al., 2013), posing the intriguing possibility that this highly accurate memory ability is subserved by a fallible memory system.

Several broad categories of memory errors can arise during encoding and retrieval: memory conjunction errors, gist-based errors, misinformation, and wholly false events. Recent evidence demonstrates that an individual's susceptibility to one type of memory error does not necessarily predict likelihood of falling prey to other types of memory distortions (Calvillo & Parong, 2015; Ost et al., 2013), alluding to the presence of multiple routes to the formation of memory errors.

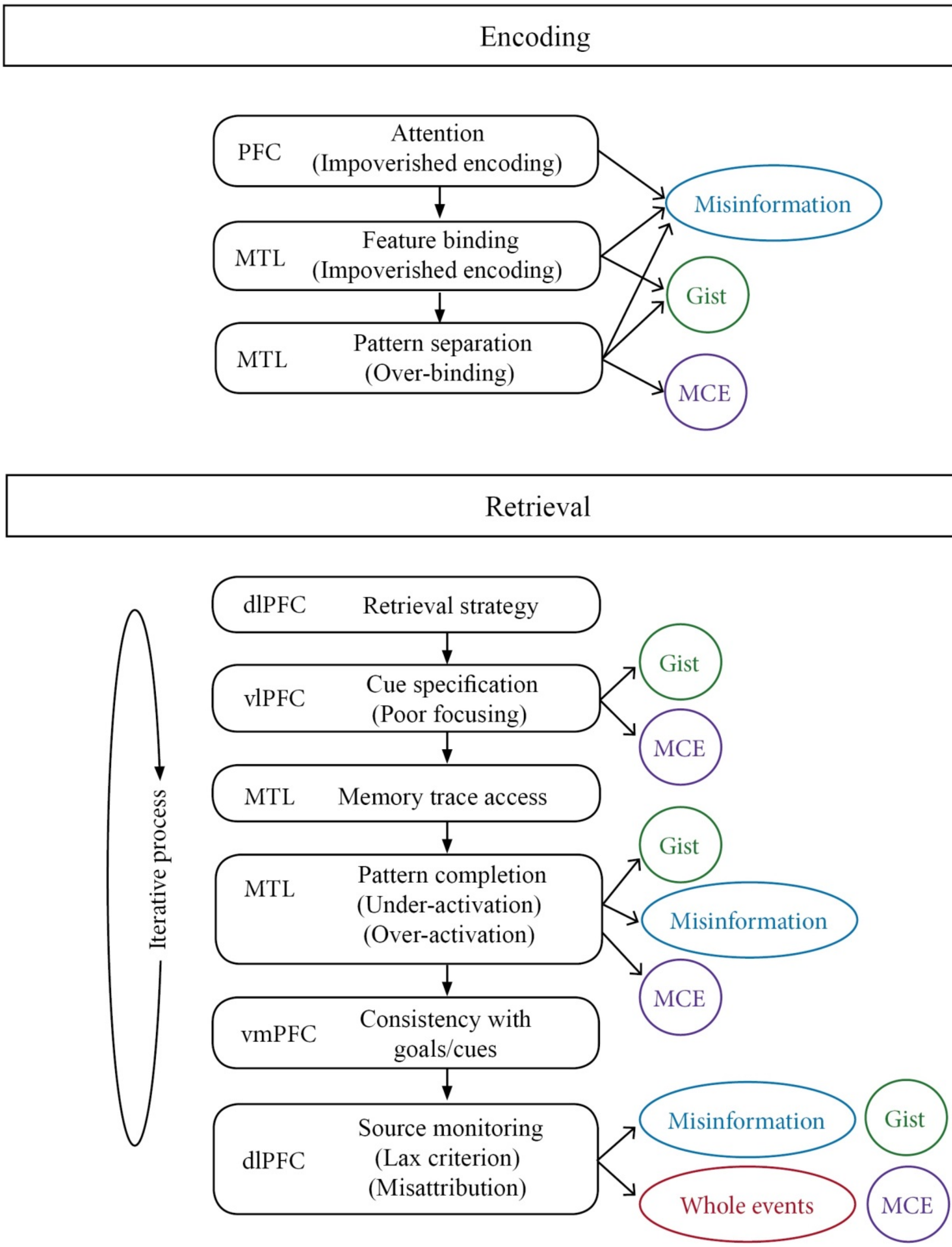

***Figure 1*. Memory errors in the encoding and retrieval pipeline.** Flow diagram for the stages of autobiographical memory (AM) encoding and retrieval, and the main neural regions contributing to each step. Failures at different points along this pipeline (noted in parentheses) can result in the formation of different memory errors (depicted in circles). MTL = medial temporal lobe; dlPFC = dorsolateral prefrontal cortex; vlPFC = ventrolateral PFC, vmPFC = ventromedial PFC; Gist = gist-based errors; MCE = memory conjunction errors.

1.4.1 *Encoding*

1.4.1.1 *Impoverished encoding*

During encoding, both the individual features of an episode, and the relations between those features, must be encoded to assist later pattern completion processes and retrieval of a coherent memory (cf. the feature binding account; Reinitz, Lammers, & Cochran, 1992; Reinitz, Verfaellie, & Milberg, 1996, see also Jones, Jacoby, & Gellis, 2001). Binding failures can result in an impoverished memory trace, where information diagnostic of source is not bound with the memory representation, leading to later misattribution of information as belonging to an incorrect source (see Johnson, 1997). Dysfunction in the neural substrates underlying feature binding, particularly the MTL, contributes to a failure to encode associations between features (Giovanello et al., 2010; Hannula, Tranel, & Cohen, 2006; Kroll, Knight, Metcalfe, Wolf, & Tulving, 1996; Pertzov et al., 2013). Taxation of frontally-mediated attentional resources, due to either task demands (Castel & Craik, 2003; Jennings & Jacoby, 1993) or PFC dysfunction (Naveh-Benjamin, 2000) may also prevent the adequate binding of individual memory features and source information (see also Attali & Dalla Barba, 2012; Dewhurst, Barry, Swannell, Holmes, & Bathurst, 2007).

Poor binding of cues pertaining to the origin of information increases susceptibility to later *misinformation effects* occurring, whereby misleading information encountered after an experience distorts memory for the original event (see Loftus, 2005 for a review). In one of the earliest demonstrations of this misinformation effect, participants watched a video depicting a car crash, and were later asked to estimate how fast the cars were going (Loftus & Palmer, 1974). Speed judgments changed depending on whether the question was asked about the speed of the cars that “smashed into” or “hit” each other, with the former leading to higher estimates of speed by 20%, and twice as many false reports of observing broken glass in the scene. Subsequent studies have corroborated this retroactive interference effect, extending the research to traumatic memories (Nourkova, Bernstein, & Loftus, 2004), as well as to nonhumans (Harper & Garry, 2000; Schwartz, Meissner, Hoffman, Evans, & Frazier, 2004). Moreover, susceptibility to misinformation increases with advancing age (Wylie et al., 2014), potentially due to PFC dysfunction leading to a lowered ability suppress irrelevant information (see Hasher, Tonev, Lustig, & Zacks, 2001; Hasher, Zacks, & May, 1999; Jacoby & Rhodes, 2006). If cues informing the source of either the original or misleading information are not fully bound with the memory representation, this misinformation may later be attributed to an incorrect source.

Impoverished encoding following feature binding failures may also underlie the formation of *gist-based errors*. In terms of cognitive resources, it is efficient to maintain memory for the overall gist of an event while discarding the largely redundant individual details (Bartlett, 1932; Schacter, 2001). The Fuzzy-trace theory (see Reyna & Brainerd, 1995, for a review) posits that two parallel memory traces are formed for every memory encoded: a verbatim trace containing information about the surface features of an experience, and a more meaning-based gist trace. These two traces can be retrieved independently of each other, depending on task demands and available cognitive resources. However, specific memory details in the verbatim trace decay relatively rapidly over time – which can be exacerbated by impoverished encoding of feature associations – leaving the individual to depend upon the longer-lasting gist trace. This gist representation is vulnerable to schematically consistent memory distortions (Brainerd & Reyna, 2005; Brainerd, Wright, Reyna, & Mojardin, 2001), resulting in an increased prevalence of gist-based errors over time (Schmolck et al., 2000; see also Frost, 2000). Bartlett noticed such gist errors in his subjects' reproductions of his folk tales; many of the unfamiliar elements of the stories were changed to be more in line with the subjects' own cultural expectations. Brewer and Treyens (1981) noted similar results when asking participants to remember objects they had seen in an office in which they had earlier been residing. These participants tended to falsely recall items usually found in an office, but that were not in the office they had encountered, suggesting they were relying on their schematic knowledge of typical offices to complete the task, rather than explicit recollection of observed items (see also Aminoff, Schacter, & Bar, 2008).

With regards to the underlying neural substrates of gist-based errors, the left ventrolateral PFC is engaged during the encoding of semantically-associated word lists that yield both true and false word recognition, suggesting that false gist memories are a by-product of normal semantic elaborative processes (Kim & Cabeza, 2007). Indeed, damage to areas involved in the production of gist traces, including the MTL and diencephalic structures (Koutstaal, Verfaellie, & Schacter, 2001) and ventromedial PFC (Warren, Jones, Duff, & Tranel, 2014), is associated with a reduced rate of semantically-consistent memory distortions (see also Dennis, Kim, & Cabeza, 2007). Encoding-related activity in the network supporting contextual processing has been shown to predict later false recognition of contextually-related lure items (Aminoff, Schacter, & Bar, 2008; see also Gutchess & Schacter, 2012), further emphasising the role of associative processes in the generation of gist-based errors.

1.4.1.2 Pattern separation

Successful encoding involves integrating newly acquired information with existing relational memory networks (Schlichting & Preston, 2015), in a way that allows discrimination of separate episodes at retrieval. The activation monitoring theory suggests that when one concept is activated in memory, this activation spreads to neighbouring semantically- and episodically-related concepts and fragments in the relational memory network (Roediger, Balota, & Watson, 2001). The activation monitoring theory was originally proposed to explain false acceptance of semantically-associated lure words in the Deese-Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger & McDermott, 1995), in which participants who study lists of related words (e.g., ‘sugar, candy, taste’), are likely to claim that an unseen yet semantically associated lure (‘sweet’) was previously presented (see Gallo, 2006). According to the activation monitoring theory, false recollection of an associated lure occurs when that lure is activated at retrieval along with its presented neighbours (‘sugar, candy, taste') in a schematic word network (Mather, Henkel, & Johnson, 1997; Underwood, 1965). As such, incomplete separation of related episodes may contribute to retrieval of the general gist shared between the overlapping events, rather than episode-specific information, resulting in overgeneralisation and subsequent gist errors (Reyna & Brainerd, 1995; Warren et al., 2014).

A further implication of inadequate pattern separation processes is the opportunity for overlapping memory elements to be miscombined into one integrated representation. If this miscombination is endorsed by the rememberer as an authentic memory, a *memory conjunction error* is said to have occurred. Such 'illusory conjunctions' were first reported in the 1970s when individuals misremembered seeing conjunctions of previously seen components of compound words (e.g., snowball + sandman = snowman; Underwood & Zimmerman, 1973), or miscombinations of the colours and letters of studied figures (Treisman, 1977). Since then, conjunction errors have been observed in memory for a range of simple laboratory stimuli, including word syllables (Kroll et al., 1996), compound words (Jones & Jacoby, 2001), sentences (Reinitz et al., 1992), line drawings of faces (Reinitz, Morrissey, & Demb, 1994) and photographs of faces (Jones & Bartlett, 2009).

The mere existence of conjunction errors further validates the constructive perspective of memory, demonstrating that memory features are not tightly bound into holistic representations, but rather are stored separately throughout the cortex and are loosely linked, thereby allowing transference between memories. Loss of associative information over time may result in the miscombination of stimulus features; the more rapid decay of configural representations over fragmental information is thought to account for the increased prevalence of memory conjunction errors forming over increasing delays (e.g., Schmolck et al., 2000). Moreover, damage to structures critical to the binding process, particularly the hippocampus, leads to difficulty distinguishing between originally studied and conjunction words in a recognition test (Kroll et al., 1996). Damage or dysfunction in MTL-binding and strategic PFC organising functions can also contribute to failures in pattern separation processes, resulting in excessive or over-binding of memory fragments from separate episodes (Fandakova, Shing, & Lindenberger, 2013; Henkel, Johnson, & De Leonardis, 1998; Kroll et al., 1996; Lyle, Bloise, & Johnson, 2006).

Memory conjunction errors also reveal how feature binding at encoding is modulated by attentional processes. For example, more conjunction errors for facial features are observed when the two original face stimuli are presented simultaneously rather than separately during encoding (Reinitz & Hannigan, 2001); sharing of attentional resources between the simultaneously presented faces results in inadequate pattern separation and the binding of the component parts of the faces into a unitary memory representation (Reinitz, 2001). Dividing attention during the study of compound words also disrupts binding processes and increases likelihood of conjunction error formation (Jones & Jacoby, 2001; Reinitz et al., 1994). Distractions at encoding result in greater impairments in memory for feature associations than for the individual features themselves (Reinitz et al., 1994), demonstrating that attention during study is less important for encoding the individual components of a stimulus than it is for binding these features into a cohesive representation.

1.4.2 Retrieval

1.4.2.1 Reconsolidation

Pattern separation failures can also occur during retrieval of a stored episodic event, whereby the memory trace is reactivated and enters a dynamic state in which it is prone to disruption and the incorporation of new information, a process known as reconsolidation (Forcato, Rodríguez, Pedreira, & Maldonado, 2010; Nadel & Land, 2000). In a rat model (Nader, Schafe, & Le Doux, 2000) reconsolidation is elicited by pairing an electric shock with an auditory tone, and later reactivating that fear memory by presenting the tone. An infusion of protein synthesis inhibitor into the amygdala disrupts retention of the memory, indicating that successful reconsolidation is required following reactivation to allow future access to that memory. Such reconsolidation effects have since been shown to occur in humans (e.g., Schiller & Phelps, 2011). Reconsolidation provides an opportunity for altering the individual details of a memory to fit with self-schemata and current retrieval goals (Neisser, 1986), and updating the memory with recently acquired information (Lee, 2009; Schacter et al., 2011; Tse et al., 2007) while still maintaining the overall essence of the experience. Nevertheless, this process leaves the memory trace vulnerable to the inclusion of errors.

In light of this reconsolidation effect, findings from misinformation studies raise questions about the fate of the original memory. Does presentation of misinformation alter the original memory trace, or merely supersede it in recollection? McCloskey & Zaragoza (1985) posit that the original memory is not entirely overwritten by misinformation. In their study, participants were presented with a slide show depicting a maintenance man lifting a hammer out of his toolbox. It was later suggested that the tool shown was a wrench, resulting in a robust misinformation effect in a standard forced-choice recognition test between a hammer and a wrench. However, in a modified recognition test, when the original item (hammer) and a new item (screwdriver) were presented, misled participants chose the hammer at an equal rate as those who had not been provided with misinformation, suggesting that the misinformation presentation did not erase the original memory.

However, a meta-analysis of similar studies implicates a small but significant detrimental memory effect for misled participants in the modified recognition test (Payne, Toglia, & Anastasi, 1994). The reconsolidation approach holds that the presentation of misinformation reactivates the original memory trace, rendering it vulnerable to alteration from misleading information (see Riccio, Millin, & Bogart, 2006 for a review). Indeed, Hupbach et al. (2007, 2009) found that when learning two lists of objects, if the second list is preceded by a reminder of the first list, items from the second list are reported when recalling the first list, but not vice versa. The reminder supposedly activates and makes labile the memory trace for the first list, allowing the incorporation of the misinformation provided by the second list (though see Sederberg, Gershman, Polyn, & Norman, 2011, for an alternative interpretation of these results). In line with this idea, neural regions involved in integrating related memories (ventromedial PFC and hippocampi) are activated during the encoding of subsequent misattributions (St Jacques, Olm, & Schacter, 2013; Okado & Stark, 2005).

1.4.2.2 Familiarity

Similarities can be drawn between the fuzzy-trace theory and the dual processing theory, which likewise posits two distinct retrieval methods: recollection of specific stimulus details, or familiarity for the overall essence of the event (Hintzman & Curran, 1994; Jacoby, 1991). An inaccessibility of recollective memory, due to either decay of specific memory details over time or high cognitive demands, necessitates heuristic source decisions based on one's sense of familiarity with a stimulus, which can be piqued by a lure sharing general similarities with studied items. Indeed, populations who experience reduced recollective ability are particularly susceptible to gist-based errors. For instance, healthy aging is associated with declines in hippocampally-mediated recollection, but a preserved sense of familiarity (Craik & McDowd, 1987; Davidson & Glisky, 2002; Dennis et al., 2014; Prull, Dawes, Martin III, Rosenberg, & Light, 2006). Consequently, older adults are more prone than younger adults to recognition errors for related but previously unencountered items, due to an overreliance on a feeling of familiarity invoked by the conceptual or perceptual similarities (Koutstaal & Schacter, 1997). Indeed, enhancing lure familiarity increases rates of false alarms in older but not younger adults (Jacoby, 1999; Kensinger & Schacter, 1999). A comparable pattern of results is observed in patients with Alzheimer's disease (Budson, Daffner, Desikan, & Schacter, 2000).

According to the dual processing theory, memory conjunction errors arise from a feeling of familiarity with the component parts of the conjunction lure, in the absence of recollection of the parental stimuli (Jones & Bartlett, 2009; Jones & Jacoby, 2001, 2005; Leding, 2015; Marsh, Hicks, & Davis, 2002; Rubin, Petten, Glisky, & Newberg, 1999).

However, conjunction errors have been demonstrated to be experienced with a sense of recollection (Burt, Kemp, & Conway, 2004; Odegard & Lampinen, 2004; Reinitz et al., 1992, 1994). While in some cases a particularly strong sense of familiarity may be misidentified as recollection (Brainerd et al., 2001; Dennis, Bowman, et al., 2014), conjunction errors can also occur in free recall (Reinitz & Hannigan, 2001). Moreover, recollection is not always successful at allowing rejection of conjunction lures (Jones & Bartlett, 2009), implying that memory conjunction errors are not simply the result of a single automatic process, but may have multiple underlying mechanisms, including feature binding errors at either encoding or retrieval.

1.4.2.3 Cue specification and pattern completion

At the early stage of retrieval, poor cue specification or 'focusing' (Schacter, Norman, et al., 1998) can contribute to false memory formation. More general memories tend to be retrieved en route to a specific episode (Haque & Conway, 2001); as such, a vague cue or pre-emptive termination of memory search may result in overgeneral retrieval, whereby the general gist of schematically consistent events is recalled, rather than specific details from any one event (Conway & Pleydell-Pearce, 2000; Conway, 2005). Furthermore, a poorly focused or inaccurate cue may activate multiple related episodes, resulting in the incorporation of individual features from separate episodes into one representation, thereby forming a memory conjunction error (Smith, 2000).

After a cue has been specified, incomplete pattern completion can result in the loss of event details and impoverished memory representations (Nakazawa et al., 2002). Failure to retrieve information relevant to the source of the memory trace can lead to misattribution errors (Johnson et al., 1993), which may partially underlie the greater likelihood of misinformation with age (Mitchell, Johnson, & Mather, 2003; Wylie et al., 2014). The loss of specific memory details over time further forces us to fill any blanks upon reconstruction by drawing from gist gleaned from similar experiences, resulting in gist-based errors (Budson et al., 2000; Dennis et al., 2007; Foley, Foley, Scheye, & Bonacci, 2007; Reyna & Brainerd, 1995; Strickland & Keil, 2011). The associative deficit hypothesis of aging (Naveh-Benjamin, 2000) partly implicates impairments in retrieving relational information between memory components in the age-related increase in conjunction errors, and such errors can be mitigated by provision of relational strategies at retrieval (Naveh-Benjamin et al., 2007). Moreover, if the spreading activation inherent to pattern completion extends to features comprising overlapping or associated memories, the erroneously activated memory features may then be over-bound with the original event, further resulting in memory conjunction errors (Lampinen, Meier, Arnal, & Leding, 2005; Lyle & Johnson, 2006, 2007; see also Gallo & Roediger, 2003).

It is worth noting that due to the inextricable links between encoding and retrieval, it is difficult to disentangle the independent influence of these two processes to false memory formation. For example, feature binding and pattern separation mechanisms at encoding influence the subsequent success of pattern completion procedures during retrieval, while reconsolidation renders a retrieved memory vulnerable to encoding errors once more. As such, delineating the independent contributions of encoding and retrieval to the generation of memory errors is an ongoing endeavour (e.g., Abe et al., 2013; Huff, Bodner, & Fawcett, 2015).

1.4.2.4 Source monitoring

Regardless of the initial acquisition, in order for a false memory to occur a source monitoring error must take place. Typically the characteristics of an experience allow for accurate source determination, but source and reality monitoring errors can arise if source information is lost, high cognitive demands necessitate a lax monitoring criteria, or the phenomenological characteristics of a false event resemble that of an authentic memory. The source monitoring framework bears similarities to dual processing accounts of memory, in that different judgment criteria are thought to be employed under different retrieval contexts, therefore the degree to which source monitoring occurs depends on demand characteristics and available cognitive resources (Johnson et al., 1993; see also Rae, Heathcote, Donkin, Averell, & Brown, 2014). When attention or time are under demand, a lower monitoring criterion may be set, which can increase the propensity to make source monitoring errors (Dodson & Johnson, 1993; Hekkanen & McEvoy, 2002; Multhaup, 1995). In such cases, source and authenticity decisions are likely based upon automatic yet less dependable heuristic processes, such as the plausibility or processing fluency of the episode.

Plausibility, belief, and memory are thought to be nested constructs (Scoboria, Mazzoni, Kirsch, & Relyea, 2004), whereby events must first be perceived as plausible before they can be considered a veridical memory (Hyman & Loftus, 1998; Mazzoni, 2007; Scoboria, Mazzoni, Jarry, & Bernstein, 2012). Plausibility is a fluid construct, in that the perceived plausibility of a fabricated event can be manipulated via suggestive techniques, such as presenting evidence that an implausible event actually occurs fairly often (Mazzoni, Loftus, & Kirsch, 2001), or by presenting doctored evidence of the event taking place (Nash, Wade, & Lindsay, 2009; Wade, Garry, Read, & Lindsay, 2002). The more plausible a distortion in memory is considered to be, the more likely it is to surpass source monitoring checks (Mazzoni et al., 2001; Mazzoni, 2007; Pezdek, Blandon-Gitlin, & Gabbay, 2006; Scoboria et al., 2004).

The processing fluency, or how quickly a stimulus comes to mind (cf. the availability heuristic, Tversky & Kahneman, 1973) is also thought to serve as an indicator of previous experience with that item, and as such is typically used as a heuristic when making recognition or source monitoring decisions (Johnston, Dark, & Jacoby, 1985; Whittlesea, 1993). This fluency perspective bears close ties to the mental workload hypothesis (Schwartz et al., 1991), whereby the amount of mental effort required to perform a task is used as a source monitoring cue; an easily performed task confers high fluency and a sense of previous exposure to the stimulus, while a difficult task is associated with low fluency, which is attributed to stimulus novelty. Jacoby & Dallas (1981) were the first to identify that more fluently retrieved items were more likely to be falsely identified as previously encountered, and it has since been demonstrated that increasing fluency artificially can result in source monitoring errors (Kurilla, 2011). The processing fluency with which a stimulus is retrieved often triggers a sense of familiarity with a stimulus (Olds & Westerman, 2012; Sharman, Manning, & Garry, 2005; Whittlesea, 1993), though this is not always the case (see Miller, Lloyd, & Westerman, 2008; Whittlesea & Williams, 1998, 2000; Whittlesea, 1993). Increased fluency elevates "know" responses during stimulus recognition, an indicator that the recognition is based on familiarity rather than recollection (which is ascribed to "remember" responses; Kurilla & Westerman, 2008; Rajaram, 1993; Tulving, 1985).

In situations where accuracy is of importance, more deliberate and conscious processes can be brought online to evaluate the episode with regards to the amount and type of associated phenomenological detail, and its consistency with other memory traces, general knowledge and belief systems. Consistent with the sensory reactivation hypothesis, recognition tends to evoke activation in areas mediating the reinstatement of the encoded stimulus, such as early sensory regions, more so for true recognition than both gist-based errors (Abe et al., 2008; Slotnick & Schacter, 2004) and misinformation (Garoff-Eaton, Slotnick, & Schacter, 2006; Stark, Okado, & Loftus, 2010). For instance, the recognition of words that were presented aurally at study reveals more activation in auditory processing regions than false recognition of semantically-related lures (Abe et al., 2008; Cabeza, Rao, Wagner, Mayer, & Schacter, 2001; Schacter, Reiman, et al., 1996). A similar pattern of results was found using visual stimuli, whereby true memories reactivated visual processing areas more so than false memories (Gonsalves & Paller, 2000; Kensinger & Schacter, 2006; Slotnick & Schacter, 2004; though see Dennis, Johnson, & Peterson, 2014). Reactivation of encoding-related areas may provide clues that allow for the determination of the source of that experience. In the absence of this sensory signal, higher-level evaluation processes must come online in order to authenticate a memory trace.

The anterior lateral and medial PFC have been implicated in the retrieval of false memories over true memories, likely reflecting increased memory monitoring or evaluation during these trials (Dennis, Johnson, et al., 2014; Guerin, Robbins, Gilmore, & Schacter, 2012; Gutchess & Schacter, 2012; Mitchell & Johnson, 2009; Slotnick & Schacter, 2004). Consistent with these findings, confabulation – the unintentional fabrication of episodic events thought to arise from faulty monitoring processes – has been linked with frontal lobe damage (Burgess & Shallice, 1996; Kopelman, 1999). However, PFC activity during false recognition may also reflect contributions of this area to the retrieval of conceptual or gist information. Greater recruitment of PFC was found for conceptual false recognition (i.e., false recognition due to semantic similarities between studied and test items) compared with perceptual false recognition (where new items were physically similar to studied items; Garoff-Eaton et al., 2007). If the PFC was involved in post-retrieval monitoring, this region should have been engaged in both cases of false alarms; as it was not, the authors proposed that PFC activity contributes specifically to gist-processing. Further research is needed to disentangle the precise role of the PFC in false memory formation.

Yet even thorough systematic processes may fail if the source cues of the false event are phenomenally indistinguishable from those of veridical memories (Heaps & Nash, 2001; Johnson et al., 1988; Thomas, Bulevich, & Loftus, 2003; von Glahn, Otani, Migita, Langford, & Hillard, 2012). Neuroimaging data supports this view; when encoding objects that were either viewed as photographs or mentally visualised, Gonsalves and Paller (2000) report greater electroencephalography (EEG) activity in posterior visual imagery regions when mentally visualised objects were later falsely attributed to the photograph condition relative to when they were correctly rejected as imagined. These findings were replicated using functional magnetic resonance imaging (fMRI), with imagery-related activity predicting later false recognition of an object as having been presented as a picture (Gonsalves et al., 2004; Kensinger & Schacter, 2005; Okado & Stark, 2003). In line with these findings, individuals with high visual imagery ability are more likely to confuse the source of items presented in a crime scene (Dobson & Markham, 1993). False identification of adjectives as having been studied using a particular strategy has also been associated with activity in regions supporting the use of that strategy (Kahn, Davachi, & Wagner, 2004), indicative that reinstatement of encoding-related activity can contribute to source confusion during retrieval. However, it is difficult to establish the causal relationship between this reactivation and false memory formation: does a false memory occur *because* the encoding conditions are reinstated at retrieval, and this is misattributed as an indication of authenticity, or does retrieval of a previously encoded false memory *cause* these areas to activate?

Memory conjunction errors, gist errors and misinformation all give rise to partial changes to the original memory representation. However, *entirely false events* can also come to be misidentified as authentic happenings. Anderson (1984) was one of the first to demonstrate that source confusion can occur following imagination of simple actions, which were misattributed as having been truly performed. The phenomenon whereby imagining an event increases later belief that the event actually happened in the past has been termed imagination inflation (for reviews, see Devitt & Addis, in press; Garry & Polaschek, 2000). Imagination inflation may manifest as an increased confidence that an event previously took place, without any accompanying memory retrieval (Garry, Manning, Loftus, & Sherman, 1996), or as a full-blown recollection of the false episode (Heaps & Nash, 2001; Loftus & Pickrell, 1995; Mazzoni & Memon, 2003). In their pioneering “lost in the mall” study, Loftus & Pickrell (1995) made the first systematic attempt to implant entirely false recollections in AM using imagination. Participants were falsely informed they had been lost in a mall at some point during their childhood, and were encouraged to recall ‘dormant’ memories of this event through imagination exercises. After several imagination exercises, 25% of participants came to form a false memory of being lost in a mall. Some of the false memories were so compelling participants expressed surprise during debrief that they were not authentic recollections.

These results have been corroborated in many ways since (Goff & Roediger, 1998; Heaps & Nash, 2001; Lampinen, Odegard, & Bullington, 2003; Nash et al., 2009; Pezdek et al., 2006; Seamon et al., 2009; Thomas et al., 2003; von Glahn et al., 2012; for a review, see Loftus, 2005), with an overall success rate of around 31% (Lindsay, Hagen, Read, Wade, & Garry, 2004). The imagination inflation effect has been shown to be more effective at generating false memories than the presentation of doctored pictorial evidence of a fabricated scenario (Garry & Wade, 2005). The implantation of impossible events such as meeting Bugs Bunny at Disney World (Braun, Ellis, & Loftus, 2002), or having a skin sample taken from a finger (a medical procedure not carried out in the country of study; Mazzoni & Memon, 2003), demonstrates that these false memories do not merely reflect the resurrection of true experiences. Even the act of imagining future events may in some cases lead to false reports that these simulated events actually occurred in the past (Gamboz, Brandimonte, & De Vito, 2010).

It is thought that guided imagination facilitates the formation of a narrative and mental image of the fabricated scenario, which is later misattributed as representing an authentic episodic occurrence (see Johnson et al., 1993). Indeed, repeated imagining has been shown to increase the recollective experience of a fabricated event (Heaps & Nash, 2001; Hyman, Gilstrap, Decker, & Wilkinson, 1998; Lampinen et al., 2003; Szpunar & Schacter, 2013). The imagination inflation effect is more effective when participants are encouraged to elaborate upon their imaginings by the inclusion of sensory information (Thomas et al., 2003). The striking similarity in the brain regions supporting memory and imagination (Addis et al., 2007) may also contribute to source confusion at retrieval due to difficulty in disentangling the signals evoked by true and false memories (see Mitchell & Johnson, 2009).

1.5 Autobiographical memory conjunction errors

While memory conjunction errors for simple laboratory stimuli such as words and pictures have been examined intensively, conjunction errors in the autobiographical domain are more difficult to induce due to the complex and deeply personal nature of the stimuli. Thus, despite the importance of AM in our day-to-day lives, and questions over the ecological validity of applying results from studies using laboratory-based stimuli to AM, conjunction errors occurring in AM have thus far received little empirical attention.

Because the *elements* of a conjunction event have been truly experienced, albeit in a different combination, conjunction errors may be highly compelling for the rememberer, experienced with a sense of recollection (Reinitz et al., 1992, 1994; Reinitz, 2001), held with a high degree of confidence and may be phenomenologically similar to authentic events (e.g., Lyle & Johnson, 2006). Furthermore, warnings about the possibility of making memory conjunction errors reduces neither the likelihood of their occurrence, nor confidence in their veracity (Reinitz et al., 1992). As such, conjunction errors in AM can cause unique difficulties in establishing the veracity of eyewitness accounts. Memory for the performer and the bystander of actions can be conflated (Kersten, Earles, & Upshaw, 2013), which may lead to incorrect identification of the perpetrator of a crime. Indeed, following a staged crime in which a student attacked a professor in front of 141 undergraduate students, a quarter of the eyewitnesses, including the professor himself, later identified an innocent bystander as the attacker (Buckhout, 1975). Yet to our knowledge, only two studies have explored AM conjunction errors, both utilising a similar time-intensive paradigm involving individual diary records.

In one study, Odegard and Lampinen (2004) had participants keep diary records over a number of weeks, describing one episode that happened every few days and recording major event details, including people, locations, emotions, actions, and objects. In a subsequent recognition test six weeks later, participants were presented with the event descriptions and corresponding features and were asked to judge whether each feature belonged to the event. However, unbeknownst to the participant, some of the features in the event descriptions were recombined across episodes to form a number of conjunction lures. Of the total 190 conjunction lures presented (Experiment 2), 15.3% were falsely accepted as belonging to the original event (given there were 19 participants, this equates to an average of 1.5 conjunction errors per person). The acceptance of conjunction lures was more likely to be based on a sense of remembering the presence of the lure in the event, rather than simply knowing the lure belongs (Tulving, 1985), suggesting AM conjunction errors are experienced as phenomenologically real. In line with this interpretation, in a subsequent free recall test where participants produced a narrative for each event, over half of the falsely recognised details were imported into the narratives.

Burt, Kemp, and Conway (2004) employed a similar technique, drawing on diaries that had been completed approximately 13 years earlier. Person, place and activity details were recombined between diary entries, with either one, two, or three of the details altered, and incorporated into short event descriptions. It was found that 13.2% of a total of 491 lures were at least partially misremembered; given there were 11 participants, this equates to 5.9 conjunction lures per person. Location-altered lures were most likely to be falsely remembered, and lures with three details altered were least likely to be identified as never having happened. Moreover, participants reported using landmark events and reconstructive strategies to help date the events, indicating that source decisions for conjunction events are based on complex evaluative processes involving associations with other memories, rather than simple heuristic judgements of familiarity with the lure components.

Together, these studies demonstrate that conjunction errors can be elicited in AM, and studied in the laboratory environment. Moreover, their results suggest that the specific detail altered and the number of memories from which a conjunction event is drawn can influence the rates of acceptance of AM conjunction lures. AM conjunction errors are shown to be compelling, experienced with a sense of recollection, and recruit complex evaluative processes, so are unlikely to be solely the result of familiarity judgements in the absence of recollection of the original stimuli, as dual processing theories would predict. Rather, they could be due to feature binding errors occurring at encoding and retrieval.

Furthermore, false memories occurring in recent AMs have also been largely over-looked in the literature; most studies examining distortions in AM have focused primarily on remote childhood memories, whereas imagination inflation studies for recent events have mainly utilised simple actions rather than complex AMs (Anderson, 1984; Gerlach et al., 2013; Goff & Roediger, 1998; Nash et al., 2009; Seamon et al., 2009; Thomas et al., 2003). Significant differences are seen in the experiential qualities of remote and recent memories: remote memories are less detailed (Johnson et al., 1988), more likely to be observed from a third-person perspective (Nigro & Neisser, 1983), more rehearsed and thus more semanticised (Rosenbaum et al., 2001), and therefore may be more prone to memory distortion (Barclay & Wellman, 1986; Johnson et al., 1988; Schmolck et al., 2000; Winkielman, Schwartz, & Belli, 1998; Yassa & Reagh, 2013), although imagination inflation has been shown to be equally if not more effective for adulthood compared to childhood autobiographical events (Sharman & Barnier, 2008). Moreover, while some legal cases do require memory for events that occurred in childhood, the majority of eyewitness testimonies are for more recent occurrences (Flin, Boon, Knox, & Bull, 1992; Read & Connolly, 2007). Inducing enough errors in recent AMs to allow empirical study is a difficult task, resulting in a considerable gap in the false memory literature, to which AM conjunction error research may contribute.

1.6 Current objectives

The reconstructive nature of episodic memory offers a myriad of opportunities for the formation of conjunction errors. Even so, the relative paucity of studies exploring these distortions in the autobiographical domain means that much remains unknown about the specific influences on their generation. The following studies further our understanding of the nature of conjunction errors in recent AMs, by exploring potential factors that play a role in the formation of this type of memory distortion. A novel approach was developed to achieve this aim, amalgamating the AM conjunction error paradigm (Burt et al., 2004; Odegard & Lampinen, 2004) and the experimental recombination paradigm used previously to study episodic future simulations (Addis et al., 2009). Our paradigm involved three sessions: in the first session person, place and object details from original AMs were collected; the second session involved imagination of novel past events (i.e., imaginary past events that could have, but did not, occur) in response to conjunction lures comprising recombinations of these AM elements; and a source test was undertaken in the third session to determine the rate at which these lures were accepted as original memories.

Study 1 explores whether imagination of a conjunction event (and the vividness and plausibility thereof) influences the generation of AM conjunction errors. The imagination inflation effect has been well established for memories of wholly false episodes (for a review, see Garry & Polaschek, 2000), however, whether imagination has a similar influence on AM conjunction error rate is currently unexplored. Similarly, while the effect of event plausibility on the formation of memories for wholly false events has been extensively studied (Mazzoni et al., 2001; Mazzoni, 2007; Pezdek et al., 2006; Scoboria et al., 2004), the previous AM conjunction error studies recombined details in a way that maintained the overall plausibility of each scenario, and so the influence of plausibility on AM conjunction error rate is also unknown. *Study 2* builds on the findings of *Study 1*, by elucidating the roles of processing fluency and perceptual detail in the imagination inflation effect for AM conjunction errors. The phenomenology of conjunction lure misattribution was examined by exploring the differences in subjective and objective metrics of event quality between correctly identified conjunction lures, AM conjunction errors and authentic AMs.

Studies 3 and *4* use healthy aging as a window into the underlying cognitive mechanisms of AM conjunction error formation. The aging process can cause structural and functional declines in neural regions supporting memory binding, retrieval and monitoring (Buckner et al., 2006; Chan & McDermott, 2007; Persson et al., 2006; Raz et al., 2005; Tisserand et al., 2004), and as such aging is associated with reduced recollective ability and increased susceptibility to memory errors (Kroll et al., 1996; McCabe, Roediger, McDaniel, & Balota, 2009; Parkin & Walter, 1992). In *Study 3* we[1] compare AM conjunction error rates between younger and older adults to determine whether an age-related increase in vulnerability to memory distortions is maintained when the stimuli are comprised of distinctive and personally-relevant autobiographical information. Finally, *Study 4* elucidates the contribution of relational memory and inhibition ability to the individual variation in AM conjunction error susceptibility in both younger and older adults.

[1] Although the research in this thesis is my own, I conducted it within a research laboratory and honours students and research assistants were involved at various points. I also received advice and direction from my supervisors and international collaborators. Therefore, I often use the word “we” in this thesis to reflect that fact.

Chapter 2: Study 1 – Factors that influence the generation of autobiographical memory conjunction errors

2.1 Introduction

The literature on false memories for entirely fabricated scenarios implicates factors such as imagination (Garry & Polaschek, 2000; Garry & Wade, 2005; Goff & Roediger, 1998; Mazzoni & Memon, 2003; Nash et al., 2009), plausibility (Mazzoni et al., 2001; Mazzoni, 2007; Pezdek et al., 2006; Scoboria et al., 2004), and the sensory detail comprising an event (Heaps & Nash, 2001; Thomas et al., 2003; von Glahn et al., 2012) as having marked effects on the formation of such false memories. *Study 1* explores, for the first time, the contribution of these factors to the generation of AM conjunction errors, with the aim of furthering our understanding of the nature of these memory distortions.

2.1.1 Imagination inflation

Imagination inflation is one possible factor influencing rates of AM conjunction errors. The imagination inflation effect, whereby imagining a fabricated scenario increases the likelihood of forming a false memory of that event, is well established for memories of simple actions (Thomas et al., 2003), as well as for wholly false episodes (Devitt & Addis, in press; Garry, Manning, Loftus, & Sherman, 1996; Garry & Polaschek, 2000; Mazzoni & Memon, 2003; Nash et al., 2009; Thomas & Loftus, 2002). One of the ways in which this imagination inflation effect is thought to propagate is through the enhancement of the phenomenological richness of the simulated event, facilitated by the formation of a mental image and narrative. The source monitoring account of false memories claims that a false memory imagined in greater detail is more likely to be misattributed as a veridical memory (Johnson et al., 1993). Several lines of evidence support this view. Although imagined events are typically rated as lower in perceptual quality than authentic memories (Johnson et al., 1988; Justice et al., 2013; McGinnis & Roberts, 1996), the recollective experience of a fabricated scenario can be enhanced though repeated imagination (Heaps & Nash, 2001; Hyman, Gilstrap, Decker, &

Wilkinson, 1998, though see Porter, Yuille, & Lehman, 1999). Additionally, the imagination inflation effect is more effective when participants are encouraged to include sensory information in their imaginings (Thomas et al., 2003), as well as for individuals with high visual imagery ability (Dobson & Markham, 1993). Moreover, imagination that activates brain regions supporting visual imagery predicts subsequent false memory formation (Gonsalves et al., 2004).

The effect of event plausibility on the formation of memories for wholly false events has also been extensively studied. The more plausible a proposed event is, the more likely it is that a false memory will form for that event (Mazzoni et al., 2001; Mazzoni, 2007; Pezdek et al., 2006; Pezdek, Finger, & Hodge, 1997; Scoboria et al., 2004). Imagination increases the subjective plausibility of future simulations (Carroll, 1978; Szpunar & Schacter, 2013), perhaps by facilitating associations between the fabricated scenario and supporting evidence from episodic memory (Koehler, 1991). However, the converse pattern of results has been reported for the simulation of past events, whereby repeated imagination decreases perceived plausibility of counterfactual scenarios (De Brigard, Szpunar, & Schacter, 2013), perhaps because each imagination increases divergence from the authentic memory. Yet imagining probable, as opposed to improbable, counterfactual episodes engages a similar pattern of neural activation as autobiographical recollection (De Brigard et al., 2013). Moreover, suggestive techniques can alter the perceived plausibility of a past event; for instance, presenting evidence that an implausible event is a frequent occurrence (Mazzoni et al., 2001), or presenting doctored evidence of the event taking place (Nash et al., 2009; Wade et al., 2002). Moreover, the relationship between imagination and plausibility appears to be reciprocal, in that imagination increases the subjective plausibility of an event, but inflation is also more effective for events that are first perceived as plausible (Pezdek et al., 2006), potentially due to a more persistent search through memory for elaborative details (Anderson, 2012).

The combination of memory components forming a conjunction lure have the potential to vary widely in plausibility depending on the memories from which the components are drawn, and the resulting event plausibility should influence the generation of AM conjunction errors. Yet previous studies on AM conjunction errors recombined event components in a way that kept consistent the overall plausibility of each scenario (Burt et al., 2004; Odegard & Lampinen, 2004), so the influence of plausibility on AM conjunction error rates is currently unknown. Our paradigm – an adaption of the experimental recombination paradigm (Addis et al., 2009; Martin, Schacter, Corballis, & Addis, 2011) – offers a unique opportunity to address the impact that plausibility has on rates of AM conjunction errors, by presenting random recombinations of event components extracted from multiple AMs as the basis for imagined scenarios. Exploring the influence that imagination, and particularly the subjective experience of vividness and plausibility of these imagined scenarios, may have on the formation of AM conjunction errors will illuminate some of the underlying processes by which these errors can propagate.

Consistent with the imagination inflation effect and source monitoring framework, we hypothesised that following imagination of a hypothetical event involving a set of recombined memory components (i.e., imagined conjunction event), the acceptance of the recombined components (i.e., conjunction lure) as belonging to a real episode would increase relative to lures for which nothing was imagined. In relation to this prediction, we also hypothesised that lures rated higher in vividness (serving as an indicator of the perceptual richness of an event) and plausibility at the time of imagining would be associated with a higher likelihood of being subsequently accepted as real. Furthermore, plausible combinations of components comprising a conjunction lure are likely to undergo more extensive elaboration during the imagination of a conjunction event, therefore a positive correlation between the vividness and plausibility ratings of imagined past events was expected, as has been observed for imagined future events (Szpunar & Schacter, 2013; though see De Brigard, Szpunar, et al., 2013).

2.1.2 Degree of recombination and type of alteration

Recombined AMs can comprise components originating from two or more separate memories, and as such the number of memories from which a recombined event is constructed may also influence AM conjunction error rate. Our paradigm enabled us to investigate two degrees of recombination across three component details: *partial recombinations*, where only one component in an event was altered (i.e., the three components originated from two parent memories), and what we term *full recombinations*, where many or all components originate from separate memories (i.e., three components originating from three parent memories). Current theories of memory retrieval and reality monitoring provide conflicting predictions as to whether partial or full recombinations of AM components are more likely to result in false memories. A few lines of evidence suggest that partial recombinations are less likely to be identified as real than full recombinations. When presented with conjunction lures, for instance, individuals may use a recall-to-reject strategy, where recollection of the parent stimuli will allow rejection of the conjunction lure (Jones & Jacoby, 2001, 2005). With respect to AM stimuli, one would expect this recall-to-reject process to be more effective for partial recombinations than full, as the two congruent components from the same event are more likely to directly cue retrieval of that original memory, allowing rejection of the erroneous detail. In contrast, full recombinations provide a less specific cue to any one of the constituent memories, thus providing less evidence to suggest that the lure is false. This hypothesis is supported by the finding that fully recombined AM conjunctions were less likely to be identified as “never [having] happened” than partial recombinations (Burt et al., 2004).

However, the evidence on the effectiveness of this recall-to-reject strategy to identify conjunction lures is mixed (Jones & Bartlett, 2009). Furthermore, Burt et al. (2004) found no difference in the rate at which partial and full recombinations were falsely *remembered*, indicating that with respect to AM, participants did not use this strategy to prevent false acceptance of a conjunction lure. An alternative hypothesis predicts that partial recombinations are more likely to result in conjunction errors. Theories emphasising the use of plausibility (Mazzoni, 2007; Scoboria, Mazzoni, Jarry, & Shapero, 2012) as a marker for source attribution suggest that when the individual components are randomly recombined, as in our paradigm, partial recombinations will be more likely to form a plausible combination of memory components than will full recombinations (where there is a greater chance that two or more of the components will be incongruent). If this view is correct, acceptance rates should be higher for partial compared to full recombinations.

For partial recombinations, another influence on acceptance rates may be the type of component that is switched out. When randomly recombined, it is possible that the alteration of a specific type of component may inherently form more or less plausible scenarios. Previous work in our lab suggests that when imagining a novel future event comprising a person, place and object, the object is the hardest to subsequently remember (McLelland, Devitt, Schacter, & Addis, 2014), suggesting that this component is less central to an event in general, and thus more easily manipulated, particularly given that peripheral components are more prone to alternation through misinformation (Wright & Stroud, 1998). The person component may be a more central feature of imagined scenarios, with evidence that the familiarity of this feature predicts subsequent accurate memory of imagined future events (McLelland et al., 2014). In line with these findings, we anticipated that the conjunction lures where the object component had been altered would have the highest rate of false acceptance, while conjunction lures where the person component was altered would have the lowest. Exploring this possibility should reveal whether a specific type of memory component is more likely to be spontaneously altered during everyday recall.

2.2 Method

2.2.1 Participants

For the current study, 22 participants were recruited. Two participants (both female) were excluded: one due to an error in memory component recombination, the other declined to participate after Session One. Data from 20 participants were analysed (eight male), aged between 19 and 27 years old (*M* = 20.83, *SD* = 2.15). All were fluent English speakers with no history of learning disabilities, neurological or psychiatric impairments. This study was approved by the University of Auckland Human Ethics Committee. Participants were compensated with $75 in supermarket vouchers for their time.

The majority of participants were university undergraduates. While it may be argued that university students are not representative of the wider population, previous studies have found that, though exhibiting greater memory accuracy than those in other occupations and age-groups, young university students displayed no difference in vulnerability to memory manipulation (Loftus, Levidow, & Duensing, 1992). This is in line with findings that those with highly superior AM are equally as susceptible to memory distortions as the average population (Patihis et al., 2013).

Power analyses were conducted using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) on the basis of the previous AM conjunction error studies, reporting a difference between conjunction and foil lures (Odegard & Lampinen, 2004), and between different degrees of recombination (Burt et al., 2004). These analyses indicated a minimum of 8 participants were needed to achieve 80% power at $\alpha = .05$. Our sample size of 22 was therefore well above this requirement.

2.2.2 Procedure

For the current study we developed a novel paradigm that integrated the AM conjunction error paradigm (Burt et al., 2004; Odegard & Lampinen, 2004), with the experimental recombination paradigm (Addis et al., 2009; Martin et al., 2011). Previous studies of AM conjunction errors either presented relatively few lures drawn from a small pool of original memories (Odegard & Lampinen, 2004, Experiment 2, used an average of 12.6 original and 10 conjunction lures per participant), or presented a range of original and conjunction events that varied widely across participants (in Burt et al.'s 2004 study, between

16-182 original events, and 12-149 conjunction lures were used per participant). In the current study we utilised a high and consistent number of original AMs and conjunction lures in order to assess the typical baseline rate of AM conjunction lures imported into memory, and to gain a better understanding of the frequency with which these errors might occur in day-to-day AMs. Each participant completed three sessions spaced approximately a week apart (see Figure 2). In the first session memory details were collected, the second session consisted of imagination of conjunction events, and the third session involved a source test.

2.2.3 Session One: Stimuli collection

Participants were asked to recall 150 personal memories from the past 10 years, which typically took between three and four hours to complete. Each memory had to be of an event specific in place and time, and that lasted for no longer than a day. For each memory, participants wrote a brief description, and then specified a person (other than themselves) who was involved in the event, the location where it occurred, and a salient object that was present. Each of these memory components were unique, in that participants were asked not to duplicate them across different events (so if 'Joe' was identified as the person in one event, 'Joe' could not be listed for any other events). We provided participants with an extensive list of event cues to facilitate retrieval (see Appendix A), but memories were not limited to these cues.

Prior to Session Two, the memories were screened for adherence to the specificity instructions; at least 100 memories that complied with instructions were required for recombination. We randomly recombined the memory components to form 162 recombined detail sets (conjunction lures), each consisting of a person, place and object, to be used in Sessions Two and Three. Of these, 81 were partially recombined sets (with either the person, place or object component switched; 27 of each type), and 81 fully recombined sets (where the person, place and object were taken from three different memories; see Figure 3). Five recombined detail sets were also created to be used as practice trials in Sessions Two and Three.

2.2.4 Session Two: Imagination phase

Session Two took place approximately one week after Session One (*M* = 7 days, *SD* = 3) and was two hours in duration. Participants were presented with 108 of the 162 recombined detail sets (of which 54 were partially and 54 fully recombined; see Figure 3), and for each they had 30 seconds to imagine a novel past event that could have occurred in the past 10 years (but did not), and that involved all three components. Guidelines for event simulations included imagining the events from a first-person (field), rather than a third-person (observer) perspective (to comply with the way in which recent authentic memories are typically viewed; Nigro & Neisser, 1983) and to silently imagine the event in as much detail as possible for the entire time (see Appendix B for detailed instructions). Previous studies using the recombination paradigm for the simulation of future events (e.g., van Mulukom, Schacter, Corballis, & Addis, 2013) indicate it takes an average of 4.37 seconds to construct a future event, so our time limit of 30 seconds was deemed more than sufficient to generate and elaborate upon a past simulation. Each imagined scenario was then rated by the participant for vividness and plausibility on a 4-point scale (1 = low, 4 = high). Finally, at the end of each trial participants typed a one sentence summary of the event they had imagined, to verify that a scenario had indeed been generated (Szpunar & Schacter, 2013). Four practice trials were first completed to ensure all instructions were understood.

While the conjunction lures were experimentally recombined in a way so as to avoid reconstructing a combination matching an authentic detail set from Session One, there was the unavoidable possibility that a recombined detail set may correspond to a memory from the individual's past that was not reported in Session One. If a recombination of components prompted a specific memory for a real event involving those particular components, participants were instructed to indicate this by pressing "R" on the keyboard during the rating phase. These sets were excluded from subsequent analysis, to eliminate the possibility of inadvertently classifying a true memory as a conjunction error. An average of 3.9 sets (*M* = 3.6% of presented lures, *SD* = 3.53) per participant were excluded for this reason.

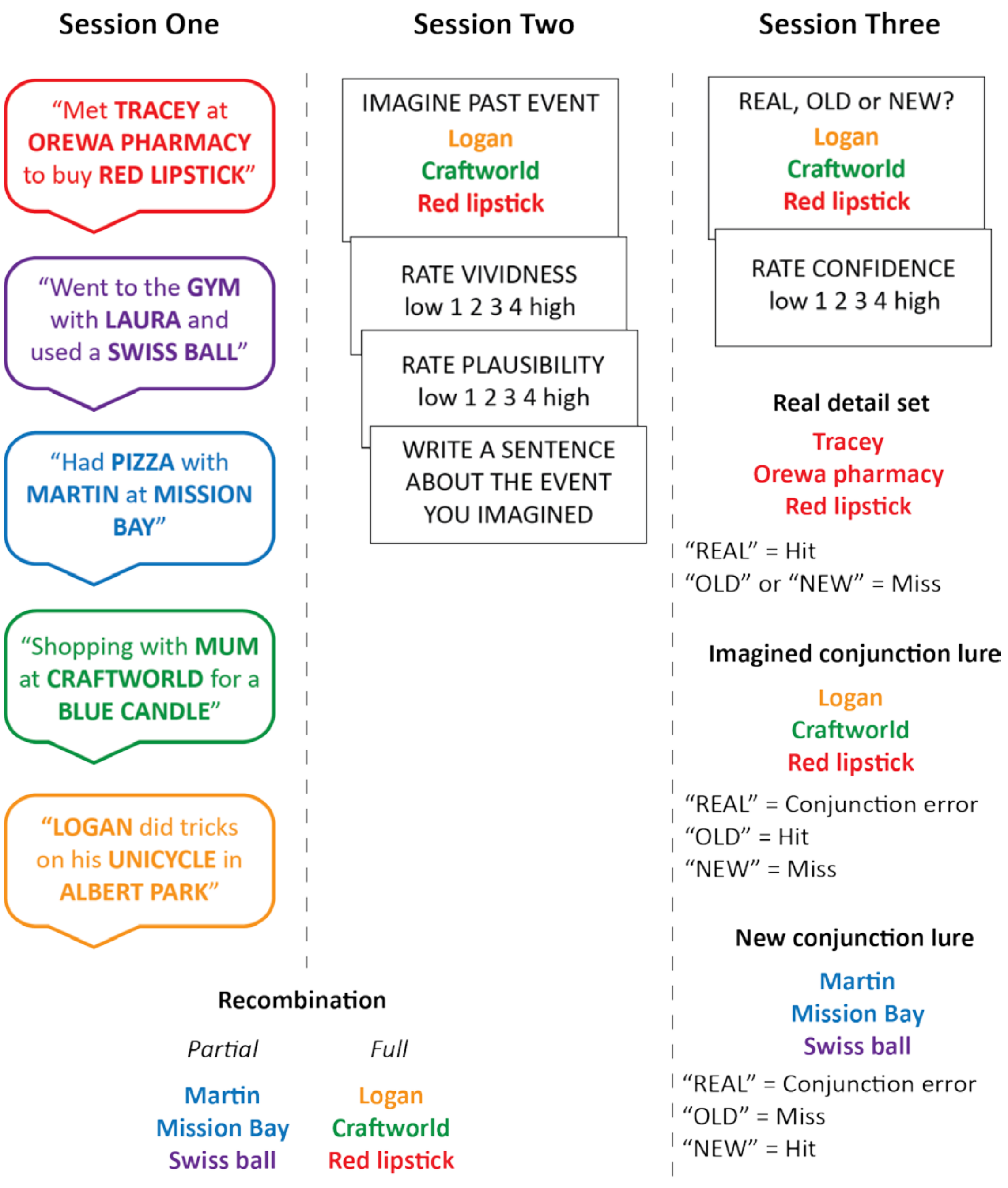

Figure 2. **Memory conjunction error paradigm.** A schematic diagram of example memory components collected during Session One, recombined detail sets for which events were imagined in Session Two, and detail sets presented in the source test during Session Three (including subsequent memory classification according to participant responses). Note colours are used to highlight recombinations; stimuli were presented to participants in black and white.

2.2.5 Session Three: Memory testing

The third and final session was completed approximately a week after Session Two (*M* = 9 days, *SD* = 3), and typically took two hours to complete. Following five practice trials, participants were presented with a total of 216 detail sets, corresponding to authentic memories or imagined events, as well as new conjunction lures that were not presented during Session Two (see Figure 3 for the number of sets presented in each condition). Each detail set was presented for 5 seconds, during which time participants made a source judgement, deciding whether they believed the detail set belonged to a real event, an imagined event, or was a new recombination they had not seen before. Button press responses were made for this decision, and were followed by a confidence rating on a 4-point scale (1 = low, 4 = high)[2]. The critical trials in this source test were those where the participant made a false alarm to a conjunction lure, incorrectly recognising it as belonging to a real event, indicating an AM conjunction error was made (see Figure 2).

It has been pointed out that AM and belief are two separate phenomena (Mazzoni & Kirsch, 2002), in that one can hold a belief that an event occurred to them in the past, without explicit recollection of the event (similar to the remember/know distinction, Tulving, 1985). As such, after the source test, 18 of the 20 participants completed a recall task[3], writing a short event description for any detail set they had judged as “real” in the source test, including any conjunction errors made. If at this stage they believed the detail set belonged to an imagined event rather than a real memory, they were asked to state this in their description. This procedure helped determine whether AM conjunction errors were simply believed to have

[2] In this session participants also completed a size judgement task and an odd/even decision task; because these conditions are not relevant to the current experiment, they are excluded from the following analyses.

[3] The first two participants did not, as this phase was not developed until after they had completed the study.

occurred based on a high level of plausibility or familiarity, or if they were *remembered* with a corresponding mental image and narrative.

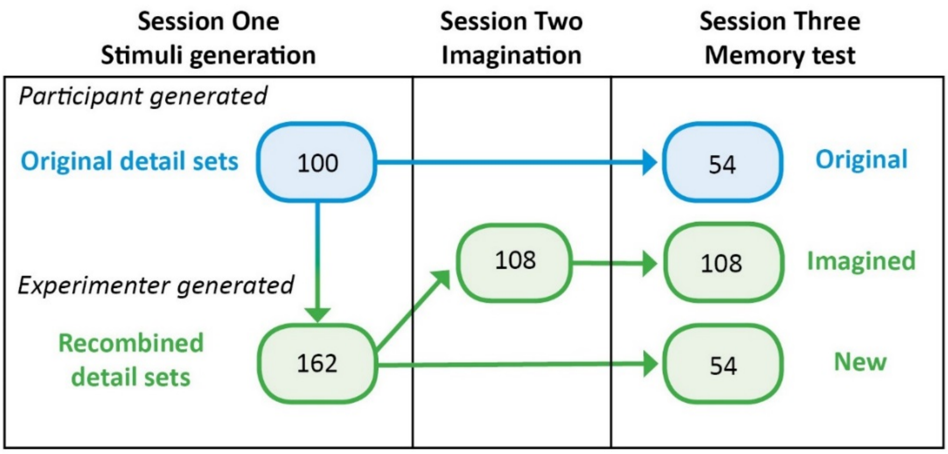

***Figure 3.* Minimum number of detail sets collected from participants in Session One, and number of detail sets presented during Sessions Two and Three of *Study 1*.** Original unaltered detail sets presented in blue, recombined detail sets in green.

2.3 Results

2.3.1 Data analysis

Memory conjunction errors were calculated as a percentage of the total number of valid trials per participant. Valid trials excluded those trials in Session Two for which participants indicated the combination of components reminded them of a real memory. Data concerning the percentage of conjunction lures accepted as real (i.e., conjunction errors) were analysed using parametric tests, while ratings of confidence, vividness and plausibility were analysed using appropriate non-parametric tests (e.g., Wilcoxon signed-rank test), due to the ordinal nature of the rating variables (Jamieson, 2004). Post hoc tests (Wilcoxon signed-rank tests) were considered significant if they exceeded the stated Bonferroni-corrected threshold.

2.3.2 Overall acceptance of conjunction lures

Overall, 95% of participants (19 out of 20) made at least one AM conjunction error. Participants made, on average, 5.45 (*SD* = 3.12) conjunction errors, falsely accepting 3.45% of conjunction lures presented in Session Three (*SD* = 1.94). Of these conjunction errors, on average 42.90% per participant were maintained in the recall phase (*SD* = 28.48). Conjunction lures for which an event was imagined in Session Two were more likely to result in conjunction errors than new lures which were unseen until the source test ($t(19) = 3.29$, $p = .004$, $d = 0.74$), consistent with an imagination inflation effect (see Table 1 and Figure 4a for percentages). No significant correlation was found between overall accuracy and conjunction error rate, $r = -.30$, $p = .19$.

***Table 1.* Mean percentage of trials resulting in autobiographical memory conjunction errors, by exposure condition and recombination type.**

Type of recombination	Exposure Condition		Total
	Imagined	New	
Partial	5.91 (4.05)	3.92 (3.06)	5.23 (3.20)
Person	3.98 (6.11)	1.31 (2.62)	2.86 (3.77)
Place	4.84 (3.77)	1.30 (3.66)	3.44 (2.76)
Object	8.96 (7.78)	6.82 (7.54)	8.02 (6.71)
Full	2.19 (2.18)	0.73 (1.51)	1.70 (1.60)
Total	4.02 (2.45)	2.33 (1.68)	3.45 (1.94)

Note. Standard deviation provided in parentheses.

A Wilcoxon signed-rank test revealed that participants were more confident in source decisions for detail sets corresponding to original memories (*Mdn* = 3.71) than for lures resulting in conjunction errors (*Mdn* = 2.14), $T = 0.00$, $p < .001$, $r = 0.85$, and also responded faster for original detail sets (*M* = 3017.94ms) than for conjunction errors (*M* = 3368.43ms), $t(18) = 4.19$, $p = .001$. Confidence responses for conjunction errors made in Session Three were not inflated by imagination during Session Two (imagined lures *Mdn* = 2, new lures *Mdn* = 3, $T = 25.5$, $p = .09$, $r = -0.44$).

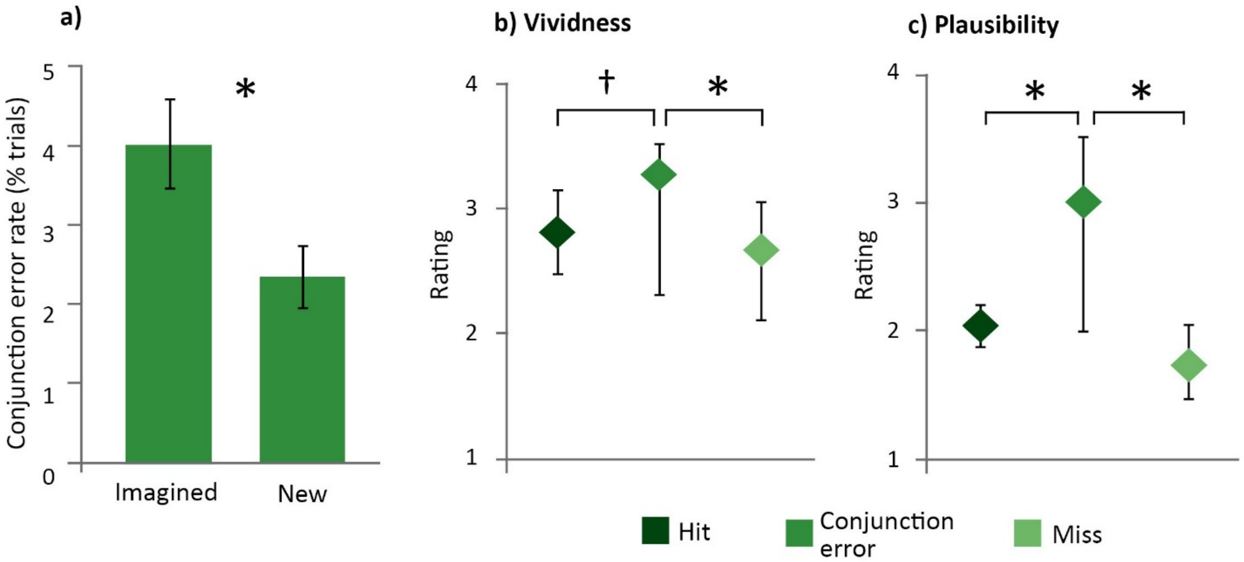

Figure 4. **Conjunction error rate and phenomenology of conjunction lures at encoding.** (a) Autobiographical memory conjunction error rate for conjunction lures presented in the imagination and new conditions in Session Three. (b) Median vividness and (c) plausibility ratings given in Session Two to imagined lures that were later identified as imagined (hit), real (conjunction error) or new (miss). Error bars for (a) reflect standard errors, and for (b) and (c) reflect interquartile range. * = $p < .05$. † = $p < .10$.

We hypothesised that imagined events resulting in conjunction errors would be those that were rated highly in vividness and plausibility in Session Two; as such, we examined whether these ratings differed for imagined conjunction lures that were subsequently correctly identified as imagined (hits), considered new (misses) or incorrectly accepted as real (conjunction errors, see Table 2 and Figure 4 for median ratings). A Friedman's analysis of variance (ANOVA) revealed a significant difference between vividness ratings across these subsequent memory conditions, $\chi^2(2) = 13.63$, $p = .001$. Consistent with our hypothesis, follow-up Wilcoxon signed-rank tests (Bonferroni-corrected threshold, $\alpha = .017$) indicated that conjunction errors had higher vividness ratings than misses, $T = 24.00$, $p = .01$, $r = -0.61$.

There was a trend towards higher vividness ratings for conjunction errors than hits, $T = 48.00$, $p = .06$, $r = –0.43$. Plausibility of imagined events also differed across the subsequent memory conditions (χ^2 (2) = 18.11, $p < .001$), with events resulting in conjunction errors rated as more plausible than misses ($T = 6.00$, $p < .001$, $r = –0.82$) and hits ($T = 12.00$, $p < .001$, $r = –0.77$). As expected, conjunction event vividness was positively correlated with plausibility, $r_s = .45$, $p < .001$.

Table 2. **Median ratings for phenomenological qualities of events imagined in Session Two, by subsequent memory condition, degree of recombination, and type of component altered.**

	Subsequent memory condition			Degree of recombination		Type of component altered		
	Hit	Conjunction error	Miss	Partial	Full	Person	Place	Object
Vividness[a]	2.78	3.25	2.66	2.80	2.66	2.96	2.52	3.06
Plausibility[a]	2.01	3.00	1.17	2.15	1.76	2.00	1.89	2.62

Note. [a]Rating scale ranges from 1 (low) to 4 (high).

2.3.3 Degree of recombination

Another aim of this study was to examine whether the degree of recombination of memory components influenced conjunction error rates. Detail sets which were partially recombined were accepted as real more often than fully recombined sets ($t(19) = 4.87$, $p < .001$, $d = 1.09$; see Table 1), although the degree of recombination did not influence confidence ratings in source decisions (partial $Mdn = 3.13$, full $Mdn = 3.14$, $T = 76.00$, $p = .29$, $r = –0.24$). Accuracy rates did not differ between partial (M = 72.85%) and full trials (M = 64.34%), $t(19) = 1.30$, $p = .21$, $d = 0.29$.

The degree of recombination influenced the phenomenology of the imagined events during Session Two (see Table 2). Specifically, vividness ratings were greater for partially recombined sets than for full recombinations, $T = 31.00$, p = .004, $r = –0.62$. Similarly, plausibility ratings were also higher for partial recombinations than for full recombinations, *T* = 12.00, $p < .001$, r = –0.78. However, the differences in phenomenology of events imagined using partial and full recombinations of event components may not be sufficient to explain the erroneous acceptance of conjunction lures during the recognition test. For instance, even when considering only highly plausible and vivid events (i.e., imagined events given ratings of 3 or 4 for both), there was still a trend for partial recombinations (*M* = 7.67%, *SD* = 8.33) to be accepted more often than full recombinations (*M* = 4.25%, *SD* = 7.55), $t(19) = 1.79$, $p = .09$, $d = 0.40$.

2.3.4 *Type of component altered*

Finally, we explored whether the specific type of event component substitution in partial recombinations impacted rates of conjunction lure acceptance (see Table 1). A repeated-measures ANOVA revealed a significant difference in the percentage of conjunction errors made between sets with either the person, place or object component substituted, $F(1.51, 28.71) = 7.69$, $p = .004$, $\eta^2_p = 0.29$. Object-altered sets were accepted as real more often than both person-altered ($p = .01$), and place-altered ($p = .04$) sets. No difference was found between person- and place-altered sets ($p = 1.00$). A Friedman's ANOVA indicated that confidence in recognition judgements for conjunction lures did not differ depending on the type of component altered (person *Mdn* = 3.11, place *Mdn* = 3.10, object *Mdn* = 3.08), $\chi^2(2) = 0.00$, $p = 1.00$.

A Friedman's ANOVA was also run to explore whether the type of component altered influenced the vividness ratings of imagined events (see Table 2). A significant main effect was found, $\chi^2(2) = 8.84$, $p = .01$. Follow-up Wilcoxon signed-rank tests revealed that events imagined for object-altered sets were more vivid than events elicited by place-altered sets ($T = 28.00$, $p = .003$, $r = –0.64$); comparisons involving person-altered sets were not significant at the Bonferroni-corrected threshold ($\alpha = .017$). A significant difference was found in plausibility ratings between events imagined for person, place and object-altered sets, $\chi^2(2) =$

10.30, $p = .005$. Imagined events elicited by object-altered sets were rated higher in plausibility than events elicited by both person-altered ($T = 32.00$, $p = .005$, $r = –0.61$) and place-altered sets ($T = 14.00$, $p < .001$, $r = –0.76$). No difference was found between the plausibility of events in the place- and person-altered conditions, $T = 65.00$, $p = .14$, $r = –0.33$.

2.4 Discussion

We were successful in eliciting AM conjunction errors using our novel recombination paradigm, confirming that time-intensive diary studies are not required to study conjunction errors in the autobiographical domain. Specifically, during the recognition test, an average of 5.5 conjunction lures per participant were falsely attributed as belonging to a veridical episode – an average rate higher than the 1.5 conjunction errors reported by Odegard and Lampinen (2004) and on par with Burt et al.'s (2004) rate of 5.9. Furthermore, over a third of these conjunction errors were maintained in the subsequent recall phase, adding to the evidence that AM conjunction errors can be recollected and experienced as phenomenologically real (Burt et al., 2004; Odegard & Lampinen, 2004; Reinitz et al., 1992, 1994). Overall, 95% of participants made at least one conjunction error in the source test, and 89% maintained at least one error during the recall phase. This is more than comparable to the rate of implantation for AMs of false childhood events (across studies an overall success rate of 31% has been recorded; Lindsay, Hagen, Read, Wade, & Garry, 2004).

Participants expressed greater confidence in their source decisions for authentic detail combinations than for conjunction lures, in line with previous findings demonstrating that authentic memories are more compelling than false memories (Heaps & Nash, 2001; Hyman et al., 1998; Mather et al., 1997; Porter et al., 1999; Reinitz et al., 1992). Yet the rate of AM conjunction error formation was unrelated to overall accuracy in the source test, indicating that these conjunction errors are not simply the result of poor performance, but rather are the result of normal constructive memory processes.

Consistent with the imagination inflation effect, conjunction lures for which an event was imagined resulted in more AM conjunction errors than new lures. The imagination inflation effect is well established for memories of simple actions (Thomas et al., 2003) and childhood events (Mazzoni & Memon, 2003); our findings suggest that imagination inflation may operate in a similar way for AM conjunction errors. Our rate of AM conjunction error formation is particularly noteworthy considering previous studies have used time-intensive guided imagination techniques (e.g., Garry & Wade, 2005; Loftus & Pickrell, 1995; Wade et al., 2002), which is in stark contrast to our short (30 second) imagination trials. Also consistent with our hypothesis, and the source monitoring framework (Johnson et al., 1993), there was a trend for lures resulting in conjunction errors to be associated with more vividly imagined events than those correctly identified as imagined. This observation is in line with the prospect that imagination serves to increase the phenomenological qualities of the conjunction event, leading to later misattribution of the event as real. The finding that 42% of the conjunction errors were later recalled further speaks towards a source misattribution driven by an increase in perceptual quality. However, we cannot make clear inferences about the mechanism underlying the imagination inflation effect observed in the current study, as the possibility remains that exposure to the conjunction lures via imagination increased the processing fluency with the component combination, and subsequent source decisions were made based on ease of processing, or feelings of familiarity with the imagined lures compared to new lures (Jones & Bartlett, 2009; Jones & Jacoby, 2001; Reinitz, 2001). This possibility is further investigated in *Study 2*, via the inclusion of a control exposure condition in Session Two, as well as by collecting phenomenological ratings not only during imagination, but also during recall of hits, correctly identified imagined events, and AM conjunction errors in Session Three.

We further hypothesised that the more plausible an imagined event for a conjunction lure, the greater the likelihood of the lure being accepted as belonging to a veridical event. Our pattern of results is consistent with this notion, with those imagined events resulting in conjunction errors rated higher in plausibility than those resulting in hits or misses. This result further replicates that of previous studies on plausibility and false memory formation (Mazzoni et al., 2001; Mazzoni, 2007; Pezdek et al., 2006; Scoboria et al., 2004), and is the first demonstration of the influence of plausibility on AM conjunction errors.

As anticipated, a positive relationship was observed between ratings of plausibility and vividness, suggesting that imagined events that are judged as more plausible are also likely to be subjected to more extensive elaborative processes during imagination (see Pezdek et al., 2006 for evidence towards this view). Individuals may be more able to draw on relevant personal experiences and autobiographical knowledge to construct plausible as opposed to implausible scenarios (Anderson, 2012). However, because our data are correlational, cause and effect cannot be confidently established, and it may be that events that are imagined with greater vividness are subsequently considered more plausible. To establish a causal relationship between these phenomenological qualities, future research is needed to experimentally manipulate one characteristic while measuring the subjective experience of the other; unfortunately, this experiment is beyond the scope of the current thesis.

Regarding the influence of the degree of recombination on AM conjunction lure acceptance, it has been suggested that partial recombinations may be more likely to be correctly rejected due to the more effective use of a recall-to-reject strategy (Burt et al., 2004). However, our results supported the alternative prediction: that the more plausible event constructions associated with partial recombinations increased the likelihood of misattribution as belonging to a veridical memory (Mazzoni, 2007; Scoboria, Mazzoni, Jarry, & Shapero, 2012). Partial recombinations were subsequently accepted as belonging to a real event twice as often as fully recombined detail sets, and were rated as more plausible than full recombinations, which, in combination with the above influence of plausibility on AM conjunction error formation, suggests a critical role for plausibility in the import of event components from one memory to another.

However, partially recombined details sets are accepted as belonging to a real event more often that full recombinations even for those events rated high in plausibility and vividness, indicating that phenomenology may not wholly account for the increased acceptance of partial recombinations. A second candidate mechanism may be processing fluency; the relative ease of constructing a scenario for partial recombinations likely increases the ease with which the event is later retrieved, and this fluency can be misattributed as an indicator of event veracity (Jacoby & Dallas, 1981; Johnston et al., 1985; Whittlesea, 1993). According to this view, full recombinations are rejected more often due to the increased mental effort required to integrate three disparate details into one cohesive scenario, as compared with the more fluent integration of only one incongruent component for partial recombinations. In line with this hypothesis, a study exploring the formation of false memories for childhood events revealed a boundary to the imagination inflation effect, whereby incorporating three details into a simulation increased confidence that the false event truly occurred more so than the incorporation of six details, supposedly because the latter condition required greater cognitive effort to generate the extra details (von Glahn et al., 2012). The greater difficulty in completing the task could be later used as a source cue to accurately identify the event as imagined (cf. information on cognitive operations, Johnson et al., 1993). Consistent with this idea, partially recombined events in the current study were likely visualised with greater ease than full recombinations, as suggested by higher ratings for vividness.

Burt et al. (2004) also explored the influence of degree of recombination on conjunction lure acceptance, and in contrast to current findings, observed that full and partial recombinations were equivalent in the rate at which they were judged as at least "somewhat remembered". A number of methodological differences between Burt et al.'s study and the current one could account for this difference in results. Notably, only recombinations considered plausible were utilised by Burt et al. (whereas plausibility was allowed to vary using random recombinations in the current study), thereby reducing the phenomenological difference between partial and full recombinations. Furthermore, the current study used a short response time limit, which may have encouraged source decisions based on fluency (Jones & Jacoby, 2005), while Burt et al. imposed no response time limitations. These differences, in addition to the much longer delay between event occurrence and source test (13 years on average) may have meant that participants in their study used alternative strategies to identify conjunction lures.

We also found that the particular event component that is altered within a conjunction lure influenced conjunction error rates, with object-altered detail sets accepted more often than person-altered sets. Given that objects may often be less salient within an episode, altering this component may be less likely to distort the overall integrity of the event, as evidenced by the higher plausibility ratings given to object-altered sets compared to either person- or place-altered sets. However, there is a possibility that the increased acceptance of object-altered sets evident in the current study is due to a presentation order artefact. All detail sets presented during the recognition test, including conjunction lures, were presented in the order "person/place/object". Due to time pressure, participants may have made a memory decision after considering only the first two components (person and place), without giving the third component (object) as much weight, despite instructions to consider all three components before responding. Thus, because the person and place components correspond to a veridical event in object-altered sets, participants may be more likely to false alarm without duly considering the object. The fact that object-altered sets were rated higher in plausibility and vividness speaks against this explanation, as well as the finding that object-altered sets comprised over a third of the conjunction errors that were falsely remembered in the recall phase. However, we address this issue in *Study 2* by presenting the three components in a counterbalanced order.

In summary, we replicated the occurrence of conjunction errors in AM, and provided further evidence that conjunction errors can be experienced with a sense of recollection, inducing these errors in the laboratory without the need for time-intensive diary studies. The current study serves to highlight potential factors underlying the generation of these errors, including the imagination and subjective vividness of a conjunction event, the plausibility of the component recombination, as well as the degree to which the event components are recombined across memories. The precise driver of the imagination inflation effect in the current study remains unclear; it is possible that familiarity with the conjunction lure and the phenomenological of the simulated event may both play a role in the increase in conjunction errors for imagined lures.

Chapter 3: Study 2 – The roles of perceptual quality and processing fluency in autobiographical memory conjunction error formation

3.1 Introduction

Study 2 builds on the findings of *Study 1,* by exploring the contribution of enhanced phenomenology and processing fluency to the imagination inflation effect for AM conjunction errors. This aim was achieved by the inclusion of a control condition to test whether exposure-related processing fluency can elicit an inflation effect similar to that resulting from imagination. We also examined the phenomenological differences between AM conjunction errors, authentic memories and correctly identified imagined events not only following the initial imagination phase in Session Two, but also during the recall phase in Session Three, using both subjective and objective metrics of event quality.

3.1.1 Phenomenological quality versus processing fluency

As discussed in *Study 1*, previous evidence suggests that increasing the phenomenological quality of a fabricated event inflates confidence that the event truly occurred (Mazzoni & Memon, 2003; Thomas et al., 2003). According to the source monitoring framework (Johnson et al., 1993), at retrieval the source of a mental experience can usually be determined by an evaluation of the phenomenal characteristics of that experience, as memories from different origins tend to have differing characteristics. Source monitoring errors take place when the phenomenological quality of an internally-generated experience, such as imagination, bears similarities to that of externally-generated experiences like authentic memories (Heaps & Nash, 2001; Lampinen et al., 2003). Consistent with this view, in *Study 1* we demonstrated that imagined events later forming AM conjunction errors were rated as higher in subjective vividness than lures that were later correctly identified.

However, an alternative prediction suggests the processing fluency associated with a conjunction lure underlies the imagination inflation effect. The fluency account of recognition memory suggests that the relative ease of stimulus processing serves as an indicator of previous experience with that item, and as such is typically used as a heuristic when making recognition or source monitoring decisions (Johnston et al., 1985; Whittlesea, 1993). The processing fluency associated with a conjunction lure can be enhanced by virtue of exposure to that combination of components in the imagination session, which may be driving the imagination inflation effect rather than the process of imagination itself (Garry & Wade, 2005; Sharman, Garry, & Beuke, 2004; Sharman et al., 2005). Indeed, memory conjunction errors for words and faces are thought to arise as a result of familiarity with the component parts of the conjunction lure in the absence of recollection of the correct component combination (Jones & Bartlett, 2009; Jones & Jacoby, 2001; Marsh, Hicks, & Davis, 2002; Rubin, Petten, Glisky, & Newberg, 1999). Moreover, memory conjunction errors have also been posited to result from over-binding of stimulus components originating from different parental stimuli (Kroll et al., 1996; Reinitz, 2001). Exposure to a conjunction lure via imagination allows associations to form between the initially unrelated components, increasing the ease of retrieval of – and thus familiarity with – the conjunction lure, which may be subsequently misattributed as an indicator of authenticity. The possibility also stands that the vividness ratings made in *Study 1* may reflect, at least in part, the enhanced ease with which a conjunction event was imagined, rather than enhanced perceptual quality per se.

There is evidence to support a fluency account. While high confident hits for conjunction stimuli (e.g., word syllables) elicit a large late positive event-related potential (ERP), thought to reflect the recollection of the stimulus, ERPs associated with false alarms to conjunction lures, feature lures and new words lack this late positive component, suggesting these errors arise due to misattribution of familiarity (Rubin et al., 1999). Sharman and colleagues (2004) found that both imagination and exposure (via paraphrasing) of a false childhood event elevated confidence that the false event actually took place. However, while the authors acknowledge that both imagining and paraphrasing requires visual imagery, it is also possible that the inflation effect in the paraphrasing condition could be due to spontaneous mental imagery (see Sharman et al., 2005; Thomas et al., 2003).

In contrast, across two experiments examining increased confidence for fabricated childhood events, von Glahn, Otani, Migita, Langford and Hillard (2012) found evidence for the role of perceptual quality over processing fluency in the imagination inflation effect. The number of times by which participants rated the likelihood of a childhood event, and were thus exposed to the event, had no influence on confidence ratings, even though response time decreased with the number of ratings, indicating that fluency was indeed enhanced. Conversely, the richness of a memory representation did influence confidence ratings, whereby generating three or six details about the event, compared to no details, resulted in enhanced confidence. This pattern of results suggests that imagination inflation is due to reality-monitoring errors following increased perceptual quality as opposed to fluency alone, consistent with the source monitoring framework.

In further support of a role of phenomenological quality over processing fluency in the formation and acceptance of AM conjunction errors, studies using simple laboratory stimuli have demonstrated that conjunction errors can occur in free recall (Reinitz & Hannigan, 2001), may be experienced with a sense of recollection (Reinitz et al., 1992, 1994), and are not always avoided by using recollective processes (Jones & Bartlett, 2009). The previous studies on AM conjunction errors (including *Study 1*) also demonstrate that these errors can be recollected, and recruit complex evaluative processes, including narrative formation (Odegard & Lampinen, 2004) and associations with existing memories (Burt et al., 2004).

The current study elucidates the relative contributions of fluency and phenomenological quality to the imagination inflation effect for AM conjunction errors. If this effect can be accounted for solely by increased fluency, a similar degree of inflation is expected following both an imagination task and an associative task involving no explicit imagination. If, however, increased phenomenological richness of the mental experience accompanying the conjunction lure also plays a role in the imagination inflation effect, higher AM conjunction error rates should be observed following the imagination task relative to the associative task. The associative task used in this study is a pleasantness judgement, which involves a deep level of processing (Jacoby, Shimizu, Daniels, & Rhodes, 2005) and thus controls for exposure to the conjunction lure, without requiring the construction of an imagined event (Gaesser, Spreng, McLelland, Addis, & Schacter, 2013).

3.1.2 Subjective phenomenology at retrieval

We also wished to assess the phenomenological differences between AM conjunction errors, veridical memories and correctly identified imagined events during retrieval. In *Study 1*, we gathered subjective ratings of vividness during the imagination phase, in line with literature demonstrating that the detail with which an event is encoded influences later false acceptance of that scenario as an authentic memory (Dobson & Markham, 1993; Gonsalves et al., 2004; Johnson et al., 1993; Lampinen et al., 2003; Okado & Stark, 2005; Thomas et al., 2003; von Glahn et al., 2012). However, the experiential quality of an event at *retrieval* may provide an important distinction between true and false memories (Heaps & Nash, 2001). Indeed, encouraging the use of mental imagery during retrieval leads to higher false recognition rates (Schlosser, 2006). As such, we obtained vividness ratings at both the imagination and retrieval phases of AM conjunction error formation.

In addition to being subjectively vivid, authentic memories tend to be more emotionally intense, and are regarded as more personally important than false memories (Heaps & Nash, 2001; though see Laney & Loftus, 2008). These findings are in line with studies demonstrating an enhancement of memory for emotional (Bradley, Greenwald, Petry, & Lang, 1992; Dolcos, LaBar, & Cabeza, 2004; Hamann, 2001; Kensinger & Corkin, 2003; Szpunar, Addis, & Schacter, 2012) and self-relevant stimuli (Rogers, Kuiper, & Kirker, 1977), as well as an increased effect of imagination inflation when self-relevant details are used (Desjardins & Scoboria, 2007). It is thought that both emotional arousal and personal significance aid in the integration of event components, thereby increasing encoding and retrieval success (Mather & Sutherland, 2011; Symons & Johnson, 1997).

Moreover, manipulating the vantage point from which an event is imagined (i.e., a first-person perspective versus a third-person perspective; Nigro & Neisser, 1983), can impact the strength with which the scenario is visualised (Vella & Moulds, 2013) and thus may affect later false acceptance. Marsh, Pezdek, & Lam (2014) demonstrate that imagining recent adulthood events from a first-person perspective results in a greater inflation effect compared with imagination from a third-person perspective, with an inverse pattern observed for childhood events. As it is more common for recent memories to be seen from a first-person perspective, and older memories from a third-person perspective (Nigro & Neisser, 1983), these findings are in line with the idea that imagined scenarios with similar properties to authentic memories are more likely to be falsely accepted as real (see also Libby, 2003). Accordingly, in addition to vividness ratings at both imagination and retrieval, in the current study participants also made ratings for emotion, personal significance, and perspective.

3.1.3 Objective measures of memory quality

Lastly, distinctions have been made between the subjective and objective experience of memory quality. For example, flashbulb memories are held with a high degree of confidence, yet are susceptible to memory decay and distortion at normal rates, demonstrating that the subjective experience of a memory does not necessarily correspond to the objective accuracy of the event (Kensinger & Schacter, 2006b; Neisser & Harsch, 1992; Schmolck et al., 2000; Talarico & Rubin, 2003). Data from confabulators supports this distinction; Ciaramelli & Ghetti (2007) examined recollective experience in confabulators and controls using subjective and objective measures of recollection. In non-confabulators both measures were associated, whereas in confabulators the subjective recollective state was inflated relative to the objective, suggesting that the experiential quality of false memories held by confabulators is not tied to objective source information.

In the current study memory quality at retrieval was objectively measured via independent scoring of an autobiographical interview (AI; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002); this scoring protocol separates episodic details from other non-episodic information that also comprise AMs (Levine, 2004). If AM conjunction errors arise due to misattribution of memory-like qualities, as per the source monitoring account, we expect conjunction errors to be more similar to authentic memories in both subjective and objective phenomenal quality than correctly identified imagined events.

3.2 Method

3.2.1 Participants

Twenty participants[4] (eight male), aged between 18 and 29 years old (M = 20.70, SD = 2.94) were recruited in compliance with the principles of The University of Auckland Human Participants Ethics Committee. All were fluent English speakers with no history of learning disabilities, neurological or psychiatric impairments, and were compensated with $75 in supermarket vouchers for their time. Data from an additional male was excluded, as the participant declined to participate following Session One. Note that for the AI, interview data for one participant was lost due to a recording issue.

3.2.2 Procedure

The current study follows a similar protocol as *Study 1*, with notable differences described below.

3.2.3 Session One: Stimuli collection

Event components were permitted to be duplicated across memories, in order to make stimuli collection easier. This session typically took three hours to complete. Prior to Session Two, we randomly recombined the event components to make 124 recombined detail sets, half partially and half fully recombined (see Figure 5).

[4] The same power analyses run for *Study 1* apply for *Study 2*.

3.2.4 Session Two: Exposure phase

Session Two took place approximately one week after Session One (*M* = 8 days, *SD* = 3) and included both an imagination and a non-imagination associative condition. Participants were presented with 84 conjunction lures; 42 each in the imagination and associative conditions. The order in which participants completed the imagination and associative tasks, as well as the presentation order of person, place and object components, was counterbalanced across trials. Participants first completed two practise trials in each condition to ensure all instructions were understood. Session Two was usually completed within two hours.

The imagination condition involved simulating a novel past event for 20 seconds. In addition to rating vividness and plausibility of the imagined events on a 5-point scale (1 = low, 5 = high), each imagined event was also rated for similarity to previous experiences on a 5-point scale[5] (1 = not at all similar to any previous experiences, 5 = identical to a previous experience), to assess the degree to which component recombinations resembled authentic memories (Addis et al., 2010). These ratings were followed by a written one sentence summary of the imagined event.

For the associative condition, participants ranked the three components of the conjunction lures in order of subjective pleasantness, from highest to lowest (Gaesser et al., 2013). For example, if shown the details "*Tracey, Pharmacy, Chocolate*" a response might be "I find chocolate more pleasant than Tracey, and Tracey is more pleasant than the pharmacy". In this way, the details comprising a conjunction lure are processed and integrated but without the formation of an imagined event. As with the imagination condition, participants completed this task silently, thinking about their decision for the full 20 seconds. To control for the ratings made in the imagination condition, participants then rated each pleasantness judgement for difficulty on a 5-point scale (1 = very easy, 5 = very difficult), similarity of pleasantness of

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[5] Five-point rating scales were used instead of the 4-point scales employed in *Study 1* to give a greater range of possible values, as well as to provide a middle response (Clark & Watson, 1995; Comrey, 1988).

the three memory components (1 = very dissimilar, 5 = very similar) and similarity of the conjunction lure to previous experiences. Finally participants wrote out a sentence indicating the order of pleasantness ranking (see Appendix B for detailed participant instructions).

The current study used a more stringent criteria for the exclusion of detail sets reminding participants of a real memory than that employed in *Study 1*; in order to determine a cut-off for ratings of "similarity to previous events", 10 unaltered detail sets corresponding to AMs collected in Session One were presented amongst the conjunction lures. These unaltered details sets were given an average rating of 4.20 (where a response of "5" indicated an event was "identical to a previous experience"). Thus all conjunction lures rated as 4 or 5 on this dimension were excluded from analysis, resulting in an average of 21.25 conjunction lures excluded per participant (*M* = 22.81%, *SD* = 8.47).

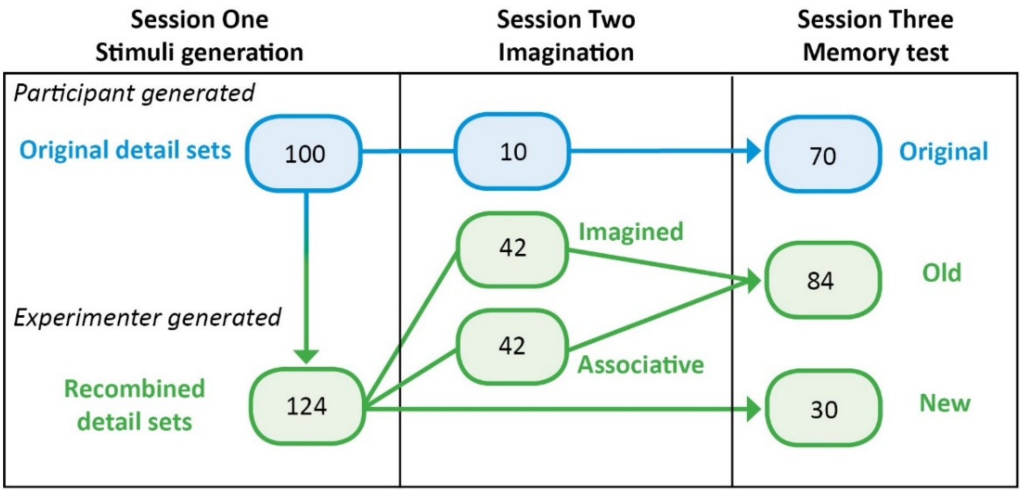

***Figure 5.* Minimum number of detail sets collected from participants in Session One, and number of detail sets presented during Sessions Two and Three of *Study 2*.** Original unaltered detail sets presented in blue, recombined detail sets in green.

3.2.5 *Session Three: Memory testing*

The final session was completed approximately one week after Session Two (*M* = 9 days, *SD* = 4). The source test was identical to that described in *Study 1*, except that participants were presented with 184 detail sets (see Figure 5 for the distribution of trials across conditions). The correct response for both imagined and associative detail sets was "old". Confidence ratings were made on a 5-point scale (1 = low, 5 = high). Participants first completed 9 practise trials to ensure all instructions were understood.

Following the source test, an adapted version of the AI (Levine et al., 2002) was conducted. An average of 10 detail sets were selected according to responses in the recognition test (based on individual performance, the total number of selected detail sets ranged from 7 to 16): around four correctly identified real sets, four correctly identified imagined sets[6], and all conjunction lures incorrectly judged real (AM conjunction errors). Participants were presented with each detail set and were given two minutes to verbally describe what they remembered about the associated event in as much detail as possible while being audio-recorded. For the lures identified as imagined, participants were instructed to only describe what they remember imagining for the conjunction event in Session Two, and to refrain from generating any new information. Participants received minimal input from the experimenter, which was limited to general probes such as "is there anything else you remember about the event?" (see administration instructions in Appendix B). Following each description, participants rated each event for vividness, level of emotional response and personal significance on a 5-point scale (1 = low, 5 = high), and indicated what perspective the event was viewed from (first- or third-person; Nigro & Neisser, 1983).

Audio-recordings of event descriptions were later transcribed and scored according to the AI scoring protocol (Addis, Wong, & Schacter, 2008, adapted from Levine et al., 2002; see Appendix C for full scoring instructions). First, transcripts were segmented into distinct pieces of information each conveying a unique idea; each segment was then classified as either internal or external. Internal details were those episodic details pertaining directly to the main event, and were further broken down into types: event (details describing the unfolding of the story), perceptual (sensory details), place (spatial location), thought/emotion (emotional state

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[6] For the real and identified imagined sets, selection was random.

and thoughts at the time of the event), and time (temporal context). External details were those not part of, or specific to, the main event being described, such as semantic facts, metacognitive statements or descriptions of episodes other than the main event. The AI scoring was completed by an independent rater blind to the type of event. To establish inter-rater reliability, this rater and five other raters scored a set of 20 recalled past and imagined future events obtained from a previous study (Addis et al., 2008). These scores were subjected to an intraclass correlation analysis, revealing that reliability across raters was acceptable (two-way mixed model; standardised Cronbach's α: internal detail score .97; external detail score .95; event, .89; emotions/thoughts, .89; place, .85; time, .90, perceptual, .97).

3.3 Results

3.3.1 Data analysis

As with *Study 1*, AM conjunction errors were calculated as a percentage of valid trials judged as belonging to a real memory in Session Three, and were analysed using parametric tests. Valid trials were those rated 3 or below on similarity to previous events in Session Two. Subjective ratings, such as confidence, vividness and plausibility were analysed using appropriate non-parametric tests, and post hoc tests (Wilcoxon signed-rank tests) were considered significant if they exceeded the stated Bonferroni threshold.

3.3.2 Overall acceptance of conjunction lures

Overall, 85% of participants (17 out of 20) made at least one AM conjunction error. Participants made, on average, 2.25 (SD = 2.69) conjunction errors, which equated to 2.30% of the 124 conjunction lures presented in Session Three (SD = 2.83; see Table 3). Of the conjunction errors made during the recognition test, 43.06% (SD = 39.86) were still considered to belong to a true memory during free recall on the AI, with 40% of participants maintaining at least one error during this recall phase. A significant negative correlation was found between overall accuracy in the source test and conjunction error rate $r = -.51$, $p = .02$.

***Table 3.* Mean percentage of trials resulting in autobiographical memory conjunction errors, by exposure condition and recombination type.**

Type of recombination	Exposure Condition			Total
	Imagination	Associative	New	
Full	1.56 (3.44)	1.24 (2.20)	0.67 (2.05)	1.20 (2.13)
Partial	4.17 (4.00)	1.53 (3.39)	4.75 (6.47)	3.47 (3.45)
Person	2.25 (6.97)	0 (0)	4.00 (8.21)	2.22 (3.81)
Place	5.05 (9.63)	1.43 (4.40)	4.00 (8.21)	3.59 (4.87)
Object	4.33 (9.04)	2.92 (7.29)	6.00 (11.42)	4.29 (6.25)
Total	2.70 (2.77)	1.38 (2.32)	3.11 (5.16)	2.30 (2.83)

Note. Standard deviations are provided in parentheses.

As with *Study 1*, we explored whether the ratings of vividness and plausibility of events imagined in Session Two differed for conjunction lures subsequently resulting in hits, misses and conjunction errors (medians presented in Table 4). A Friedman's ANOVA revealed a significant difference between vividness ratings across these subsequent memory conditions, $\chi^2(2) = 10.50$, $p = .004$. Follow-up Wilcoxon signed-rank tests (Bonferroni-adjusted $\alpha = .017$) indicated that hits were rated as more vivid than misses ($T = 28.00$, $p = .003$, $r = –0.64$), while no difference was found between conjunction errors and hits ($T = 34.00$, $p = .73$, $r = –0.11$) or misses ($T = 15$, $p = .06$, $r = –0.54$). There was also a significant difference in plausibility across the subsequent memory conditions ($\chi^2(2) = 6.17$, $p = .05$), whereby hits were more plausible than misses ($T = 20.00$, $p = .001$, $r = –0.71$). Conjunction errors did not differ in plausibility from hits ($T = 32.00$, $p = .62$, $r = –0.16$) or misses ($T = 17.50$, $p = .10$, $r = –0.49$).

Table 4. **Median ratings for phenomenological qualities during the encoding of events imagined in Session Two.**

	Subsequent memory condition			Degree of recombination		Type of component altered		
	Hit	Conjunction error	Miss	Partial	Full	Person	Place	Object
Vividness†	3.60	3.75	2.78	3.20	3.00	3.46	3.14	3.36
Plausibility†	2.66	3.00	2.08	2.41	1.83	2.29	2.00	2.77

Note. †Rating scale ranges from 1 (low) to 5 (high).

3.3.3 Imagination versus associative task

We first examined whether the imagination inflation effect observed in *Study 1* was replicated. Contrary to what we found in *Study 1,* the percentage of conjunction errors occurring in response to new lures did not significantly differ from the percentage of imagined conjunction errors ($t(19) = .47$, $p = .65$, $d = 0.10$; see Table 3). This unexpected pattern of results is likely attributable to the more stringent exclusion criteria for recombined events in the current study. While conjunction lures presented in Session Two that reminded participants of a real memory were excluded from analysis, it was not possible to do the same for new lures. Thus the percentage of new lures resulting in conjunction errors likely includes recombinations corresponding to real events unreported in Session One. As a result, the true rates of AM conjunction error acceptance for previously unseen lures may be more conservative than that reported. Indeed, when comparing the uncorrected rate of conjunction errors (those in the imagined condition without trials considered similar to real memories removed), there is a trend for more conjunction errors to occur in the imagined condition (M = 5.17%, SD = 5.41) than the new condition (M = 3.11%, SD = 5.16), $t(19) = 1.99$, $p = .06$, d = 0.44.

However, the main aim of the current study was to compare the influence of the imagination and associative tasks on conjunction lure acceptance rates to determine whether increasing fluency results in a similar inflation of conjunction lure acceptance as imagination. For the associative condition, 35% of participants made at least one conjunction error, whereas in the imagination condition, 60% of participants made at least one conjunction error. When examined as a percentage of total trials for each condition, significantly more AM conjunction errors were made in the imagination condition than the associative condition, $t(19) = 2.62$, $p = .02$, $d = 0.59$ (see Table 3 and Figure 6). A Wilcoxon signed-rank test demonstrated that participants were more confident in responses for imagined detail sets (*Mdn* = 4.03) compared to associative details sets (*Mdn* = 3.46), $T = 29.00$, $p = .003$, $r = –0.63$. This is consistent with the accuracy results: participants were more accurate in determining source for imagined detail sets ($M = 68.50\%$ correct, $SD = 19.73$) than associative detail sets ($M = 29.51\%$ correct, $SD = 14.5$; $t(19) = 9.33$, $p < .001$, $d = 2.09$), though no difference in response times were found.

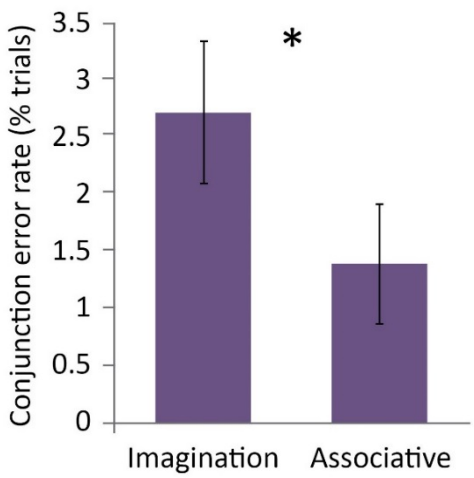

***Figure 6.* Autobiographical memory conjunction error rate for conjunction lures presented in the imagination and associative conditions.** The conjunction error rate is measured as the percentage of valid conjunction lures accepted as an authentic memory during the source test in Session Three. Error bars reflect standard error of the mean. * = $p < .05$.

3.3.4 Subjective ratings of event phenomenology

During the AI, subjective ratings of vividness, emotion and personal significance were collected for real memories, conjunction errors and correctly identified imagined events (see Table 5 and Figure 7). A Friedman’s ANOVA found that vividness ratings differed across these conditions, $\chi^2(2) = 12.40$, $p = .001$. Follow-up Wilcoxon signed-rank tests ($\alpha = .017$)

revealed that real memories were rated higher in vividness than imagined events, *T* = 5.00, $p < .001$, *r* = –0.78. Conjunction errors were rated intermediary in vividness, and did not differ significantly from either real (*T* = 7.00, *p* = .04, *r* = –0.60) or imagined events (*T* = 18.00, *p* = .20, *r* = –0.39). A similar pattern of results was observed for ratings of emotion ($\chi^2(2) = 13.74$, $p < .001$), with real events rated significantly more emotional than imagined events, *T* = 21.00, *p* = .001, *r* = –0.70. No significant differences were found at the Bonferroni-corrected threshold between emotion ratings for conjunction errors and real events (*T* = 10.50, *p* = .02, *r* = –0.65), or imagined events (*T* = 13.50, *p* = .17, *r* = –0.42). Personal significance ratings also differed across conditions ($\chi^2(2) = 16.44$, $p < .001$), with real events considered more significant than imagined events (*T* = 0.00, $p < .001$, *r* = –0.81) and conjunction errors (*T* = 0.00, *p* = .002, *r* = –0.81).

***Table 5.* Median ratings for subjective phenomenological qualities and mean objective Autobiographical Interview scores during the retrieval of events in Session Three.**

Phenomenological quality			Hit (real)	Conjunction error	Correctly identified imagination
Subjective	Vividness†		3.82	3.26	2.67
	Emotion†		2.67	2.11	1.58
	Personal significance†		2.50	1.13	1.29
Objective	Internal details		23.18 (10.48)	13.32 (5.47)	13.03 (5.40)
		Event	13.65 (6.84)	7.17 (2.82)	8.01 (4.43)
		Thought	2.84 (2.34)	0.7 (1.61)	0.45 (0.51)
		Place	2.47 (0.97)	2.5 (1.20)	2.25 (0.74)
		Time	1.46 (1.29)	0.56 (0.79)	0.74 (0.76)
		Perceptual	2.77 (1.59)	2.29 (2.48)	1.58 (1.35)
	External details		7.48 (4.90)	12.39 (12.43)	9.36 (7.32)

Note. Standard deviations are provided in parentheses. †Rating scale ranges from 1 (low) to 5 (high).

A significant main effect was also found for the perspective the event was viewed from, $F(2, 22) = 6.64$, $p = .006$, $\eta^2_p = 0.38$. Real events were more often viewed from a first-person perspective (proportion = .87, *SD* = 0.21) than imagined events (proportion = .62, *SD* = .32), $p = .04$. The rate of first-person perspective for real events and conjunction errors (proportion = .85, *SD* = .31) did not differ, $p = 1.00$. Similar to the difference between real and imagined events, there was also a trend towards conjunction errors being viewed from a first-person perspective more often than imagined events, $p = .08$.

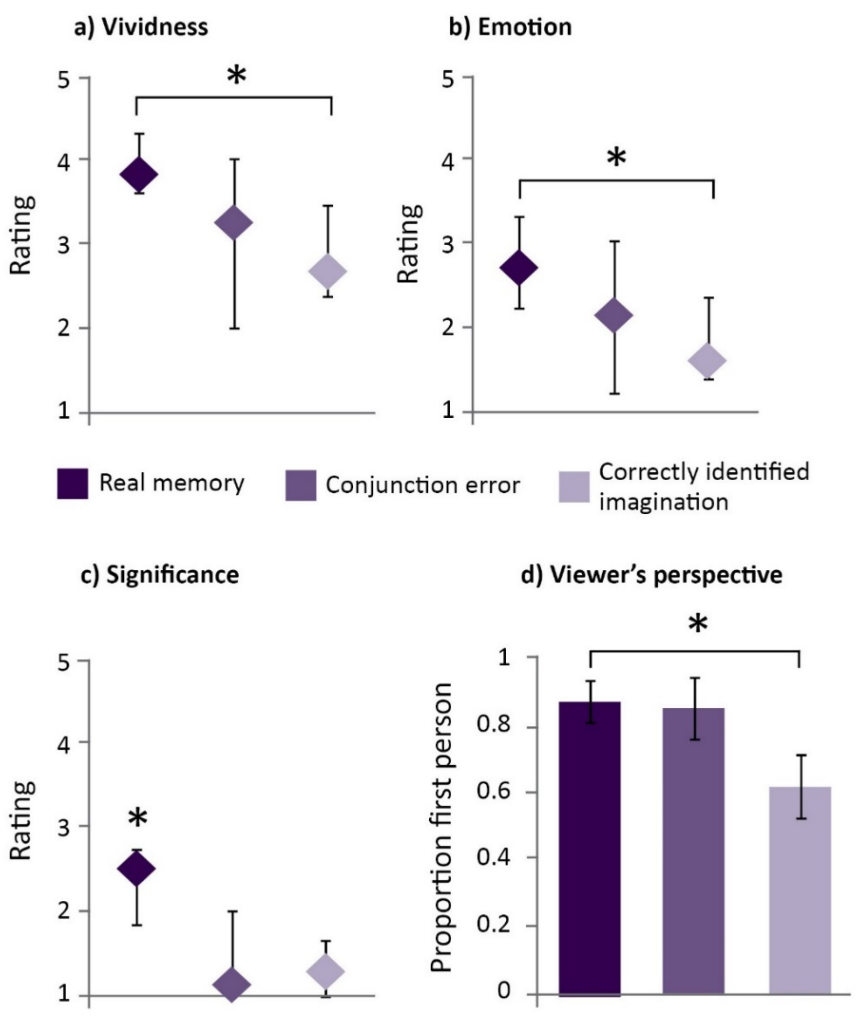

***Figure 7.* Subjective ratings of event phenomenology at retrieval.** (a) Median ratings of vividness, (b) emotion and (c) personal significance collected during retrieval of real memories, conjunction errors and correctly identified imagined events. Ratings are on a scale of 1-5 (1 = low, 5 = high). (d) Proportion of events recollected from a first-person perspective, as opposed to a third-person perspective. Error bars for (a)-(c) represent interquartile range, and for (d) represent standard error of the mean. AM = autobiographical memory, * = $p < .05$.

3.3.5 Objective scoring of event phenomenology

Average AI scores for each event type (real, conjunction error and correctly identified imagined) were analysed using a 3×2 repeated measures ANOVA, to explore differences in type of AI detail (internal, external). A significant main effect of event type was found (F(1.33, 13.32) = 4.76, p = .04, η^2_p = 0.32); pairwise comparisons revealed that real events were recalled with more detail on average than identified imagined events (p = .01; see Table 5), but no difference was found between conjunction error and real events, or between identified imagined events (p > .51 for both comparisons). There was also a significant main effect of AI detail type (F(1, 10) = 5.51, p = .04, η^2_p = 0.35), with more internal than external detail generated overall. Importantly, a significant interaction was found between event type and detail, F(2, 20) = 8.57, p = .004, η^2_p = 0.46. Pairwise comparisons revealed that real events had more internal detail than both imagined (p = .002) and conjunction errors (p = .03). No differences were found across the event types for external detail.

We further broke down internal details into subcategories (event, perceptual, place, thought, time) to explore whether one particular type of detail was driving this effect. A 3×5 ANOVA revealed a significant interaction between event type and internal detail subcategory, F(2.33, 23.31) = 8.25, p = .001, η^2_p = 0.45 (see Figure 8). Pairwise comparisons revealed that real events had more event and thought details than both imagined events (p = .01 for both) and conjunction errors (p = .02, p = .01 respectively). Interestingly, conjunction errors had a similar amount of perceptual detail as real events (p = 1.00), while events correctly identified as imagined had less perceptual content than real events (p = .04). No differences were found for place or time details.

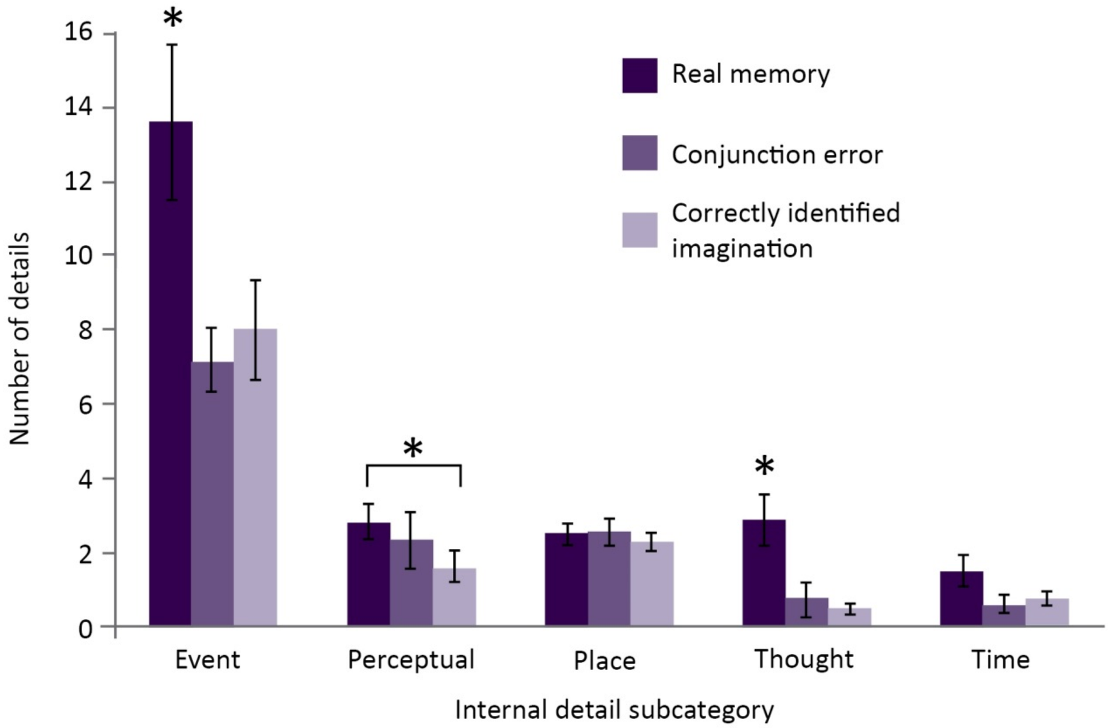

Figure 8. **Objective scoring of event phenomenology**. Average number of internal details generated by participants in the adapted Autobiographical Interview for real memories, conjunction errors and correctly identified imagined events, broken down by subcategory. Error bars reflect standard error of the mean. * = $p < .05$.

3.3.6 Degree of recombination and type of component altered

Replicating the results of *Study 1*, detail sets which were partially recombined were accepted as real more often than fully recombined sets, $t(19) = 4.68$, $p < .001$, $d = 1.05$ (see Table 3 for percentages). A Wilcoxon signed-rank test revealed no difference in confidence ratings between partially (*Mdn* = 3.62) and fully recombined sets (*Mdn* = 3.69), $T = 57$, $p = .08$, $r = –0.40$. Degree of recombination influenced the vividness and plausibility of the imagined events during Session Two, where imagined partial recombinations were rated as more vivid ($T = 44.00$, $p = .02$, $r = –0.51$) and more plausible ($T = 8.00$, $p < .001$, $r = –0.75$) than full recombinations (see Table 4). A 2×2 ANOVA with recombination (partial, full) and exposure condition (imagined, associative) showed that, even with invalid trials removed (i.e., those rated 4 or 5 in similarity to previous events), partial recombinations were still rated as more similar to previous events ($M = 2.02$) than fully recombined sets ($M = 1.42$), $F(1, 19) = 44.68$,

$p < .001$, $\eta^2_p = .70$. No main effect of exposure condition, or interaction between condition and recombination was found (*F* values < 1.14, *p* values > .30).

We tested whether the type of component altered (person, place, object) influenced conjunction lure acceptance event after counterbalancing the order of component presentation. When examined as a percentage of conjunction lures accepted of the total lure trials, no significant differences were found across component types, $F(2, 38) = 1.11$, $p = .34$, η^2_p = 0.06. A Friedman's ANOVA was run to explore differences in vividness and plausibility ratings for imagined events according to the type of component altered (see Table 4). While there was no significant difference in vividness ($\chi^2(2) = 2.84$, $p = .26$), a significant main effect for plausibility was found ($\chi^2(2) = 9.95$, $p = .005$). Specifically, place-altered sets were rated as less plausible than both object- ($T = 13.50$, $p = .001$, $r = –0.67$) and person-altered sets ($T = 41.50$, $p = .016$, $r = –0.53$). Moreover, the similarity of conjunction lures to previous events differed depending on the type of component altered ($F(2, 38) = 7.30$, $p = .002$, η^2_p = .28), with place-altered sets ($M = 1.84$) rated as less similar to previous events than object-altered sets ($M = 2.14$, $p = .001$), and trending towards lower similarity than person-altered sets ($M = 2.01$, $p = .06$).

3.4 Discussion

An average of 2.25 conjunction lures per participant were falsely accepted as belonging to a real event in the current study. The main purpose of this study was to delineate the role of phenomenological quality and processing fluency on the imagination inflation effect, by comparing false acceptance rates between an imagination and an associative task. In line with our hypotheses, conjunction lures for which an event had been imagined were accepted as real more often than conjunction lures for which an association had been made between components but no explicit event imagined, despite higher overall accuracy in source decisions in the imagination condition. These results suggest something other than increased fluency inflates AM conjunction error rates for imagined events. A likely candidate, consistent with the source monitoring account of false memories, is increased phenomenological quality afforded by the imagination task (Johnson et al., 1993).

The subjective ratings collected in Session Three support the perspective that AM conjunction errors occur as a result of misattribution of memory-like qualities, as conjunction errors were rated as intermediary between correctly identified imagined and real events for vividness and emotionality, and were more often viewed from a first-person perspective, similar to real memories. For personal significance, however, real events were rated significantly higher than both correct identifications of imagined events and conjunction errors. In order to determine the significance of an event in one's life, associated memories are likely to be retrieved for evidence of any lasting consequences of the target event. Because both AM conjunction error and identified imagined events did not truly take place, they will have fewer associations with existing memories (Johnson et al., 1988), and therefore less available evidence to suggest these events have had a significant impact on one's life (Heaps & Nash, 2001).

We were also interested in whether objective AI results conferred with the subjective ratings; however the AI results were mixed. Descriptions of real events contained more internal details overall than both imagined and conjunction error events, and this effect appeared to be mainly driven by differences in event and thought details. Phenomenological distinctions have previously been found between true and false memories, which were largely accounted for by differences in rehearsal frequency (Heaps & Nash, 2001). Indeed, repeated imagination has been shown to increase the recollective qualities of false memories (Hyman et al., 1998). The short imagination time in the current study may have limited the phenomenological similarities between authentic and conjunction error events. Place and time details did not differ across the memory conditions. This is unsurprising, as regardless of recombination, all detail sets included a place in which to locate the event, and the combination of person and place components typically allowed distinction of a period in which the event could have occurred.

Interestingly, however, the pattern of perceptual detail mirrored the subjective vividness ratings, with descriptions of real events containing more perceptual detail than imagined, and conjunction events intermediary, indicating that perceptual detail may play a particularly important role in source misattribution. While previous studies have demonstrated the importance of sensory detail for false memory formation (Gonsalves et al., 2004; Johnson et al., 1993; Thomas et al., 2003; von Glahn et al., 2012), the relationship between perceptual detail and false memory construction is not clear cut, as some studies report no relationship between quality ratings of an imagined event and false memory formation (Garry, Frame, & Loftus, 1999), between general mental imagery ability and susceptibility to false memories (Heaps & Nash, 1999), or between the vividness of a specific event and later false belief in that event (Ost, Vrij, Costall, & Bull, 2002; Porter et al., 1999). Future research may focus on delineating the conditions under which increasing perceptual detail contributes to the construction of false memories.

Although the associative task was designed to facilitate component association without generation of a mental image, we cannot rule out the possibility that spontaneous construction of an event and corresponding mental image may have occurred during the associative task, leading to the moderate increase in conjunction lure acceptance due to an enhancement in phenomenological quality (Thomas et al., 2003). Unfortunately, the numbers of conjunction errors were too low when split into imagined and associative conditions to statistically test whether conjunction errors differed in phenomenological characteristics at retrieval between these conditions. It is also important to note that the fluency and phenomenological quality explanations of false memory formation are not necessarily mutually exclusive. In addition to enhancing recollective detail, imagination likely facilitates the binding of disparate memory components, increasing the fluency of later retrieval, and both the detail and fluency of memories can be misattributed as indicators of event authenticity (for example, Garry & Wade, 2005)

Some notable differences between the current findings and those of *Study 1* are worth considering. While the overall acceptance of conjunction lures is lower than that observed in *Study 1*, this is likely due to lower acceptance of conjunction lures in the associative condition. Consistent with this hypothesis, the percentage of accepted *imagined* events is comparable between the two studies (4% vs. 3%), as well as the percentage of conjunction errors maintained in the subsequent recall test (43% for both). It is possible that the inclusion of the size judgement and odd/even task in *Study 1*, which were not relevant to the current analyses, may also account for the greater AM conjunction error rate observed in *Study 1,* by increasing task difficulty and thus error rate (Jones & Jacoby, 2001, 2005; Reinitz et al., 1994). Moreover, unlike *Study 1,* a negative correlation was found between overall accuracy in the source test and conjunction error rate, suggesting that declines in memory ability may enhance susceptibility to conjunction error generation.

While imagined lures were not accepted more often than new lures, as was observed in *Study 1*, the current pattern of results is likely due to the more stringent exclusion criteria used: any events rated 4 or 5 on a scale of similarity to previous events were excluded, potentially excluding lures that were similar – but not identical – to previous events, thus likely reducing the conjunction error rate in the imagination condition. Moreover, because it was not possible to obtain these ratings for the new conjunction lures, some of the conjunction errors made in response to new lures may in fact have corresponded to previously experienced events. Therefore, the true conjunction error rate of new lures is likely to be somewhat more conservative than that reported. Indeed, when comparing the uncorrected rate of conjunction errors for imagined detail sets to new sets, the imagination inflation effect approached significance. Imagined events resulting in conjunction errors were rated as more vivid and plausible in Session Two than those subsequently identified as imagined or considered new, similar to *Study 1*. However, surprisingly these differences did not reach significance, potentially due to a lack of power owing to fewer imagined trials (in which vividness and plausibility ratings were obtained) relative to *Study 1* due to the inclusion of the associative condition and more stringent exclusion criteria.

The effect of recombination degree in *Study 1* was replicated, with partial recombinations accepted as real more often, and rated as more vivid and plausible, than full recombinations. We further theorised in *Study 1* that due to the peripheral nature of object components within an episode, this component type would be more interchangeable between events (Dijkstra & Misirlisoy, 2009). While in the current study object- as well as place-altered sets were accepted more than person-altered sets, with the counter-balanced component presentation this difference did not reach significance, suggesting that one type of event component is not inherently more interchangeable within episodes than another. It is likely that different features are particularly salient depending on the nature of the memory; for example, when remembering lunch with a friend, the person or place may be the most salient detail, but when recalling a shopping trip, the object purchased could be considered the most important feature of the event. In line with this view, no difference in vividness was found according to the type of component altered. Place-altered sets were rated as less plausible and less similar to previous events than both object- and person-altered sets. Many of the locations spanned continents as well as time periods (e.g., high school versus university), and so randomly switching this component could have resulted in a conjunction event taking place on the other side of the world, or at a completely different period in one's life than it had originally, resulting in more implausible recombinations than when altering either the person or object.

According to the source monitoring account of false memories, one possible mechanism underlying the imagination inflation effect is that imagination enhances the phenomenological richness of a simulated event and its similarity to authentic memories, thus increasing the likelihood of source confusion taking place. A number of our findings are consistent with this idea. Though not reaching significance, generating a more vivid and plausible simulation during the imagination session increased the likelihood of a later conjunction error during the memory testing session. At retrieval, conjunction error events were rated as intermediate between real and identified imagined events in terms of subjective vividness, emotionality and use of a first-person perspective. Moreover, the objective scoring of memory content indicated that it is not just an overall increase in episodic detail, but specifically perceptual detail, that may be most important for the occurrence of AM conjunction error events. While *Studies 1* and *2* demonstrate that factors pertaining to conjunction lures (such as phenomenological quality, processing fluency and the nature of recombination) influence on AM conjunction error formation, the effect of individual differences in memory and source monitoring ability on susceptibility to this type of memory distortion have yet to be explored.

Chapter 4

Healthy aging is associated with reductions in general cognitive abilities (Dennis & Cabeza, 2008), but perhaps the most prominent declines are those observed in episodic memory, both in terms of reduced memory accessibility (Balota, Dolan, & Duchek, 2000; Hoyer & Verhaeghen, 2006; Park et al., 2002), and an enhanced susceptibility to false memory formation (e.g., Jacoby & Rhodes, 2006; Mitchell & Johnson, 2009; Pierce, Simons, & Schacter, 2003). Structural and functional dysfunction in brain areas involved in memory encoding, retrieval, and monitoring – in particular, the MTL and PFC – may contribute to these memory changes (Kroll et al., 1996; McCabe et al., 2009; Parkin, Bindschaedler, Harsent, & Metzler, 1996). Age-related increases in vulnerability to memory distortions occur for gist-based errors (Kensinger & Schacter, 1999), misinformation (Cohen & Faulkner, 1989; Wylie et al., 2014), imagination inflation (McDaniel, Lyle, Butler, & Dornburg, 2008; Thomas & Bulevich, 2006) and memory conjunction errors for simple laboratory stimuli (Castel & Craik, 2003; Jones & Jacoby, 2005; Kroll et al., 1996). Older adults are an informative population in which to study errors in memory, as the typical cognitive changes accompanying aging provide a window into the mechanisms underlying the formation of these memory distortions. As such, in *Studies 3* and *4* we explore the factors contributing to the generation of AM conjunction errors in a group of older adults.

Study 3 – Age-related changes to autobiographical memory conjunction error susceptibility

4.1 Introduction

Previous work has demonstrated an age-related increase in the rates of memory conjunction errors for words (Castel & Craik, 2003; Jones & Jacoby, 2005; Rubin et al., 1999) and faces (Kroll et al., 1996). However, it is not clear whether these findings for laboratory stimuli translate to the autobiographical domain, given that age differences in source monitoring are diminished when the stimuli to be memorised are distinctive (Dodson & Schacter, 2002; Ferguson, Hashtroudi, & Johnson, 1992; Johnson, De Leonardis, Hashtroudi, & Ferguson, 1995). Indeed, older adults perform better on memory tests employing a naturalistic setting than those using laboratory stimuli (Rendell & Craik, 2000), perhaps because in everyday life older adults do not frequently need to remember pallid laboratory materials without aid (Hashtroudi, Johnson, & Chrosniak, 1990). Moreover, older adults selectively remember information they consider relevant as a means of strategically recruiting limited memory resources (Castel, Murayama, Friedman, McGillivray, & Link, 2013; Castel, 2007). Considering that AMs tend to be more distinctive and personally-relevant than simple laboratory stimuli (McDonough & Gallo, 2008; though see St-Laurent, Abdi, Burianová, & Grady, 2011), studies utilising laboratory stimuli may not accurately reflect age changes in susceptibility to AM conjunction errors (Koutstaal, 2003). Although an increased rate of conjunction errors has been observed in older adults for more complex scenes (actors performing basic actions; Kersten, Earles, Curtayne, & Lane, 2008; Kersten, Earles, & Upshaw, 2013; Kersten & Earles, 2010), such scenarios are still devoid of the emotional and personal significance that accompanies autobiographical events. Thus the current study employs the AM conjunction error paradigm from *Study 2* to determine whether aging is associated with an increased rate of AM conjunction errors, and whether similar factors influence these errors rates in both young and older adults.

Despite the distinctive nature of autobiographical stimuli, several lines of evidence suggest that age may nevertheless be associated with a heightened vulnerability towards AM conjunction errors. Older adults exhibit a reduced reliance on recollection and a corresponding increased reliance on familiarity relative to younger adults (Anderson et al., 2008; Craik & McDowd, 1987; Davidson & Glisky, 2002; Dennis, Bowman, & Peterson, 2014; Giovanello, Kensinger, Wong, & Schacter, 2010; Prull, Dawes, Martin III, Rosenberg, & Light, 2006), which may contribute to an increased rate of AM conjunction error formation (Jacoby, 1999; Jones & Jacoby, 2005). This shift may reflect the fact that neural regions mediating familiarity (e.g., parahippocampal and perirhinal cortices) tend to be largely intact in older adults (Daselaar et al., 2006; Dennis, Kim, et al., 2008; Yonelinas et al., 2007), while regions involved in recollection (e.g., the hippocampus) become increasingly dysfunctional with age (Daselaar et al., 2006; Driscoll et al., 2003; Grady et al., 1995; Prull, Gabrieli, & Bunge, 2000). In particular, hippocampal dysfunction results in deficits in the formation and retrieval of relations between memory components (Hannula et al., 2006; Mitchell et al., 2000; Pertzov et al., 2013), an ability that underpins recollection; thus reductions in feature binding may be an important reason for the decreased utilisation of recollective processes in older adults (Chalfonte & Johnson, 1996; Henkel et al., 1998; Kessels, Hobbel, & Postma, 2007; Lyle et al., 2006). Indeed, older adults find retrieval of associative information more difficult than retrieval of individual memory features (cf. associative deficit hypothesis*;* Naveh-Benjamin, 2000; Old & Naveh-Benjamin, 2008; see also Becker et al., 2015; Dennis, Hayes, et al., 2008; Spencer & Raz, 1995).

Utilising a sense of familiarity when making source discriminations tends to be less cognitively demanding than the recruitment of recollective processes, but it is also less accurate (Craik & Byrd, 1982), thus increasing susceptibility to memory distortions in older age. For instance, repeated presentation of original stimuli leads to an increased false alarm rate for conjunction lures in older but not younger adults (Jones & Jacoby, 2005). According to the dual-processing approach (Jacoby, 1991), such repetition facilitates recollection of the original stimuli in younger adults, allowing for rejection of the recombined lures. However, for older adults the inability to use recall-to-reject processes, coupled with enhanced familiarity for the component parts of the stimuli, results in a greater likelihood of conjunction error formation. In support of this view, younger adults making source decisions for conjunction stimuli under time pressure (thereby increasing reliance on familiarity) respond in a similar manner to older adults (Jones & Jacoby, 2005). Reliance on familiarity may be compounded by declines in PFC-mediated source monitoring processes (Craik, Morris, Morris, & Loewen, 1990; Glisky, Polster, & Routhieaux, 1995), contributing to the employment a lax monitoring criteria (McDonough & Gallo, 2013; Parkin & Walter, 1992), and an inability to inhibit the sense of familiarity associated with the individual memory components of a conjunction lure (see Jones & Jacoby, 2001).

However, recollective declines cannot be the sole culprit in older adults' heightened vulnerability to conjunction errors, as age-related increases in these errors persist even when memory hit rates are equated across younger and older adults (Kersten et al., 2008, see also Jones & Jacoby, 2005). Another possible consequence of MTL dysfunction is the erroneous binding of features across memory representations (Dodson, Bawa, & Krueger, 2007; Kroll et al., 1996) as a result of spreading activation at encoding or retrieval (Lampinen, Meier, Arnal, & Leding, 2005; Lyle & Johnson, 2006, 2007; see also Gallo & Roediger, 2003). However, the PFC may counteract such over-binding: inhibitory control processes can suppress the signals derived from the spreading activation of related memory traces, providing protection from erroneous detail importation (Shimamura, 1995). Yet reductions in inhibition following PFC changes (see Gazzaley, Cooney, Rissman, & D'Esposito, 2005; Hasher, Zacks, & May, 1999) may mean suppression of irrelevant memory associations is less effective (Biss, Campbell, & Hasher, 2013; Campbell, Hasher, & Thomas, 2010; Campbell, Trelle, & Hasher, 2014), therefore magnifying the tendency to over-bind activated elements pertaining to separate memory traces (Fandakova et al., 2013; Henkel et al., 1998; Lyle et al., 2006; Lyle & Johnson, 2006). Such disinhibition in feature binding can give rise to memory conjunction errors that are experienced with a sense of recollection and a high degree of confidence (Burt et al., 2004; Dijkstra & Misirlisoy, 2009; Dodson et al., 2007; Kroll et al., 1996; Odegard & Lampinen, 2004; Reinitz et al., 1992, 1994; Reinitz, 2001).

Older adults may be particularly susceptible to lures for which a conjunction event is imagined. Age-associated recollective reductions mean that the enhanced phenomenological quality typically used to tag a memory as veridical may no longer available or reliable (Johnson & Raye, 1981), thus authentic memories and imagined events are less distinguishable (Duarte, Graham, & Henson, 2010; Gallo, Korthauer, McDonough, Teshale, & Johnson, 2011; Karpel, Hower, & Toglia, 2001). As such, a more prominent imagination inflation effect is observed with age (Cohen & Faulkner, 1989; Lindner & Davidson, 2014; McDaniel et al., 2008; Thomas & Bulevich, 2006; though see Pezdek & Eddy, 2001, for evidence against this claim). In support of a phenomenological dedifferentiation between true and false memories, the neural signatures associated with veridical and false recognition become less distinguishable as we age (Duarte et al., 2010; Gutchess, Ieuji, & Federmeier, 2007; see also Dennis et al., 2014). Furthermore, affective information takes a more prominent role during encoding and retrieval with age (Hashtroudi et al., 1990; Johnson, 2006) due to changes in memory and communicative goals (Adams, Smith, Nyquist, & Perlmutter, 1997; Carstensen, Isaacowitz, & Charles, 1999; Gaesser et al., 2011; James, Burke, Austin, & Hulme, 1998; Madore & Schacter, 2014). Focusing on affective characteristics may divert attention away from more source-informative perceptual qualities of an event (Hashtroudi et al., 1990; Johnson & Multhaup, 1992), contributing to a lowered discrimination between authentic and imagined memories (Hashtroudi, Johnson, Vnek, & Ferguson, 1994; Rahhal, May, & Hasher, 2002; Suengas & Johnson, 1988; but see McGinnis & Roberts, 1996).

On the basis of previous literature exploring memory distortions with age, we expected older adults to be more susceptible than younger adults to AM conjunction lures overall, due to an overreliance on familiarity-based recognition, in association with disinhibition of feature binding. In particular, we predicted a heightened vulnerability to AM conjunction errors in the imagination condition for older adults, given that age-related reduction in recollection contributes to a dedifferentiation between internally- and externally-derived experiences.

4.2 Method

4.2.1 Participants

We recruited 30 younger adults and 28 older adults, in compliance with the principles of The University of Auckland Human Participants Ethics Committee. Data from two younger adults were excluded (both female), one due to task noncompliance in Session Three, and the other due to abnormalities found in a follow-up MRI scan[7]. Data from two older adults were also excluded (both female), one due to a history of transient ischemic attack, and the other due to a conjunction error rate more than three standard deviations above the mean, indicating a misunderstanding of Session Three instructions[8].

Therefore data from 28 younger adults (*M* age = 21.29 years, *SD* = 3.54, 5 male) and 26 older adults (*M* age = 71.85 years, *SD* = 4.61, 9 male) were included in this study. All were fluent English speakers with no history of learning disabilities, neurological or psychiatric impairments, and had normal or corrected to normal vision. All older adults scored 88 or above on the Addenbrooke's Cognitive Examination-Third Edition (ACE-III), indicating no early signs of dementia (*M* = 94.42, *SD* = 3.35). Overall, the younger and older adult groups did not differ in level of education (*younger M* = 14.95 years, *SD* = 1.90; *older M* = 15.80 years, *SD* = 3.35), $t(36.99) = 1.12$, $p = .27$. Participants were compensated with $75 in supermarket vouchers for their time.

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[7] This MRI scan was part of an on-going follow-up study. Because data collection is still in progress, these data are not reported here.

[8] This participant also showed signs of not engaging with the tasks. Removing them from the analyses did not change the pattern of results.

Power analyses were conducted using G*Power (Faul et al., 2007) on the basis of published data demonstrating age group differences in conjunctions errors for actors and actions (Old & Naveh-Benjamin, 2008), as well as an age by detail type interaction using the AI (Levine et al., 2002). These analyses indicated a minimum of 13 participants per group were needed to achieve 80% power at $\alpha = .05$. Of our two groups, our minimum sample size of 26 was well above this requirement.

4.2.2 Procedure

The current study followed a similar protocol as *Study 2*, with notable differences described as follows to accommodate for older adults' reduced amenability to testing. A reduced number of trials was used in all sessions (see Figure 9). Although older adults produced slightly fewer memories in Session One ($M = 40.81$, $SD = 3.10$) than younger adults ($M = 44.93$, $SD = 2.14$), both groups generated sufficient stimuli for the paradigm (see Figure 9). Importantly, the groups did not differ in terms of the recency of the memories retrieved (*younger adults* $M = 2.84$ years, $SD = 0.99$, *older adults* $M = 2.99$ years, $SD = 1.31$), $t(52) = 0.47$, $p = .64$.

Session Two took place approximately one week after Session One ($M = 10$ days, $SD = 4$). In Session Two, the time to imagine novel past events (imagination condition) or rank the three components based on pleasantness (associative condition) was increased from 20 to 30 seconds. Instead of inferring from the similarity rating whether a recombination referred to a true memory (as done in *Study 2*), the explicit question similar to that used in *Study 1* was reinstated (i.e., "has an event involving these three details together actually occurred before? Yes or no"). An average of 3.41 detail sets ($M = 5.89\%$, $SD = 4.96$) per participant were excluded from analysis due to being given a "yes" response. Exclusion of detail recombinations did not differ across the imagination and associative conditions ($F(1, 52) = 0.17$, $p = .68$), nor across younger and older adults ($F(1, 52) = 2.05$, $p = .16$).

The final session was completed approximately one week after Session Two (*M* = 9 days, *SD* = 4). The source test was identical to that used in *Study 2*. The only difference in from *Study 2* in the administration of the adapted AI was that participants were provided with three minutes (instead of two) to describe each event. For the AI, an average of 12 detail sets were randomly selected based on responses in the source test: 5 correctly identified real sets, 5 correctly identified imagined sets, and any AM conjunction errors (*M* = 2.41, range = 0-7). Four raters blind to event condition and age group scored the AI transcripts. To establish inter-rater reliability, all raters scored a set of 20 recalled past and imagined future events obtained from a previous study (Addis et al., 2008). These scores were subjected to an intraclass correlation analysis, revealing that reliability across raters was acceptable (two-way mixed model; standardised Cronbach's α: internal detail score .94; external detail score .86).

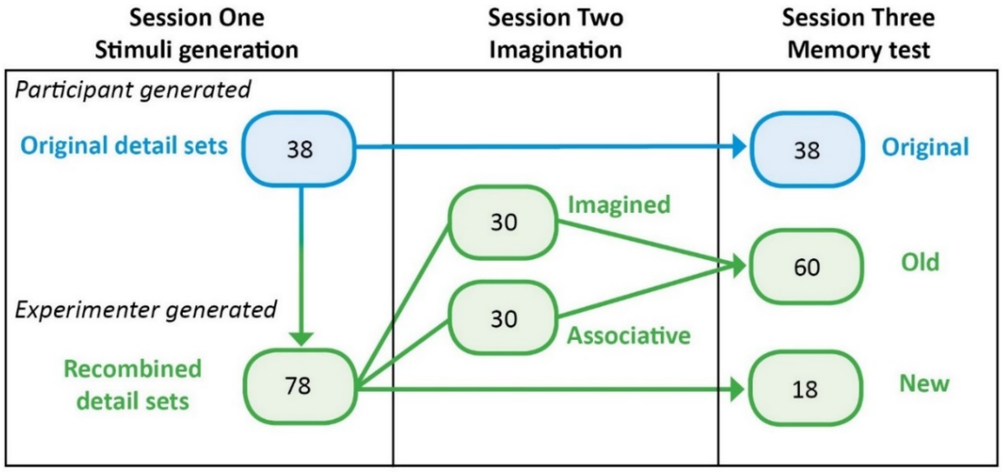

***Figure 9.* Minimum number of detail sets collected from participants in Session One, and number of detail sets presented during Sessions Two and Three of *Study 3*.** Original unaltered detail sets presented in blue, recombined detail sets in green. [9]

[9] Note that in Session One, one older adult managed to retrieve only 29 valid memories; for this participant the number of recombinations presented in Sessions Two and Three were reduced (48 and 89 respectively). Removing this participant from the dataset did not alter the overall results, thus they were included in the following analyses.

4.3 Results

4.3.1 Data analysis

As with *Studies 1* and *2*, AM conjunction errors were calculated as a percentage of valid trials considered to belong to a real memory in Session Three, and were analysed using parametric tests. Valid trials were those given a "no" response to the question "has an event involving all three details occurred to you before?" in Session Two. For data comparing AM conjunction error rates, a log transform was used to normalise the data; all statistical tests reported were computed using the transformed data, while means and standard deviations presented in tables and figures are based on the untransformed data. Subjective ratings were analysed using appropriate non-parametric tests, and pairwise comparisons (t-tests and Wilcoxon signed-rank tests) were considered significant if they exceeded the stated Bonferroni threshold (corrected for multiple comparisons).

4.3.2 Overall acceptance of conjunction lures

Overall, 72.22% of participants made at least one AM conjunction error. Participants made, on average, 2.50 (*SD* = 2.91) conjunction errors, equating to 3.49% of the conjunction lures presented in Session Three (*SD* = 4.12). This rate differed across the age groups, with older adults making over twice as many conjunction errors on average than younger adults, $t(52) = 2.90$, $p = .005$, $d = 0.79$ (see Table 6 for percentages). While a greater number of older than younger adults made conjunction errors (76.92% of older, 67.86% of younger), a significant age difference in conjunction error rate still existed when examining only those individuals who made conjunction errors, $t(37) = 3.44$, $p = .001$, $d = 1.10$. A Mann-Whitney U test found no difference in confidence for AM conjunction errors between younger (*Mdn* = 3.75) and older adults (*Mdn* = 3.57), $U = 189.00$, $p = .98$, $r = 0.00$.

***Table 6.* Mean percentage of trials resulting in autobiographical memory conjunction errors, by age group and exposure condition.**

Exposure Condition	Younger adults	Older adults	Total
Imagination	2.66 (4.19)	6.26 (6.03)	4.39 (5.43)
Associative	1.39 (2.20)	4.92 (6.37)	3.09 (4.98)
New	1.43 (2.94)	4.07 (6.23)	2.70 (4.95)
Total	1.89 (2.12)	5.22 (5.01)	3.49 (4.12)

Note. Standard deviations are provided in parentheses.

Of the conjunction errors made in the source test, overall 32.37% (*SD* = 33.19) were still considered to belong to an authentic event during the AI. Younger adults maintained a greater percentage of conjunction errors during this recall phase (*M* = 40.79%, *SD* = 42.39) than older adults (*M* = 24.36%, *SD* = 19.03), although this difference was not significant, $t(24.70) = 1.55$, $p = .13$, $d = 0.42$. There was a trend toward older adults being unable to retrieve a memory for a greater percentage of the conjunction errors presented in the AI (*M* = 32.45%, *SD* = 32.80) compared with younger adults (*M* = 13.16%, *SD* = 28.64), $t(37) = 1.95$, $p = .06$. Younger adults were more accurate in their source decisions overall (*M* = 68.13%, *SD* = 8.82) than older adults (*M* = 54.91%, *SD* = 9.10), $t(52) = 5.42$, $p < .001$, $d = 1.48$. Moreover, a negative correlation between overall accuracy in the source task and total conjunction errors was found for younger adults ($r = -.39$, $p = .04$), yet no relationship was observed in older adults ($r = .01$, $p = .98$).

4.3.3 Imagination inflation

The influence of prior exposure to lures on conjunction error rate was explored using a 2×3 mixed ANOVA, with age group as the between-subjects variable (younger, older), and exposure condition as the within-subjects variable (imagination, association, new). Because recombinations in the new condition could not be screened prior to the source test for those corresponding to unreported authentic events (by virtue of these combinations being previously unseen), comparing the uncorrected conjunction error rate in the new condition to valid trials only in the imagination and associative conditions artificially inflates errors made to new lures. Therefore for this comparison, as in *Study 2*, the uncorrected rates of all conditions (without removal of invalid trials) was used. A main effect of condition was found ($F(2, 104) = 13.88$, $p < .001$, $\eta^2_p = .21$); pairwise comparisons revealed that more conjunction errors were made on average in the imagination (uncorrected $M = 6.92\%$, $SD = 7.42$) and associative (uncorrected $M = 4.86\%$, $SD = 6.52$) conditions compared to new lures ($M = 2.70\%$, $SD = 4.95$, $p < .001$ and = .004 respectively), consistent with a familiarity effect. A main effect of age was also found ($F(1, 52) = 13.39$, $p = .001$, $\eta^2_p = .21$), with older adults making more conjunction errors overall than younger adults. No significant interaction was observed, $F(1, 104) = .39$, $p = .68$, $\eta^2_p = .01$.

The influence of aging on the use of processing fluency and perceptual quality in source decision making was examined with a 2×2 mixed ANOVA, using age group and Session Two exposure condition (imagination, association, see Table 6 and Figure 10). The main effect of condition was trending towards significance, $F(1, 52) = 3.09$, $p = .09$, $\eta^2_p = .06$, with more errors made in the imagination compared to the associative condition, consistent with an imagination inflation effect. Again a main effect of age was found, with older adults making more conjunction errors on average than younger adults, $F(1, 52) = 9.30$, $p = .004$, $\eta^2_p = .15$. No significant interaction between age and exposure condition was found $F(1, 52) = 0.70$, $p = .41$, $\eta^2_p = .01$.

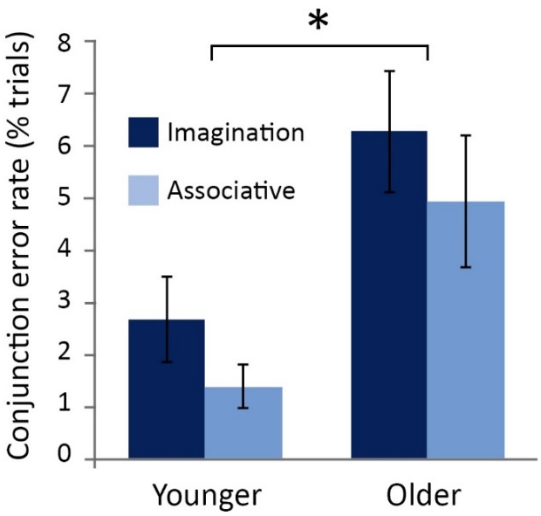

Figure 10. **Autobiographical memory conjunction error rate for younger and older adults, for conjunction lures presented in the imagination and associative conditions.** Conjunction error rate is measured as the percentage of valid conjunction lures accepted as an authentic memory during the source test in Session Three. Error bars reflect standard error of the mean. * = $p < .05$.

4.3.4 Phenomenological characteristics of conjunction errors

4.3.4.1 Subjective ratings of simulation quality during imagination

Age differences in vividness or plausibility ratings at the time of imagining were tested with Mann-Whitney U tests (see Table 7 for medians). Older adults subjectively rated their imagined conjunction events as more vivid than did younger adults, $U = 244.50$, $p = .04$, $r = –0.62$, although no group difference in plausibility ratings was found, $U = 283.50$, $p = .17$, $r = –0.19$.

We next examined how the Session Two ratings (at the time of imagining) differed according to whether the imagined events subsequently resulted in hits, misses and conjunction errors, and whether these patterns differed with age (see Table 7). A Friedman's ANOVA was run separately for each age group. No significant effect of vividness ratings across these subsequent memory conditions was found for either age group, $\chi^2(2) < 3.49$, $p > .18$. For plausibility, younger adults did exhibit an effect of subsequent memory condition,

$\chi^2(2) = 7.09$, $p = .03$. Follow-up Wilcoxon signed-rank tests (Bonferroni-adjusted $\alpha = .017$) indicated that hits were rated as more plausible than misses ($T = 53.00$, $p = .002$, $r = –0.61$), while no difference was found between conjunction errors and hits ($T = 28.00$, $p = .66$, $r = –0.13$) or misses ($T = 17.00$, $p = .16$, $r = –0.43$). No change of plausibility ratings was seen across the memory conditions for older adults, $\chi^2(2) = 2.09$, $p = .36$.

***Table 7.* Median ratings for phenomenological qualities during the encoding of events imagined in Session Two.**

	Vividness		Plausibility	
	Younger adults	Older adults	Younger adults	Older adults
Subsequent memory				
Hit	3.33	3.57	2.33	2.90
Conjunction error	3.33	3.5	2.67	3.84
Miss	3.2	3.55	2.00	3.21
Total	3.27	3.64	2.36	2.58

Note: Rating scale ranges from 1 (low) to 5 (high).

4.3.4.2 Subjective ratings of memory quality during retrieval

Overall age differences in vividness, emotion, and personal significance ratings made during the AI were tested with Mann-Whitney U tests (Bonferroni corrected $\alpha = .017$). Compared to younger adults, older adults subjectively rated their retrieved memories as more emotional (*younger Mdn* = 2.35, *older Mdn* = 2.85, $U = 226.00$, $p = .02$, $r = –0.33$) and personally significant (*younger Mdn* = 2.03, *older Mdn* = 2.85, $U = 137.00$, $p < .001$, $r = –0.53$). No differences in vividness ratings were found (*younger Mdn* = 3.35, *older Mdn* = 3.50), $U = 314.00$, $p = .39$, $r = –0.12$.

Differences in these ratings (vividness, emotion, and personal significance) across real memories, conjunction errors and correctly identified imagined events were tested using a series of Friedman's ANOVAs for each rating, with follow-up Wilcoxon signed-rank tests for significant effects (Bonferroni-adjusted α = .017). These follow-up tests were run separately for each age group, but because the overall pattern of significance did not differ between younger and older adults, collapsed results across age groups are reported here for brevity (see Table 8 for medians). Vividness ratings differed across the subsequent memory conditions, ($\chi^2(2) > 15.46$, $p < .001$), with real events rated higher in vividness than identified imagined events ($T < 2.00$, $p < .001$, $r > –0.87$) and conjunction errors ($T < 25.00$, $p < .015$, $r > –0.57$); however conjunction errors and imagined events did not differ ($T > 39.00$, $p > .13$, $r < –0.35$). Emotion ratings also differed across the subsequent memory conditions, ($\chi^2(2) > 14.60$, $p < .001$), again with real events rated higher in emotion than identified imagined events ($T < 3.00$, $p < .001$, $r > –0.84$) and conjunction errors ($T < 30.50$, $p < .017$, $r > –0.55$), and no significant difference between conjunction errors and imagined events ($T > 47.00$, $p > .16$, $r < –0.33$). Lastly, personal significance differed across the subsequent memory conditions, ($\chi^2(2) > 15.72$, $p < .001$), with real events rated as more personally significant than identified imagined events ($T < 3.00$, $p < .001$, $r > –0.86$), while no difference was found between conjunction errors and real memories ($T > 27.00$, $p > .02$, $r < –0.55$), or imagined events ($T > 20.00$, $p > .02$, $r < –0.54$).

Participants also indicated the perspective from which the event was viewed (first- or third-person). For the proportion of events viewed from a first-person perspective, a 2×2 ANOVA revealed a main effect of memory condition ($F(2, 68) = 4.88$, $p = .01$, $\eta^2_p = .13$), as well as a significant interaction between age and condition ($F(2, 68) = 4.11$, $p = .02$, $\eta^2_p = .11$; see Figure 11). Pairwise comparisons demonstrate that younger adults were more likely than older adults to report conjunction errors as being viewed from a first-person perspective ($p = .003$). Furthermore, for younger adults only, conjunction errors were more likely to be viewed from a first-person perspective than were correctly identified imagined events ($p = .004$).

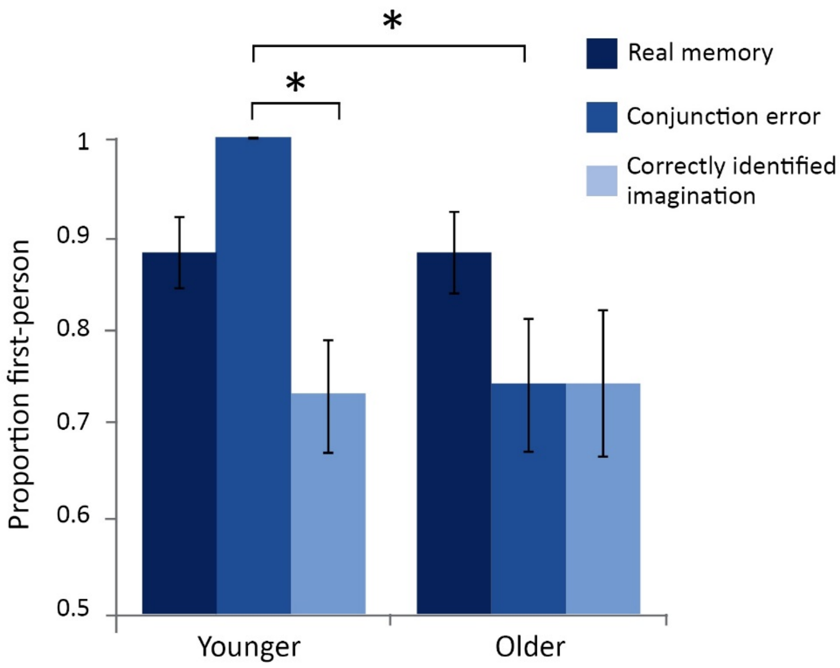

Figure 11. **Proportion of events recollected from a first-person perspective for younger and older adults, across subsequent memory conditions.** Error bars reflect standard error of the mean. AM = autobiographical memory, * = $p < .05$.

***Table 8.* Mean and median ratings for subjective phenomenological qualities and objective Autobiographical Interview scores during the retrieval of events in Session Three.**

Phenomenological quality		Younger adults			Older adults		
		Real	Conjunction error	Correctly identified imagination	Real	Conjunction error	Correctly identified imagination
Subjective	Vividness[a]	4.20	3.83	3.00	4.45	3.11	2.50
	Emotion[a]	3.10	2.00	1.73	3.50	2.43	2.17
	Personal Significance[a]	2.30	1.00	1.37	3.45	2.49	2.13
	Proportion first-person perspective	0.88 (0.21)	1.00 (0.00)	0.73 (0.31)	0.88 (0.22)	0.74 (0.35)	0.74 (0.39)
Objective	Internal details	29.69 (15.73)	20.07 (14.14)	14.02 (7.05)	20.97 (7.92)	12.42 (7.58)	7.97 (3.19)
	Event	17.63 (9.98)	12.57 (10.03)	7.71 (4.3)	12.78 (5.24)	8.64 (5.61)	4.72 (2.57)
	Perceptual	6.45 (4.43)	3.75 (3.92)	3.3 (2.82)	3.74 (2.99)	1.39 (1.96)	1.11 (0.99)
	Place	2.28 (1.33)	1.81 (1.56)	1.97 (1)	2.03 (0.97)	1.24 (0.71)	1.28 (0.61)
	Thought	1.98 (1.23)	1.11 (2.13)	0.64 (0.83)	1.43 (1.02)	0.82 (1.66)	0.32 (0.63)
	Time	1.36 (1.31)	0.83 (0.92)	0.41 (0.56)	0.97 (0.53)	0.33 (0.48)	0.23 (0.44)
	External details	8.65 (5.11)	11.13 (11.16)	7.84 (7.96)	19.88 (11.95)	14.72 (10.71)	11.30 (5.10)

Note. Standard deviations are provided in parentheses. [a]Medians presented, rating scale ranges from 1 (low) to 5 (high).

4.3.4.3 Objective scoring of event phenomenology in the AI

We examined the influence of age on the type of detail generated in the event descriptions from the AI (internal, external) according to event condition (real, conjunction error and correctly identified imagination) using a 2×2×3 mixed ANOVA (see Table 8). As expected, an interaction between detail type and group was evident ($F(1, 35) = 27.21$, $p < .001$, $\eta^2_p = 0.44$; see Figure 12), whereby younger adults recalled more internal details than older adults ($p = .01$), while older adults generated more external details ($p = .02$). More internal than external detail was generated overall for younger ($p < .001$) but not older adults ($p = .39$). A significant three-way interaction between group, condition and detail type was also found ($F(2, 70) = 3.25$, $p = .04$, $\eta^2_p = 0.09$). In order to run simple effects tests on the three-way interaction, the data were split by group. For both age groups, real events contained more internal detail than conjunction errors and imagined events (*p*s < .006). However, for older adults only, conjunction errors had more internal details than imagined events ($p = .03$). For younger adults, no differences were found across the event types for external detail (*p*s > .21), yet for older adults real events contained more external detail than imagined events ($p = .002$).

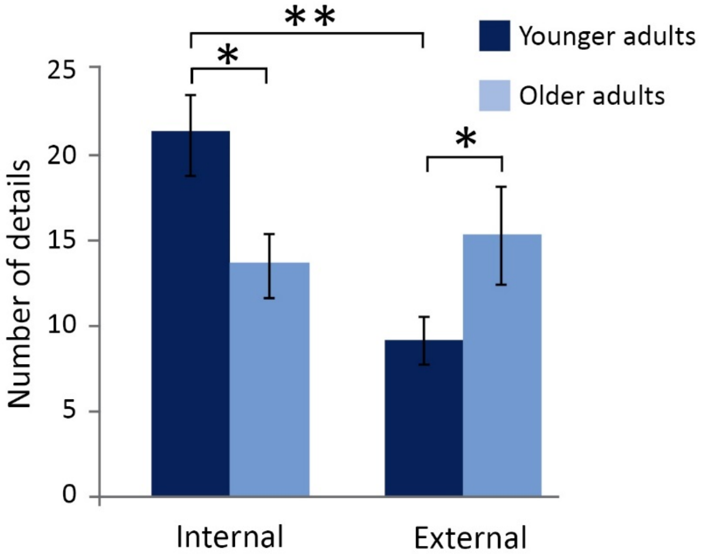

***Figure 12.* Average number of internal and external details in the adapted Autobiographical Interview for younger and older adults.** Collapsed across memory condition. Error bars represent standard error of the mean. * = $p < .05$, ** = $p < .001$.

We further broke down internal detail into subcategories (event, perceptual, place, thought/emotion, time), which were compared across memory conditions and age groups. A 2×3×5 mixed ANOVA revealed a significant interaction between memory condition and detail subcategory, $F(2.53, 88.45) = 17.54$, $p < .001$, $\eta^2_p = 0.33$ (see Figure 13 and Table 8). Pairwise comparisons demonstrated that real events had more event, perceptual, place and time detail than both identified imagined events and conjunction errors ($p < .01$ for all comparisons). Imagined events contained less thought detail than real events ($p < .001$), while no difference between conjunction errors and either real or imagined events was observed ($p = .15$ and $.27$ respectively). Moreover, conjunction errors contained more event details than imagined events ($p = .01$). None of these results differed according to age group (three-way interaction: $F(2.53, 88.45) = 0.26$, $p = .82$, $\eta^2_p = 0.01$).

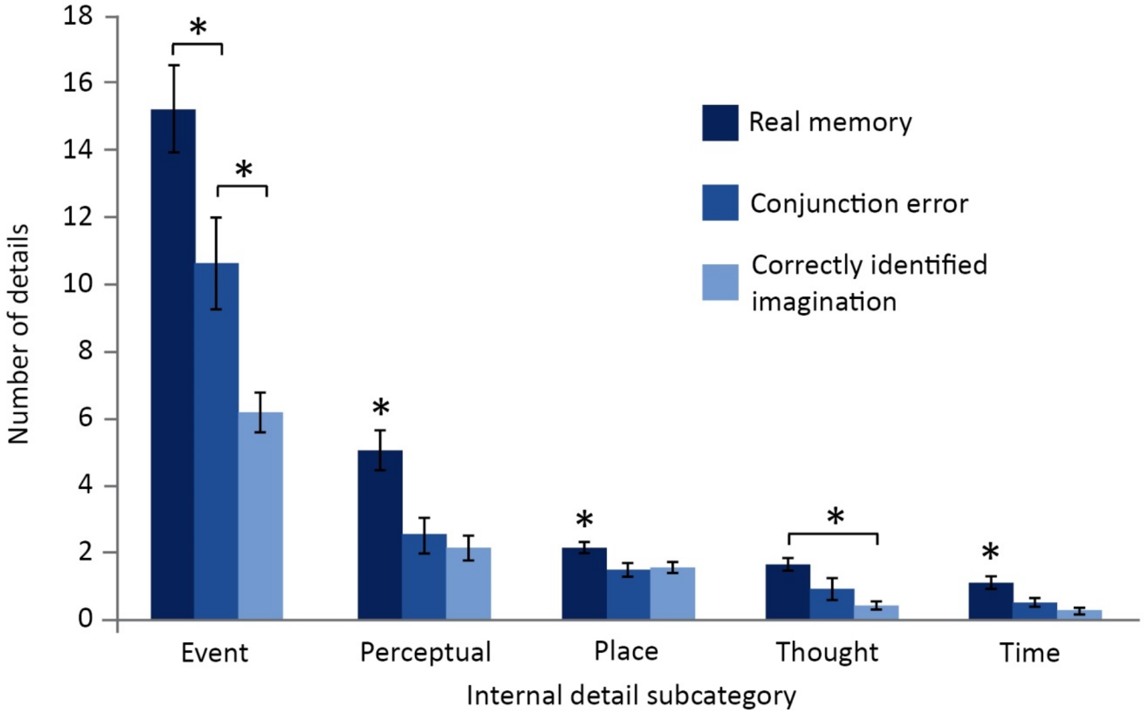

***Figure 13.* Objective scoring of event phenomenology broken down by subcategory.** Average number of internal details generated by participants in the adapted Autobiographical Interview for real memories, conjunction errors and correctly identified imagined events, separated by subcategory and collapsed across age group. Error bars reflect standard error of the mean. * = $p < .05$.

4.3.5 *Type of component altered and degree of recombination*

A 2×3 mixed ANOVA revealed no effect of the type of detail altered (person, place or object) on conjunction error rates, (person M = 5.30%, SD = 7.88; place M = 3.78%, SD = 6.93; object M = 4.86%, SD = 6.77), $F(2,104) = 0.64$, $p = .53$, $\eta^2_p = .01$. Furthermore, a 2×2 mixed ANOVA was run to test the influence of age on the conjunction error rates for partially and fully recombined detail sets. Replicating the results from *Studies 1* and *2*, a main effect of recombination degree on conjunction error rate was found, with partially recombined sets (M = 4.67%, SD = 5.44) accepted as real more often than fully recombined sets (M = 2.36%, SD = 3.63), $F(1, 52) = 15.69$, $p < .001$, $\eta^2_p = .23$. A main effect of age was also found, with older adults making more conjunction errors than younger adults, $F(1, 52) = 9.38$, $p = .003$, $\eta^2_p = .15$ (see Table 6). Because the effect of recombination degree on conjunction error rates did not differ across age groups (interaction: $F(1, 52) = 0.70$, $p = .41$, $\eta^2_p = .01$), the phenomenological analyses were collapsed across age groups to directly compare across degree of recombination. Wilcoxon signed-rank tests showed that in Session Two, imaginings from partial recombinations were rated as more vivid (Mdn = 3.61, T = 121.50, $p < .001$, $r < –0.66$) and plausible (Mdn = 2.61, $T > 103.50$, $p < .001$, $r < –0.74$) than those from full recombinations (vividness Mdn = 3.27, plausibility Mdn = 2.18).

4.4 Discussion

In line with our hypothesis, as well as previous research exploring memory conjunction errors for simple laboratory stimuli (Castel & Craik, 2003; Jones & Jacoby, 2005; Kersten et al., 2008, 2013; Kersten & Earles, 2010; Kroll et al., 1996; Rubin et al., 1999), older adults exhibited a greater susceptibility to AM conjunction errors than younger adults, thereby demonstrating that age differences in memory conjunction errors are apparent even for distinctive and personally-relevant autobiographical stimuli. We expected older adults would also demonstrate an increased imagination inflation effect as a result of reduced differentiation between internally and externally generated events (Cohen & Faulkner, 1989; Lindner &

Davidson, 2014; McDaniel et al., 2008; Thomas & Bulevich, 2006), yet no age-difference in imagination inflation was observed. A number of our findings are consistent with the idea that this increased rate of conjunction lure acceptance with age is attributable to difficulties in the encoding and retrieval of associations between AM features, resulting in source decisions made on the basis of familiarity with the individual memory components (Jones & Jacoby, 2005; Leding, 2015).

Older adults were more prone than younger adults to making conjunction errors regardless of prior exposure, suggestive of an overreliance on familiarity in the absence of recollection. This age-difference was also observed for the new condition, which at first glance could indicate that the increased rate of conjunction error acceptance with age is simply due to a bias towards responding "real" (Gerlach, Dornblaser, & Schacter, 2013; Huh, Kramer, Gazzaley, & Delis, 2006; see also Kapucu, Rotello, Ready, & Seidl, 2008; Koutstaal, Schacter, Galluccio, & Stofer, 1999). However, because conjunction stimuli are being used, it is difficult to tease apart a general response bias from an influence of familiarity. While the recombinations of event components in the new condition are novel, the components themselves are familiar, and if older adults rely more on a sense of familiarity than explicit recollection to make source judgements (Jones & Jacoby, 2005), this may be driving the greater tendency to misattribute previously unseen conjunction lures as corresponding to real events.

Older adults were less accurate than younger adults on the source test overall, consistent with a general decline in memory ability with age (Balota et al., 2000; Hoyer & Verhaeghen, 2006; Park et al., 2002). A negative relationship between memory accuracy and AM conjunction error rate was found for younger adults, whereby those who were more accurate at determining source also made fewer conjunction errors, consistent with the results of *Study 2* as well as a recall-to-reject mechanism of source monitoring (Jones & Atchley, 2006; Jones & Jacoby, 2005; Lampinen, Odegard, & Neuschatz, 2004). Such an approach would allow rejection of a conjunction lure by recalling either the authentic component combinations or the recombined detail sets encountered in Session Two. Interestingly, no relationship between overall source accuracy and conjunction error susceptibility was evident for older adults, perhaps indicative of a global inability to use recall-to-reject processes (Jones & Jacoby, 2005). It is worth noting that the overall percentage of conjunction errors made by younger adults in the current study is lower than that observed in *Studies 1* and *2,* potentially due to the fewer number of lures presented, which may have enabled more efficient use of a recall-to-reject strategy (Gallo, 2004). Despite this lower overall rate of conjunction errors for younger adults, a comparable rate of conjunction errors were maintained during the recall phase as in *Studies 1* and *2*, suggesting the AM conjunction errors made were no less compelling than these previous studies.

With regards to the degree of recombination and nature of alteration, no effect of age was observed on patterns of conjunction errors generated, although we replicated the findings of *Studies 1* and *2* that partial recombinations are accepted as real at a higher rate, and are judged as more vivid and plausible at the time of imagining compared to fully recombined conjunction lures. Regardless of age, more conjunction errors were made in the imagination and associative conditions relative to those in the new condition, consistent with a processing fluency or familiarity effect (Garry & Wade, 2005; Jacoby & Dallas, 1981; Kurilla, 2011; Sharman et al., 2004, 2005). Moreover, although only a trend, lures for which an event was imagined were more likely to result in conjunction errors than those presented in the associative condition, in line with the imagination inflation effect of *Study 2* (Mazzoni & Memon, 2003; Thomas et al., 2003).

Contrary to our hypothesis, both older and younger adults exhibited the same degree of imagination inflation. Moreover, age did not influence the pattern of subjective or objective quality measures across memory conditions (for corroborating results, see McGinnis & Roberts, 1996), inconsistent with the notion of an age-related dedifferentiation of memories for authentic and conjunction events. Due to time pressures in the source test, it is likely that older adults based source decisions on feelings of familiarity rather than the phenomenological characteristics elicited by the lures, accounting for the general increase in conjunction error rate across both exposure conditions. Older adults' reliance on familiarity during source decisions (Anderson et al., 2008; Craik & McDowd, 1987; Davidson & Glisky, 2002; Dennis et al., 2014; Jacoby, 1999; Jones & Jacoby, 2005; Prull et al., 2006) is further supported by the fact that older adults maintained fewer AM conjunction errors than younger adults when asked to describe the events in the AI.

It is also possible that age-related difficulties in retaining simulated conjunction events between Sessions Two and Three could have dampened the expected influence of imagination on conjunction error formation. Of the older adults, those scoring below chance on the source test for the imagination condition (N = 11) made fewer AM conjunction errors in response to imagined lures (M = 3.52%, SD = 4.69) than those scoring above chance (N = 15, M = 8.27%, SD = 6.25, $t(24) = 2.11$, $p = .05$, $d = 0.57$). Subjective and objective phenomenology at the time of imagination was equal between these two subgroups, ruling out imagery deficiencies as a driving factor. Instead, an inability to form lasting associations between memory features (Naveh-Benjamin, 2000) and thus declines in remembering imagined events over time (Gerlach et al., 2013; Romero & Moscovitch, 2012) seems to preclude the formation of memory conjunction errors (see also St. Jacques et al., 2015).

The perspective taken during recall further suggests that older adults have difficulty in retrieving recollective information about conjunction errors. Younger adults were more likely to report viewing conjunction errors from a first-person (as opposed to a third-person) perspective than were older adults. Moreover, only younger adults viewed conjunction errors from a first-person perspective more often than identified imagined events. Piolino and colleagues (2006) also report decreased use of a first-person perspective with age, and implicate deficits in memory recall to account for this finding; our results suggest this effect may be more pronounced when retrieving events that did not truly take place. Despite this difficulty in retrieving AM conjunction error events, no age difference in confidence for conjunction errors was apparent, which is at odds with previous studies reporting an age-related increase in confidence for false memories (Cohen & Faulkner, 1989; Dehon & Brédart, 2004; Jacoby & Rhodes, 2006; Jacoby, Wahlheim, Rhodes, Daniels, & Rogers, 2010; Karpel et al., 2001). It could be that the difficulty in retaining conjunction events lowered the confidence levels of older adults to that of younger adults. However, the relationship between confidence and memory accuracy in older adults is far from consistent (Adams-Price & Perlmutter, 1992; Karpel et al., 2001), and prevalence of conjunction errors with age has previously been found to be unrelated to confidence (Rubin et al., 1999). Moreover metamemory (that is, knowledge of one's memory abilities) is posited to be relatively unimpaired by aging (see Halamish, McGillivray, & Castel, 2011; Light, 1996; Rubin et al., 1999; though see Chua, Schacter, & Sperling, 2009).

The fact that like younger adults, older adults were able to describe and maintain a proportion of the conjunction errors in the AI phase suggests at least some of these errors are associated with a sense of phenomenological recollection (Dijkstra & Misirlisoy, 2009). These recollected errors may occur due to excessive binding of the independent features across memory traces (Fandakova et al., 2013). Subjective differences in vividness and plausibility at the time of imagination did not influence subsequent memory decisions, nor did vividness and emotion at the time of recall. However, for personal significance, conjunction errors were rated as intermediate between authentic and identified imagined events during recall, suggesting that lures that were falsely recognised as real were more personally salient than those that were correctly rejected, and may also have had stronger associations with stored memory traces (Burt et al., 2004; Heaps & Nash, 2001; Johnson et al., 1988).

The objective measures of memory content revealed an age-related decrease in episodic information, replicating previous findings (Addis et al., 2010, 2008; Gaesser et al., 2011; Levine et al., 2002). Despite this age difference in overall memory content, real events were phenomenologically distinct from correctly rejected imagined events in all subcategories of internal detail (e.g., Johnson et al., 1988; Justice et al., 2013) regardless of age. Furthermore, conjunction errors contained more information relevant to the unfolding of the story (i.e., event details) than identified imagined events, and were comparable to real events in amount of detail pertaining to thoughts. These findings are in line with the source monitoring framework (Johnson et al., 1993), implicating increases in conjunction error phenomenology in source misattribution for both younger and older adults. While these comparisons were not significant in *Study 2*, the greater number of participants in the current study likely increased power to detect subtle differences between subsequent memory conditions. However, conjunction errors were associated with lower measures of subjective vividness and objective perceptual detail at retrieval than real events, which is at odds with the results of *Study 2.* As noted in *Chapter 3*, the nature of the relationship between event imagery and false memory generation is unclear (Ost et al., 2002; Porter et al., 1999), with several factors contributing to the perceptual experience of memory distortions, including personality (Heaps & Nash, 1999), detail congruence (Pérez-Mata & Diges, 2007) and imagination repetition (Heaps & Nash, 2001).

In summary, the current study demonstrates that the prevalence of AM conjunction errors increases with age, extending similar findings for laboratory conjunction stimuli to that for distinctive and personally-relevant autobiographical events. This age-related increase in AM conjunction errors was comparable across exposure conditions, and furthermore no phenomenological dedifferentiation between true and false memories was observed for older adults. With regards to the potential cognitive processes contributing to this heighted susceptibility to AM conjunction errors, these findings implicate an age-associated decrease in recollective memory and a subsequent overreliance on familiarity processes when making source decisions. However, those conjunction errors that were associated with a sense of recollection were richer in phenomenological quality than identified imagined events, consistent with a source monitoring perspective. It is possible that individual differences in general memory and inhibitory capabilities may further contribute to the variation in AM conjunction error rates both between and within our younger and older adult groups; these possibilities will be investigated in *Study 4*.

Chapter 5: Study 4 – Neuropsychological correlates of autobiographical memory conjunction error susceptibility

5.1 Introduction

In *Study 3* we demonstrated that the false acceptance rate of AM conjunction lures was significantly higher for older than younger adults. However, considerable individual variation in conjunction error rates was observed within both age groups. This variability may be accountable by individual differences in relational processes and executive functions vital to episodic memory encoding and retrieval. Indeed, an abundance of research has demonstrated that dysfunction in the neural regions underpinning these mechanisms (primarily MTL and PFC) is associated with false memory formation (Chan & McDermott, 2007; Delbecq-Derouesné, Beauvois, & Shallice, 1990; Fandakova et al., 2013; Garoff-Eaton et al., 2007; Glisky et al., 1995; Janowsky, Shimamura, & Squire, 1989; Koutstaal et al., 2001; McCabe et al., 2009; Melo, Winocur, & Moscovitch, 1999; Mitchell & Johnson, 2009; Parkin et al., 1996, 1999; Pertzov et al., 2013; Plancher, Guyard, Nicolas, & Piolino, 2009; Rapcsak, Reminger, Glisky, Kaszniak, & Comer, 1999; Rhodes & Kelley, 2005; Schacter, Curran, Galluccio, Milberg, & Bates, 1996; Swick & Knight, 1999; Verfaellie, Rapcsak, Keane, & Alexander, 2004). The current study explores whether heterogeneity in AM conjunction error vulnerability can be accounted for by individual and age-related variation in memory and/or executive functioning.

Individual differences in false memory susceptibility in healthy younger adults has been linked with variation in performance on neuropsychological tests of episodic memory (e.g., Fandakova et al., 2013; Zhu et al., 2010; though see Lepage, Brodeur, & Bourgouin, 2003; McCabe et al., 2009) and executive functioning ability (Chan & McDermott, 2007; Fandakova et al., 2013; Glisky et al., 1995; McCabe et al., 2009; Plancher et al., 2009; Rhodes & Kelley, 2005). There is also evidence that age-related differences in these factors contributes to an increased false memory susceptibility in older adults. For instance, older adults recruit MTL regions to a lesser extent than younger adults during false recollection (Dennis, Bowman, et al., 2014) and correct rejection of lures (Giovanello et al., 2010; Tsukiura, Shigemune, Nouchi, Kambara, & Kawashima, 2014), likely reflecting decreased recruitment of reconstructive processes, and an overreliance on familiarity-based recognition with age (Anderson et al., 2008; Davidson & Glisky, 2002). Such deficits in relational memory can lead to the formation of conjunction errors due to declines in recall-to-reject processes; consistent with this notion, poorer associative binding ability has been linked with an increased rate of conjunction errors in both younger and older adults (Fandakova et al., 2013). The results of *Study 3* further support this view: older adults were more susceptible to AM conjunction errors overall due to an increased reliance on familiarity during source decisions. In addition, relational memory deficits may contribute to older adults' tendency to over-bind separate memory components into one representation (Fandakova et al., 2013; Kroll et al., 1996). Indeed, poorer episodic memory performance has been associated with greater conjunction error rates in older adults, regardless of the degree of similarity of the original and lure stimuli, indicative of excessive binding mechanisms (Rubin et al., 1999). However, until now, the contribution of relational memory processes to memory distortions in *AM* has not been examined.

Age-related impairments in executive functions critical to encoding and retrieval can exacerbate the overreliance on familiarity or gist information, (as per Jacoby, 1991; Jones & Jacoby, 2001; Schacter, Verfaellie, Anes, & Racine, 1998; for a review, see Mitchell & Johnson, 2009). However, executive functioning can be considered an umbrella term for a range of inter-dependent sub-processes, including conceptual fluency, updating information and inhibitory control (Latzman & Markon, 2010; Miyake et al., 2000). The ability to inhibit irrelevant stimuli or internally-generated signals may be particularly important for accurate memory encoding and retrieval (see for example, Balota et al., 1999, 2000; Budson et al., 2002; Plancher et al., 2009). Indeed, it has been posited that reductions in inhibitory control mechanisms partially underlies episodic memory declines with age, resulting in competition between relevant and irrelevant information for working memory resources (Gazzaley et al., 2005; Hasher et al., 1999), and an increased susceptibility to the negative effects of distraction (Healey, Campbell, & Hasher, 2008), contributing to a “hyper-binding” of stimuli components across memory traces (Henkel et al., 1998; Lyle et al., 2006; Lyle & Johnson, 2006). Therefore, inhibition may be a candidate process underpinning the age-related increase in AM conjunction error rates (see Lövdén, 2003).

Broad measures of executive functioning have been linked with susceptibility to conjunction errors for laboratory stimuli in older adults (Fandakova et al., 2013; Rubin et al., 1999), yet the influence of inhibition in particular on conjunction error rates is currently unknown. Disruption of inhibitory control could potentially increase rates of false acceptance of conjunction stimuli in two ways. First, reduced inhibition can result in a lowered capacity to suppress the automatic sense of familiarity garnered by the individual memory components comprising a conjunction lure (e.g., Jones & Jacoby, 2001). Second, inhibitory control is necessary for supressing related but irrelevant memories triggered via spreading activation (Biss et al., 2013; Campbell et al., 2010, 2014; Henkel et al., 1998; Kensinger & Schacter, 1999; Watson, McDermott, & Balota, 2004; see also Shimamura, 1995), and thus reduced inhibition may lead to the erroneous binding of memory components to form conjunction errors (i.e., overbinding; Fandakova et al., 2013; Kroll et al., 1996; Lyle et al., 2006). Such inhibitory control processes may be particularly taxed when presented with AM conjunction lures, which are comprised of complex and personally-relevant autobiographical information and share features with veridical memories.

While the studies reviewed above have focused on group differences in memory accuracy, cognitive aging is a heterogeneous process (Hultsch, Strauss, Hunter, & MacDonald, 2008; Van Petten, 2004), and it is clear that increased susceptibility to false memories is not a universal and inevitable feature of aging (see for example, Intons-Peterson, Rocchi, West, McLellan, & Hackney, 1999; Umanath & Marsh, 2012). Individual variation in the preservation of cognitive function plays a large role in susceptibility to memory errors; the cognitive reserve literature suggests that high functioning older adults compensate for declines in specific brain areas by recruiting additional neural resources, particularly PFC, to support cognition (Berlingeri, Danelli, Bottini, Sberna, & Paulesu, 2013; Cabeza, Anderson, Locantore, & McIntosh, 2002; Cabeza, 2002; Grady, McIntosh, & Craik, 2003; Park & Reuter-Lorenz, 2009; Reuter-Lorenz & Cappell, 2008; Rosen et al., 2002), including episodic memory (Grady, McIntosh, & Craik, 2005; Gutchess et al., 2005; Maguire & Frith, 2003). Indeed, older adults who perform highly on neuropsychological tests sensitive to MTL and PFC functioning are no more vulnerable to false memories than younger adults (Butler, McDaniel, Dornburg, Price, & Roediger, 2004; Chan & McDermott, 2007; Fandakova et al., 2013; Glisky, Rubin, & Davidson, 2001; Henkel et al., 1998; McCabe et al., 2009; Rubin et al., 1999; Thomas & McDaniel, 2013).

In the current study, we aimed to explore cognitive contributors to the individual and age-related variation in AM conjunction error rates, as a means of further identifying the cognitive mechanisms underpinning these errors. In particular, we examined the role of relational memory ability and inhibition on conjunction errors for autobiographical stimuli. Consistent with previous research, we expected reduced performance in neuropsychological tests tapping these processes to be associated with an increased AM conjunction error rate in both younger and older adults. Furthermore, we expected the effect of age on source accuracy and AM conjunction error rates to be mediated by age-related declines in memory and/or inhibition performance.

5.2 Method

5.2.1 Participants

Of the participants from *Study 3*, 25 younger (5 male) and 25 older adults (8 male) also completed this neuropsychological session (see Table 9 for demographic information). Participants were compensated with $25 in grocery vouchers for their time.

A power analysis was conducted using G*Power (Faul et al., 2007) on the basis of published data for a regression including false alarms as the outcome measure and memory and executive measures as predictors (Chan & McDermott, 2007). This analysis indicated a minimum of 25 participants per group were needed to achieve 80% power at $\alpha = .05$. Thus our sample size satisfies this requirement.

5.2.2 Procedure

This session was carried out approximately 2 months after the final session of *Study 3* (M = 57 days, SD = 56), and took two hours to complete.

5.2.3 Neuropsychological measures

5.2.3.1 Memory measures

Three measures of relational memory abilities were used; the selection of these tests was guided by the results of a factor analysis of measures in Glisky et al.'s neuropsychological test battery (1995; see also Henkel et al., 1998; McCabe et al., 2009; Thomas & McDaniel, 2013). For all memory tests, immediate learning scores are used, because they provided the largest amount of variance in the younger adult group, and also captured the ability to form associations between items in memory.

1. The *California Verbal Learning Test Second Edition* (CVLT-II; Delis, Kramer, Kaplan, & Ober, 2000) consists of 16 words from four semantically related categories, which are read aloud multiple times. The participant is instructed to remember as many words as possible. Learning sum (trials 1-5 free recall) was used as the primary

measure. Number of semantically related intrusions (recall of words not on the word list, but semantically consistent with one of the four categories) was also recorded.

2. For the *visual paired associates* (PA; Wechsler Memory Scale – Revised; Wechsler, 1987) participants learn associations between six abstract figures and colours. At test participants are presented with the figures, and are asked to recall the appropriate colour. Learning sum (trials 1-3) was used as the primary measure.
3. In the *verbal PA* (Wechsler Memory Scale – Revised; Wechsler, 1987) eight word pairs are read aloud, after which one of the words in each pair is read out, and the participant is instructed to recall the associated word. Half of the word pairs are semantically related (easy list), and half are non-semantically related (hard list). Learning sum (trials 1-3) for the hard list was used as the primary measure. Number of conjunction errors (i.e., intrusions where the participant answered with a word belonging to a different word-pair) was also recorded.

5.2.3.2 Inhibition measures

We selected five subtests from the Delis-Kaplan Executive Function System test battery (D-KEFS; Delis et al., 2001) that have been found to load onto an inhibition factor (Floyd, Bergeron, Hamilton, & Parra, 2010; Latzman & Markon, 2010; Li et al., 2015)[10].

1. The *trail making* task involves linking numbers and letters in ascending and alphabetical order. A ratio of the time (in seconds) to complete the number-letter

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[10] Three potential subcategories for the D-KEFS tests have been identified which are relatively consistent across a large age range (8-89 years; Latzman & Markon, 2010; see also Miyake et al., 2000): *conceptual flexibility*; *updating/monitoring*; and *inhibition*. Although monitoring is an important aspect of avoiding memory distortions (Johnson et al., 1993), the monitoring factor described by Latzman and Markon specifically involves active evaluation and updating of information held in working memory (see Miyake et al., 2000), which may be differentiated from the source monitoring involved in evaluating memory veracity. With respect to inhibition, a high number of the D-KEFS subtests are consistently found to load onto the inhibition subcategory (Floyd et al., 2010; Latzman & Markon, 2010; Li et al., 2015) suggesting that this factor represents a core aspect of executive functioning (see also Miyake & Friedman, 2012).

switching task with completion time of the numbers only task was used as the primary measure, where a lower ratio indicates better performance.

2. For the *verbal fluency letter* task, participants generate as many words as possible in 60 seconds, beginning with target letters F, A and S. Number of words generated in accordance with the set rules was recorded.
3. For the *design fluency switching* task, participants connect dots to draw as many novel line figures as possible in 60 seconds, using only four straight lines for each and switching between black and white dots. Total number of complying figures was recorded.
4. In the *colour-word interference* task participants must name the ink colour for colour words printed in an incongruous ink (inhibition condition). A ratio of the time (in seconds) taken to name the words in the inhibition condition with completion time for the simple colour naming condition was used as the primary measure, where a lower ratio indicates better performance.
5. For the *tower test*, participants move stacks of disks according to set rules, so as to match the configuration of disks to a pictorial representation. Total achievement score was used as the primary measure.

5.2.3.3 Composite scores

To obtain reliable and stable measures of memory and inhibition functioning, raw scores for all tests were converted to *z*-scores and collapsed across tests to form separate composite scores of memory and inhibition (Glisky & Kong, 2008; Salthouse et al., 2003), whereby a lower composite score indicates lower functioning.

5.2.4 Overview of path analyses

To assess the influence of age and neuropsychological composite scores on memory accuracy and conjunction error rates, two separate path analyses were carried out using Mplus 7.3 (Muthén & Muthén, 2012), with Maximum Likelihood Estimation using 5,000 bootstrapped re-samples. The dependent variable for the first model was overall accuracy rate, and for the second model was AM conjunction error rate: both measures were from the source test of *Study 3*. For both models, age group, memory and inhibition composite scores were the independent variables of interest. With 50 participants we had 10 observations for each parameter in our model, satisfying the recommended lower limit for path analysis (Kline, 2011). Diagnostic tests indicated that the models were not unduly biased by multicollinearity, as tolerance statistics for all variables were above the minimum value of .20 as recommended by Menard (1995).

5.3 Results

5.3.1 Age differences in neuropsychological test performance

Younger adults outperformed older adults on all three of the memory tests, a difference reflected in the composite memory score (see Table 9). For memory errors in these tests, no age difference in intrusions in the CVLT-II or conjunction errors in the verbal PA test (whereby the response given was a word belonging to a different word-pair) was observed (though this latter comparison was trending at the Bonferroni corrected threshold of $\alpha = .008$: $t(47) = 2.70$, $p = .01$). For the tests of inhibition, younger adults outperformed older adults on the design fluency and colour-word inhibition tests, but no age differences were observed for the trails, verbal fluency or tower tests. Younger adults displayed better inhibitory control overall, as reflected in the inhibition composite score.

***Table 9.* Mean demographics and neuropsychological test scores for young and older participant groups.**

	Younger adults	Older adults
Demographics		
Age (years)*	21.44 (3.68)	72.04 (4.60)
Education (years)	14.94 (1.93)	15.86 (3.21)
ACE-III	--	94.64 (3.23)
AM conjunction error rate from *Study 3* (% trials)*	2.12 (2.17)	5.24 (5.06)
Memory performance		
CVLT-II: 1-5 free recall total correct*	60.16 (7.10)	48.48 (9.64)
Visual PA: learning sum*	15.04 (2.63)	10.74 (3.43)
Verbal PA: learning sum hard pairs*	9.92 (1.41)	6.25 (3.63)
Memory composite (z-score)*	0.56 (0.38)	-0.63 (0.82)
Memory errors		
CVLT-II: semantic intrusions	5.00 (6.22)	3.20 (3.81)
Verbal PA: conjunction errors	0.48 (0.92)	1.63 (1.91)
Inhibition performance		
Trails: ratio number-letter switching to number	2.19 (0.63)	2.5 (0.98)
Verbal fluency: total letter	45.8 (8.45)	41.44 (10.97)
Design fluency: switching*	10.58 (2.75)	7.58 (2.24)
Colour-word inhibition: ratio inhibition to colour naming*	1.70 (0.29)	1.95 (0.31)
Tower: achievement score	18.88 (3.47)	17.44 (4.59)
Inhibition composite (z-score)*	0.28 (0.43)	-0.29 (0.48)

Note. Standard deviations provided in parentheses. PA = paired associates, AM = autobiographical memory, ACE-III = Addenbrooke's Cognitive Examination, Third Edition. * = difference between groups is significant at the Bonferroni corrected threshold (for demographics α = .05, for both memory and executive functioning measures α = .008).

***Table 10*. Bivariate correlations for variables entered into path analyses predicting source accuracy and autobiographical memory conjunction error rate.**

	1	2	3	4	5
1. AM conjunction error rate	–				
2. Source accuracy	-.33*	–			
3. Age group	.38**	-.61***	–		
4. Memory composite score	-.24	.47**	-.69***	–	
5. Inhibition composite score	-.37**	.29*	-.55***	.45**	–

AM = Autobiographical memory. * $p < .05$, ** $p < .01$, *** $p < .001$

5.3.2 *Model One: Relationship between neuropsychological test performance and source accuracy*

The first model examined the contributions of age group and neuropsychological measures to accurate source determination of authentic and conjunction detail sets (see Table 11 and Figure 14). Bivariate correlations between variables are presented in Table 10. The model fit was good, using a minimum criterion of a CFI of .97, and a RMSEA of < .05 (Schermelleh-Engel, Moosbrugger, & Müller, 2003), χ^2(1, N = 50) = 0.85, CFI = 1.00, RMSEA = .00, *p* = .36. Age group was the only significant predicator of source accuracy (*z* = 3.31, *p* = .001); when accounting for the influence of age, neither the memory (*z* = 0.64, *p* = .52) nor inhibition composite scores (*z* = 0.49, *p* = .63) contributed significantly to source accuracy. Age significantly predicted memory (*B* = -1.19, *SE* = 0.18, 95% CIs = -1.54, -0.84, *z* = -6.64, *p* < .001) and inhibition ability (*B* = -0.58, *SE* = 0.13, 95% CIs = -0.83, -0.33, *z* = -4.55, *p* < .001). The indirect effects of age group as mediated by memory (*B* = -1.62, *SE* = 2.58, 95% CIs = -7.33, 2.85 *z* = 0.63, *p* = .53) and inhibition composite scores were not significant (*B* = 0.87, *SE* = 1.82, 95% CIs = -2.66, 4.56, *z* = 0.48, *p* = .63).

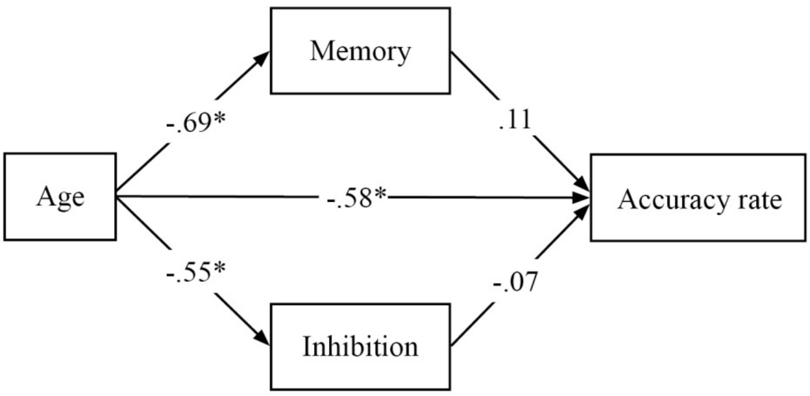

Figure 14. **Path analysis predicting source accuracy**. Standardised coefficients shown. * *p* < .05.

5.3.3 *Model Two: Relationship between neuropsychological test performance and AM conjunction error susceptibility*

Next we examined the contribution of age group, memory and inhibition to AM conjunction error rates (see Table 11 and Figure 15). Bivariate correlations between variables are presented in Table 10. The model fit was good, χ^2(1, N = 50) = 0.85, CFI = 1.00, RMSEA = .00, *p* = .36. The inhibition composite score was significantly associated with an AM conjunction error rate (*z* = 2.01, *p* = .04), while the memory composite score appeared to have no influence on the conjunction error rate (*z* = 0.34, *p* = .74). Age group did not significantly predict AM conjunction error rate when accounting for the memory and inhibition scores (*z* = 1.14, *p* = .26). As with the source accuracy analysis, age group significantly predicted memory and inhibition ability (see accuracy analysis). The indirect effect of age group on AM conjunction error rate through inhibition was trending towards significance (*B* = 1.11, *SE* = 0.62, 95% CIs = 0.08, 2.58, *z* = 1.79, *p* = .07); the fact that the direct effect of age on AM conjunction error rate was insignificant when controlling for this indirect effect suggests that the influence of age on conjunction error rate is mediated by a decrease in inhibition ability. The indirect effect of age group via the memory composite score was not significant (*B* = -0.47, *SE* = 1.40, 95% CIs = -3.90, 1.74 *z* = 0.34, *p* = .73).

***Table 11.* Unstandardised and standardised betas for the path analyses predicting source accuracy and autobiographical memory conjunction error rates.**

	B	*SE(B)*	*β*	R^2
Source accuracy				.38
Age	-12.89	3.89	-0.58*	
Memory	1.36	2.13	0.11	
Inhibition	-1.50	3.08	-0.07	
AM conjunction error rate				.19
Age	2.48	2.18	0.30	
Memory	0.40	1.17	0.08	
Inhibition	-1.91	0.95	-0.25*	

AM = autobiographical memory. * *p* <.05

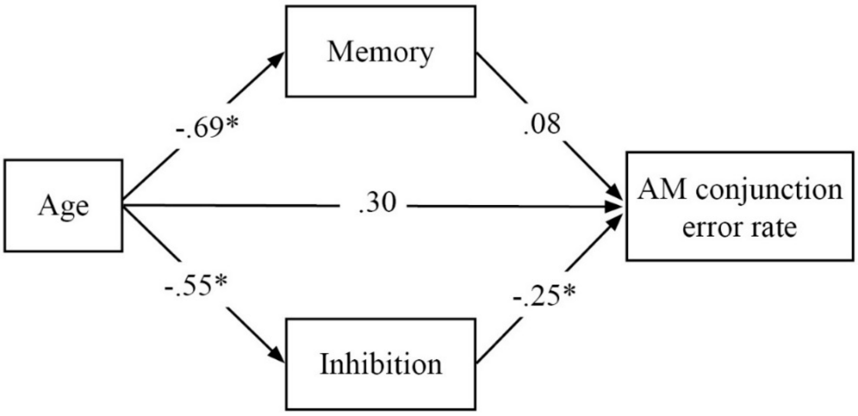

Figure 15. **Path analysis predicting autobiographical memory (AM) conjunction error rate**. Standardised coefficients shown. * $p < .05$.

Because memory and executive functioning are not entirely independent processes, we also ran the above model including a memory by inhibition interaction term, in order to determine whether the influence of memory on AM conjunction error susceptibility was moderated by inhibition ability. The interaction was not significant, indicating that influence of relational memory abilities on AM conjunction error rates did not differ as a function of inhibition ability (B = -0.62, SE = 1.22, 95% CIs = -3.30, 1.37, z = 0.51, p = .62).

5.3.4 Neuropsychological scores and exposure condition

To determine whether reduced inhibition had a differential influence on AM conjunction error rates across exposure conditions (see *Study 3* for more detail) , a 2×2×3 mixed ANOVA was computed, with inhibition ability (high, low, as determined by a median split) and age (younger, older) as the between-subjects factors, and exposure condition (imagined, associative, new) as the within-subjects variable[11]. In line with the results of the path analysis, a main effect of inhibition ability was found, where those with poor inhibition made more conjunction errors overall, $F(1, 46) = 5.46$, $p = .02$, $\eta^2_p = .11$. The interactions between inhibition and both condition and age were not significant ($F < 0.90$, $p > .88$),

[11] As with *Studies 2* and *3*, uncorrected rates of the imagined and associative were used to adequately compare against the new condition, for which invalid trials could not be removed prior.

suggesting that individuals with poor inhibition are more susceptible to AM conjunction errors regardless of condition or age (see Figure 16a).

Similarly, a 2×2×3 mixed ANOVA was run to determine whether the influence of memory ability on AM conjunction errors differed by exposure condition (see Figure 16b). Although the overall conjunction error rate did not differ based on memory ability (high, low, as determined by a median split), results from Rubin and colleagues (1999) suggest that the *pattern* of conjunction errors across exposure conditions may differentiate those with low and high MTL function. In line with the path analysis, no main effect of memory ability was found, $F(1, 46) = 10.13$, $p = .003$, $\eta^2_p = .18$. However, no interaction between memory ability and condition or age group was found ($F < 0.05$, $p > .83$).

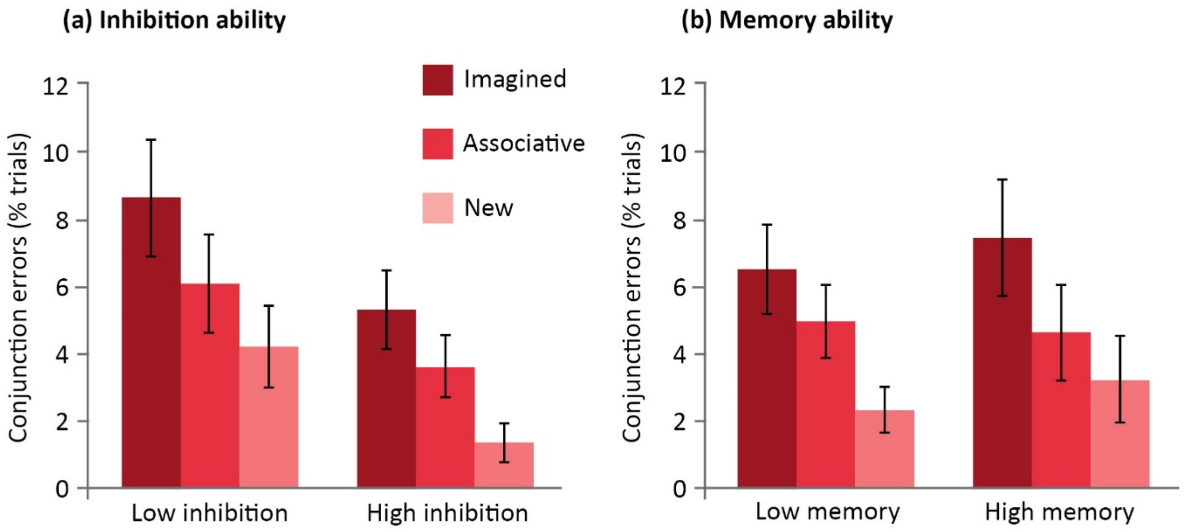

Figure 16. **Uncorrected rates of autobiographical memory conjunction errors across exposure conditions (imagined, associative and new) for those with high and low memory and inhibition ability.** Both memory and inhibition ability were determined by a median split of the composite scores. Because the pattern of conjunction errors across conditions did not differ according to age, the graphs depict conjunction error rate collapsed across younger and older adult groups. Error bars represent standard error.

5.3.5 *Relationship between AM conjunction error rate and neuropsychological test measures of memory errors*

Two of the neuropsychological memory tests included measures of memory errors, providing the opportunity to assess the relationship between these error scores and AM conjunction error rates. To this end, the overall AM conjunction error rate was correlated with the number of semantic intrusions on the CVLT-II and the number of conjunction errors in the verbal PA test. These correlations were run separately for the younger and older adult groups to avoid Simpson's paradox effects (Kievit, Frankenhuis, Waldorp, & Borsboom, 2013), and Spearman's correlations were used due to skewed distributions of errors. No significant correlation was found between overall AM conjunction error rate and intrusions in the CVLT-II for either younger (r_s = .09, p = .67) or older adults (r_s = -.03, p = .89). For the younger adults, AM conjunction error rate was positively correlated with number of conjunction errors made in the verbal PA (r_s = .40, p = .05), while no correlation was seen for older adults (r_s = .02, p = .94). The difference between these correlation coefficients for younger and older adults was formally compared using a Fisher's z-transformation (see Myers & Sirois, 2014), the correlation coefficients did not significantly differ between the age groups (p = .16).

5.4 Discussion

The results from the current study reveal an age-invariant influence of executive functioning on susceptibility to conjunction errors in the autobiographical domain, expanding upon similar findings exploring memory distortions for simplistic laboratory stimuli (Delbecq-Derouesné et al., 1990; Fandakova et al., 2013; Garoff-Eaton et al., 2007; Glisky et al., 1995; McCabe et al., 2009; Parkin et al., 1996; Plancher et al., 2009; Rapcsak et al., 1999; Rhodes & Kelley, 2005; Swick & Knight, 1999). Specifically, a composite measure of inhibition ability (Latzman & Markon, 2010), but not memory ability (Glisky et al., 1995) accounted for the increased susceptibility to AM conjunction errors with age (although this effect was only marginally significant), and significantly predicted individual AM conjunction error rate above and beyond the influence of age.

Individuals with lower inhibition scores were more likely to make AM conjunction errors regardless of exposure condition. This heightened susceptibility to conjunction errors following reductions in inhibition ability may arise due to a difficulty in suppressing the sense of familiarity piqued by the individual components comprising a conjunction lure at retrieval (Arndt & Jones, 2008; Jacoby, 1991; Jones & Jacoby, 2001). Individuals with lowered inhibition ability may also be more susceptible to conjunction errors due to a disinhibition of erroneous binding of features originating from separate memory traces (Fandakova et al., 2013; Kroll et al., 1996; see also Reinitz & Hannigan, 2001). While the current findings elucidate inhibition as playing a vital role in conjunction error formation, future research is required to confirm whether one or both of these explanations regarding reduced inhibition are applicable to the formation of AM conjunction errors.

With regards to general performance on the neuropsychological tests, older adults were impaired relative to younger adults on all memory measures, consistent with an age-related memory decline (Balota et al., 2000; Hoyer & Verhaeghen, 2006; Park et al., 2002). Younger adults also outperformed older adults for the inhibition factor, in line with typical age-related deficits in frontal integrity (Buckner, 2004; Hedden & Gabrieli, 2004; Moscovitch & Winocur, 1995; Raz et al., 2005; Tisserand et al., 2004; West, 1996). We found that inhibition ability mediated the influence of age on AM conjunction error rates, providing evidence for reductions in PFC-functioning as a primary driver of this form of memory distortion within the older population. The current findings suggest that interventions for improving memory accuracy in older adults may benefit from strategies that target inhibition ability, as well as from tailoring training programmes to the needs and remaining cognitive resources of the individual (Fandakova, Shing, & Lindenberger, 2012; Fandakova et al., 2013).

We further hypothesised that reductions in relational memory would result in underutilisation of recollective strategies and overreliance on familiarity in the source test (Anderson et al., 2008), conferring an increased susceptibility to AM conjunction errors; however, this hypothesis was not borne out. This is not the first report of a lack of relationship between MTL-mediated memory functioning and vulnerability to memory distortions (see Balota et al., 1999; Glisky et al., 1995; McCabe et al., 2009). It is possible that the influence of relational memory on AM conjunction error susceptibility is dependent on executive processes, in that those with poorer memory may have been protected from making these errors by a relatively high inhibition capability, while conversely those with good memory but poor executive functioning could have displayed a heightened susceptibility to these errors. However, the lack of interaction between memory and inhibition does not lend support to this interpretation. Instead, the role the MTL plays in source monitoring is likely highly dependent on the type of information to be remembered, and the conditions under which encoding and retrieval occur (Glisky et al., 1995). As such, higher-level cognitive resources (such as those regulated by the PFC) may be required to make fine-grained distinctions between small content changes in complex AMs (as occurs with AM conjunction errors), and thus relational memory may not have had as noticeable an impact on memory distortions of this type. Moreover, in older adults at least, the source monitoring deficits attributable to MTL-decline may have been balanced by the recruitment of compensatory PFC mechanisms (see Cabeza, 2002; Grady et al., 2003; Reuter-Lorenz & Cappell, 2008). A follow-up fMRI study could be informative in terms of determining whether compensatory mechanisms are at play.

Despite a lack of overall relationship between relational memory ability and conjunction error rate, Rubin and colleagues (1999) found an association between MTL-functioning and the *pattern* of false alarms across lure conditions. No such relationship was found in the current study; a graded response to lures in the imagined, associative and new conditions was observed for both high and low MTL-functioning individuals. Participants with poor memory may have had difficulty remembering the simple laboratory stimuli (compound words) used by Rubin and colleagues, thereby responding to all lures as if they were equal in novelty and resulting in the flat gradient of false alarms across conditions. In contrast, the lures used in the current study were comprised of inherently familiar components by virtue of originating from participant's own AMs, removing the need to remember individual elements, and therefore also removing some of the differences due to MTL-functioning. Thus all participants exhibited the graded false alarm pattern expected from exposure to and imagination of the conjunction lures. If this is the case, it serves to further demonstrate how AM conjunction errors can be compelling, particularly when paired with imagination, regardless of relational memory ability.[12]

In *Study 3* we found similar age effects on conjunction error susceptibility in AM as has previously been shown when using simple laboratory stimuli (Jacoby & Rhodes, 2006; Mitchell & Johnson, 2009; Pierce et al., 2003). Thus in the current study we utilised two neuropsychological measures of memory errors to further explore this relationship. For younger adults, those individuals who were more susceptible to AM conjunction errors were also prone to making conjunction errors in the visual PA test, further establishing a link between performance on tests using simple laboratory stimuli and those employing autobiographical information (Clancy, McNally, Schacter, Lenzenweger, & Pitman, 2002; Gallo, 2010; Meyersburg, Bogdan, Gallo, & McNally, 2009; see also Burianova, McIntosh, & Grady, 2010; Cabeza et al., 2004). Although older adults were more susceptible to making conjunction errors during the verbal PA test than younger adults, mirroring the age effect seen for AM conjunction errors, for older adults verbal PA errors did not correlate with AM conjunction error rates. This result potentially indicates an age limit in the generalisability of laboratory stimuli to autobiographical events (see Rendell & Craik, 2000). Intrusions on the

[12] The possibility also holds that the sample of older adults in the current study had superior memory ability on average than those in Rubin et al., (1999), though this theory is difficult to confirm or deny as Rubin reports only z-scores for MTL-functioning.

CVLT-II were not related to AM conjunction error rates for either age group, possibly because the semantic associations leading to gist-based errors are reliant on different mechanisms than the episodic associations contributing to conjunction errors in AM (Burianova & Grady, 2007; Lee, Robbins, Graham, & Owen, 2002; Moscovitch et al., 2005; see also Calvillo & Parong, 2015; Ost et al., 2013).

Neither relational memory nor inhibitory control were associated with overall accuracy in the source test (from *Study 3*). It may be that the heterogeneity in the strategies that could be employed to successfully perform the source test masks an influence of these measures on source accuracy. For instance, correct source determination may be possible with either a predominately recollective or familiarity strategy: one may explicitly recall a previous experience with the component combination (as self-generated in Session One, or presented in Session Two); alternatively, in the absence of recollection one might rely on familiarity with the detail combination (high familiarity may be interpreted as a sign of authenticity, slight familiarity with a recombination seen in Session Two, and no familiarity as a sign the combination is new). While the familiarity strategy would be expected to inflate rates of false alarms (and indeed, evidence from *Study 3* suggests this is the case), hit rates would remain fairly comparable as when a recollective strategy is utilised.

Neuropsychological studies in general are limited by the fact that neuropsychological tests are indirect measures of neural functioning, although the connection between the two is well supported by the literature (e.g., Davidson et al., 2007; Johnson, Saykin, Flashman, Mcallister, & Sparling, 2001; Robinson et al., 2014; Yochim, Baldo, Nelson, & Delis, 2007; Yochim, Baldo, Kane, & Delis, 2009). To further complicate matters, memory and executive functioning tests are not functionally independent in terms of the neural regions they engage. For example, PFC functioning plays a role in performance on the visual PA test (Neuner et al., 2007), as well as on the CVLT (Alexander, Stuss, & Fansabedian, 2003). Relational memory in particular is thought to rely on both MTL and PFC (see Cabeza, 2006); associative memory tasks recruit the dorsolateral PFC (Blumenfeld et al., 2011), while impairments in relational encoding with age have been linked with ventrolateral PFC dysfunction (Addis, Giovanello, Vu, & Schacter, 2014, see also Becker et al., 2015). Though neuropsychological tests can be highly informative about the cognitive operations involved memory distortions, it is clear that caution must be taken when extrapolating findings from such studies to potential underlying neural substrates. Neuroimaging research in combination with neuropsychological testing has much to offer in substantiating such claims.

In summary, we found that declines in inhibitory control was associated with an increased likelihood of generating conjunction errors for autobiographical events in both younger and older adults. Moreover, the enhanced vulnerability to such conjunction errors observed in older adults can be attributable to reductions in inhibition ability with age. In contrast, relational memory functioning does not appear to contribute to AM conjunction error rates. It is likely that declines in PFC-mediated inhibition results in an inability to suppress the sense of familiarity garnered by the individual memory features comprising the lures, resulting in an increase in AM conjunction errors regardless of exposure condition. Disinhibition may also contribute to excessive binding between features originating from separate memories, by allowing related, though irrelevant, memory traces to be activated. The current findings take us one step closer to understanding the contribution of broad executive functioning measures to conjunction error susceptibility, yet there is still much to disentangle with regards to the role of inhibition on the formation of distortions in AM.

Chapter 6: General discussion

6.1 Summary

The reconstructive memory system is subject to a range of distortions arising at many points along the encoding and retrieval pipeline (Johnson, Hashtroudi, & Lindsay, 1993; Schacter, Norman, & Koutstaal, 1998; Schacter, 2001; Straube, 2012; see Figure 1 in the *General Introduction*). Memory conjunction errors are one such distortion, whereby features from one memory are incorrectly incorporated into another. Because the individual elements of a conjunction event have been truly experienced, albeit in a different combination, these errors can be highly compelling and experienced with a sense of recollection (Reinitz et al., 1992, 1994; Reinitz, 2001). Despite the myriad of opportunities for conjunction errors to arise in AM, inducing enough errors in recent AMs in a laboratory environment to allow empirical study is challenging, due to the complex and deeply personal nature of the stimuli. As such, to date only two studies have explored the occurrence of these errors in the autobiographical domain (Burt et al., 2004; Odegard & Lampinen, 2004). The studies in this thesis replicate and expand upon these prior studies, illuminating several factors that influence the prevalence of AM conjunction errors.

In *Study 1* we extended findings of an imagination inflation effect reported in the literature on wholly false episodic memories (e.g., Garry & Polaschek, 2000; Heaps & Nash, 2001; Loftus & Pickrell, 1995; Mazzoni & Memon, 2003) into the domain of AM conjunction errors. *Study 2* corroborates these results, further demonstrating that lures for which conjunction events are imagined are more likely to result in AM conjunction errors than those processed but without explicit imagination. This finding suggests that something more than simple processing fluency underlies this inflation effect. In line with a source monitoring account of false memories (Johnson et al., 1993), we found support for a role of phenomenological quality in the false acceptance of imagined conjunction events as veridical memories. Specifically, in *Study 1* generating a highly vivid and plausible simulation at encoding increased the likelihood of a conjunction error later forming, while in *Study 2* both the subjective and objective quality of conjunction events at retrieval was more similar to that of authentic memories than were correctly rejected imagined events.

In *Studies 3* and *4* the cognitive processes underlying AM conjunction error formation were evaluated through the lens of healthy aging. *Study 3* adds to the literature of an age-related increase in conjunction errors for simple laboratory stimuli (Castel & Craik, 2003; Jones & Jacoby, 2005; Kersten et al., 2008, 2013; Kersten & Earles, 2010; Kroll et al., 1996; Rubin et al., 1999), demonstrating a similar effect for recent, distinctive and personally-relevant AMs. Nevertheless, older adults were not differentially vulnerable to the inflating effects of imagination, suggestive of a generalised susceptibility to conjunction errors with age, potentially due to misattribution of familiarity piqued by the individual components of a lure. The findings from *Study 4* substantiate this idea, revealing that the influence of age on AM conjunction error vulnerability, as well as some of the individual variation observed in younger adults, is attributable to declines in inhibitory capabilities. This lowered inhibition ability may manifest as an inability to suppress the cumulative familiarity of the individual AM components, and the erroneous binding of features due to spreading activation of related memory traces.

The novel autobiographical recombination paradigm employed in *Studies 1*, *2* and *3* was successful in eliciting a small but nevertheless reliable rate of AM conjunction errors, a significant proportion of which were experienced with a sense of recollection. Across these studies, 81% of younger adults generated at least one AM conjunction error, an average of 3 errors per participant. This rate is comparable to the two previous studies on AM conjunction errors, which report a false acceptance rate of 1.5 lures (Odegard & Lampinen, 2004) and 5.9 lures per person (Burt et al., 2004). Our rate of AM errors is especially notable comparative to these earlier studies considering we allowed for varying levels of plausibility in the lures, utilised relatively recent AMs, and did not require time-intensive recording of diaries.

6.2 Heuristic contributors to source misattribution of AM conjunction errors

When determining the source of a mental experience, automatic heuristics may be employed in place of more comprehensive source evaluation methods, due to impoverished encoding, high retrieval demands, or poor executive functioning, all of which may result in the adoption of a lax monitoring criteria (Dodson & Johnson, 1993; Hekkanen & McEvoy, 2002; Mitchell & Johnson, 2009; Multhaup, 1995; Schacter, Verfaellie, et al., 1998; Swick & Knight, 1999). In such cases, and in line with a dual processing account of memory (Hintzman & Curran, 1994; Jacoby, 1991), the familiarity garnered by the individual memory components can be incorrectly considered a marker of event authenticity, particularly in the absence of recollection of the original feature combination (Jones & Bartlett, 2009; Jones & Jacoby, 2001, 2005; Marsh et al., 2002; Rubin et al., 1999). The findings from *Studies 3* and *4* implicate executive functioning (and thus the PFC) as a key contributor to the prevalence of AM conjunction errors, in that both the heightened vulnerability towards these errors with age, as well as individual variation in susceptibility, appear largely accountable by differences in inhibition ability. Reductions in the efficacy of inhibition may result in a lowered ability to suppress the familiarity inherent in the individual components of a conjunction lure (Jones & Jacoby, 2001). The increased rate of AM conjunction errors in the associative compared to the new condition in *Study* 3 (and to a lesser extent *Study 2*) implicates a further misattribution of familiarity with the conjunction lure as a whole as a result of prior exposure.

Plausibility can also provide a quick source heuristic, whereby presentation of an implausible recombination in the source test terminates search for a relevant event, resulting in automatic dismissal of that lure (see Mazzoni, 2007; Pezdek, Blandon-Gitlin, & Gabbay, 2006; Reder, Wible, & Martin, 1986; Scoboria, Mazzoni, Jarry, & Shapero, 2012). The culmination of *Studies 1* to *3* demonstrate that enhanced subjective judgements of plausibility of an imagined event increases the likelihood of subsequent conjunction error formation, consistent with previous empirical research demonstrating an influence of plausibility on acceptance of entirely false AMs (Mazzoni et al., 2001; Mazzoni, 2007; Pezdek et al., 2006; Scoboria et al., 2004). Furthermore, a robust effect of the degree of recombination on AM conjunction error rate was found across *Studies 1, 2* and *3*, whereby partially recombined lures were more likely to result in false alarms than fully recombined lures. Because only a single detail was incongruent, partial recombinations likely facilitated the formation of more believable events, as evidenced by the higher subjective plausibility ratings given to conjunction events imagined in response to partial lures. Interestingly, the enhanced false acceptance rates of partially recombined sets persisted even at high levels of plausibility and vividness in *Studies 1* and *2*, indicative of an additional fluency effect. The relative ease of constructing a scenario for partial recombinations translates to more fluent retrieval, which may further be used as a heuristic indicator of event veracity (Johnston et al., 1985; von Glahn et al., 2012; Whittlesea, 1993).

In some cases plausibility may also be used as a deliberate source identification method, in which one draws from supporting memories and self-beliefs to verify the credibility of an event (Johnson et al., 1993; see also Mazzoni et al., 2001; Scoboria, Mazzoni, Jarry, & Bernstein, 2012). The plausibility of imagined conjunction events at the time of encoding also likely assists in the construction of detailed and convincing scenarios, through the provision of a framework allowing elaboration and integration with existing memories (Anderson, 2012; Pezdek et al., 2006; Sharman & Scoboria, 2009). Indeed, increased ratings of plausibility have been correlated with increases in ease of simulation, arousal and vividness (Szpunar & Schacter, 2013; though see Anderson, 2012), which contribute to the memorability of a simulated event (McLelland et al., 2014; Szpunar et al., 2012). Conversely, more vividly experienced simulations may also have been judged as more probable, as it is likely a reciprocal relationship exists between subjective vividness and plausibility (Pezdek et al., 2006).

6.3 Phenomenological contributors to source misattribution of AM conjunction errors

While AM conjunction errors tend to arise due to reliance on automatic source monitoring heuristics, these errors can also be endowed with recollective experience, and may surpass even stringent source monitoring checks (Burt et al., 2004; Odegard & Lampinen, 2004). This phenomenon was clearly demonstrated in the current thesis by the maintenance of over a third conjunction errors in the recall phase. This thesis raises the possibility that an over-binding of individual memory features contributes to the formation of AM conjunction errors that are experienced with a sense of recollection (Dodson et al., 2007; Fandakova et al., 2013). Declines in inhibition ability may lead to deficits in preventing excessive feature binding during pattern separation and completion (Schacter, Norman, et al., 1998) resulting in the miscombination of elements from overlapping memory traces into one integrated representation (cf. activation monitoring theory, Roediger, Balota, & Watson, 2001; see also Lampinen, Meier, Arnal, & Leding, 2005; Lyle & Johnson, 2006, 2007; Gallo & Roediger, 2003). Poor inhibitory control explains a proportion of the increase in AM conjunction errors observed for older adults, identifying one mechanism by which the aging process heightens susceptibility to erroneous feature transfer across memories. However, further research is needed to substantiate the link between PFC-mediated inhibition capacity and excessive featuring binding (see for example, Henkel, Johnson, & De Leonardis, 1998; Lyle, Bloise, & Johnson, 2006; Lyle & Johnson, 2006), as many studies exploring the cognitive underpinnings of memory distortions focus more broadly on executive functioning, which may be comprised of a number of separable processes, such as conceptual fluency, updating and inhibition (Latzman & Markon, 2010).

According to the source monitoring account of false memories (Johnson et al., 1993), simulated experiences that are phenomenologically rich, and therefore similar in quality to authentic memories, are more likely to be misidentified as such. A number of findings across the studies in this thesis are consistent with this idea. The highest rate of conjunction errors were observed for those lures for which a past event was imagined, reflective of an imagination inflation effect resulting from enhanced phenomenological quality (see Devitt & Addis, in press; Garry & Polaschek, 2000; also Heaps & Nash, 2001; Loftus & Pickrell, 1995; Mazzoni & Memon, 2003; Garry & Wade, 2005; Braun, Ellis, & Loftus, 2002; Gamboz, Brandimonte, & De Vito, 2010). *Studies 1* and *2* demonstrate that generating a more vivid simulation during imagination further increased the likelihood of a conjunction error arising in the source test, potentially both because such simulations were more similar in quality to veridical memories (see Dobson & Markham, 1993; Gonsalves et al., 2004; Hyman, Gilstrap, Decker, & Wilkinson, 1998; Johnson et al., 1993; Lampinen, Odegard, & Bullington, 2003; Okado & Stark, 2005; Thomas, Bulevich, & Loftus, 2003; von Glahn et al., 2012), and were more memorable over time (Martin et al., 2011; McLelland et al., 2014).

Across the recall phases of *Studies 1* to *3*, 50% of younger adults maintained the authenticity of – and recollected details for – at least one conjunction error, when only a week prior they had explicitly claimed no event had taken place for that combination of features. In comparison, an average of 31% of individuals generate a false memory in imagination inflation studies for childhood AMs (Lindsay et al., 2004). Our rate of AM errors is particularly noteworthy given the relatively short self-guided imagination period used (20-30 seconds per event), as opposed to time-intensive experimenter-guided imagination sessions typical of previous imagination inflation studies (e.g., Garry & Wade, 2005; Loftus & Pickrell, 1995; Wade, Garry, Read, & Lindsay, 2002). Also noteworthy is the fact that the distorted memories were from recent adulthood (at most 10 years old, but on average only 2 years old), whereas previous studies have focused on childhood AMs. Many memory distortion studies do not allow for differentiation between false *belief* and false *memory*, yet a belief can be held that a past event took place without necessarily recalling an explicit memory about the event (Scoboria et al., 2004; see also Hyman & Loftus, 1998) and vice versa (Mazzoni & Kirsch, 2002; Mazzoni, Scoboria, & Harvey, 2010). In the current studies, the persistence of approximately a third of the AM conjunction errors into the recall phase indicates that a significant proportion of these errors can be classified as a type of rich false memory (Loftus & Bernstein, 2005), rather than simply false beliefs.

At retrieval, conjunction error events were rated as intermediate between real and imagined events in several properties typically distinctive of authentic memories, including subjective vividness, emotionality and personal significance, and were often viewed from a first-person perspective (Heaps & Nash, 2001; Johnson, Foley, Suengas, & Raye, 1988; Johnson et al., 1993; Justice, Morrison, & Conway, 2013; Marsh, Pezdek, & Lam, 2014; McGinnis & Roberts, 1996; Nigro & Neisser, 1983; Vella & Moulds, 2013). The objective measures of memory content add another layer to the phenomenological similarities between memories differing in veracity. Few studies have explored the phenomenological attributes of false memories using independent measures of event quality (Heaps & Nash, 2001; Mazzoni & Memon, 2003; Schooler, Gerhard, & Loftus, 1986; see also Vrij, 2005). *Studies 2* and *3* are novel in the use of the AI to objectively examine the content of false memories, as well as in contrasting the phenomenology of memory distortions with correctly sourced imagined events, which stands as a critical control condition (see McGinnis & Roberts, 1996, for a similar comparison). Our results indicate that while AM conjunction errors are objectively not as richly experienced as authentic memories, they are more so than events correctly identified as imagined. In particular, conjunction errors were higher in perceptual quality and information relevant to the unfolding of the event, which may be enough to dupe the source monitoring system into accepting the events as authentic memories.

These differences in event content have implications for the on-going effort to objectively identify false memories, which if successful would be invaluable in determining the veracity of eyewitness accounts (see Simpson, 2008). While the current data in no way allow for this discrimination, and certainly not at the level of individual events (and indeed, some have questioned whether it is possible at all; Bernstein & Loftus, 2009b; Schacter &

Loftus, 2013), the results are indicative of fine-grained objective differences existing between memories of differing authenticity. However, in a testament to the difficulty in distinguishing events according to veracity, the precise phenomenological qualities of AM conjunction error events differed across the studies reported in this thesis. *Study 2* implicated perceptual detail as a substantial driver of AM conjunction error generation, mirroring the subjective vividness ratings (see Gonsalves et al., 2004; Johnson et al., 1993; Thomas et al., 2003; von Glahn et al., 2012). In contrast, *Study 3* identified event/plot details as differentiating conjunction errors from identified imagined events, for both younger and older adults. Small differences in methodology, such as the time allowed for imagination, intervening days between sessions, number of overall memories used, or even simply population sampling effects, may have resulted in reliance on slightly different source identification strategies across the studies. These inconsistencies further highlight the complexity in objectively determining the veracity of a group of memories, let alone one single experience.

6.4 Applications and future directions

The studies in this thesis demonstrate that AM conjunction errors can be influenced by similar processes as those that form conjunction errors for simple laboratory stimuli, as well as those leading to entirely false AMs. Thus, it is becoming increasingly clear that memory distortions are better thought of as interrelated constructs rather than discrete categories. Indeed, false memories for entire events may be viewed as a combination of conjunction and gist-based errors, in that content is borrowed from authentic memories in order to fabricate a recollection (Garry & Wade, 2005; Lampinen et al., 2005; Lindsay et al., 2004; see also, Anderson, 2012), while gaps are filled with schematic knowledge (Bartlett, 1932; Foley et al., 2007; Kleider, Pezdek, Goldinger, & Kirk, 2008; Reyna & Brainerd, 1995; Strickland & Keil, 2011). Moreover, as demonstrated in *Studies 2* and *3*, both AM conjunction errors and entirely false memories are subject to the imagination inflation effect, which may be considered a form of internally-generated misinformation (Gerlach et al., 2013; Loftus, 2005; Reyna & Lloyd, 1997). Questions have been raised about the fate of the initial memory following misinformation (e.g., Hupbach, Gomez, Hardt, & Nadel, 2007; Hupbach, Gomez, & Nadel, 2009; McCloskey & Zaragoza, 1985) – similar questions can be asked regarding AM conjunction errors: does the altered feature override the original, or form part of a new memory trace? Answering this question in the future will further elucidate the mechanisms underlying the generation and maintenance of these and other memory errors.

It is important to note that AM conjunction errors may not only be a by-product of an otherwise advantageous memory system, but may hold adaptive value in and of themselves. The AM system is deeply intertwined with one's self-construct (see Conway, 2005), and we are inclined to misremember the past in a way that belies a sense of consistency or improvement in our sense of self over time (Bahrich, Hall, & Da Costa, 2008; Karney & Coombs, 2000; Sharman, Garry, Jacobsen, Loftus, & Ditto, 2008; Wilson & Ross, 2003), thereby reducing cognitive dissonance (Rodriguez & Strange, 2015), and leading to a more positive and emotionally gratifying self-construct (Newman & Lindsay, 2009). As such, memories are constantly changing, being altered to fit with self-schema (Bartlett, 1932; Neisser, 1986) and updated to accommodate recently acquired information (Lee, 2009; Schacter et al., 2011; Tse et al., 2007). AM also serves a strong social purpose (Alea & Bluck, 2003; Ciaramelli et al., 2013), whereby changes to and elaborations upon a memory provide for a more coherent and engaging story during conversation (Principe & Schindewolf, 2012).

It has recently been shown that content from another individual's AMs may be borrowed in order to embellish one's own memories in social situations, and such appropriation can lead to confusion over the initial source of the memory trace (Brown, Croft Caderao, Fields, & Marsh, 2015). With this in mind, future research may provide participants with ready-made conjunction events to elaborate upon (for example, Gerlach et al., 2013). It is thought that the effort required to actively generate an imagined scenario can imbue the simulation with information about the cognitive operations involved in its construction, which may later provide a cue as to the correct source of the experience, thereby dampening the imagination inflation effect (Johnson et al., 1988, 1993; Johnson, Raye, Foley, & Foley, 1981; McDonough & Gallo, 2008). Providing participants with a scenario removes the effort of constructing an event, which could confer an increased inflation effect (see for example, Foley, Cowen, Schlemmer, & Belser-Ehrlich, 2012).

6.4.1 Eyewitness testimony

The fallibility of memory is ubiquitous, permeating all memories (Greenberg, 2004; Neisser & Harsch, 1992; Nourkova et al., 2004; Schmolck et al., 2000) and individuals (Patihis et al., 2013), and resulting in measurable repercussions on attitudes and behaviour (Bernstein, Scoboria, & Arnold, 2015; Geraerts et al., 2008; Laney, Morris, Bernstein, Wakefield, & Loftus, 2008; Scoboria, Mazzoni, & Jarry, 2008). While the majority of memory errors may pass by unnoticed, or may even provide some adaptive value, in some circumstances memory authenticity is of vital importance; particularly within the legal system where memory imperfections provide a significant challenge (Buckhout, 1975; Howe & Knott, 2015; Loftus, 2003; Schacter & Loftus, 2013). Less than 10% of criminal cases in the USA obtain physical evidence or use forensic science, meaning that the majority of prosecutions are based on eyewitness testimony (see Zember, Brainerd, Reyna, & Kopko, 2012). Yet faulty eyewitness accounts were a factor in over 75% of the first 250 cases in which DNA evidence was used for exoneration (Garrett, 2011). Even the accused may themselves remember distorted versions of the event in question, in some cases leading to false confessions (Kassin, Bogart, & Kerner, 2012; Nash & Wade, 2009; Shaw & Porter, 2015). Thus it is imperative for an effective justice system to recognise the conditions under which memory can become distorted, as currently no behavioural or neuroimaging methods exist that can reliably distinguish between true and false memories (Bernstein & Loftus, 2009a), and even personal confidence in the accuracy of one's memory is not necessarily a reliable indicator of genuine accuracy (Talarico & Rubin, 2003).

AM conjunction errors can contribute to flawed eyewitness accounts; for instance, spectators can conflate the perpetrator of a crime with innocent bystanders (Buckhout, 1975; see also Kersten et al., 2008, 2013; Kersten & Earles, 2010). This thesis is novel in the examination of distortions in *recent* AMs, which more often than not are the subject of inquiry in eyewitness testimony (Flin et al., 1992; Read & Connolly, 2007). Our results indicate that witnesses may be vulnerable to such errors if questioning conditions mean a suboptimal verification strategy must be used (Wade & Garry, 2005), resulting in reliance on heuristic decisions of plausibility and fluency, which may be exacerbated by a poor ability to inhibit the integration of erroneous details. Moreover, we demonstrated that conjunction errors that are endowed with phenomenological quality are more likely to be regarded as authentic, even under more rigorous source monitoring checks. This enhancement of recollective quality may occur during discussions with other witnesses (Gabbert, Memon, & Allan, 2003; Jack, Zydervelt, & Zajac, 2013; Shaw, Garven, & Wood, 1997; Zajac & Henderson, 2009), or even during interrogation itself (Kassin & Gudjonsson, 2004; Leding, 2012; Poole, Lindsay, Memon, & Bull, 1995). An interesting prospect for future research would be to determine the degree to which multiple questioning sessions induces single feature substitutions across related memories, potentially resulting in a build-up of AM conjunction errors in one memory trace over time.

The increased susceptibility to AM conjunction errors with age also has relevance for eyewitness testimony (see for example Adams-Price & Perlmutter, 1992). Older adults are more likely to report incorrect information in an eyewitness account (Aizpurua, Garcia-Bojos, & Migueles, 2009; Cohen & Faulkner, 1989; Kersten et al., 2013), and can be more confident in the accuracy of their memory errors than younger adults (Aizpurua et al., 2009; Cohen & Faulkner, 1989; Jacoby & Rhodes, 2006; Karpel, Hower, & Toglia, 2001; Loftus, Levidow, & Duensing, 1992; although note that the current studies are inconsistent with these findings regarding confidence). Distortions in AM may further have implications for healthy aging; a functional AM system is vital for preserving a high quality of life with advancing age, particularly with regards to maintaining independent living (Farias et al., 2009; Rog et al., 2014) and a positive outlook (Serrano, Latorre, Gatz, & Montanes, 2004). With a rapidly aging population in New Zealand (Statistics New Zealand, 2006) and other Western and Asian countries (see Wylie et al., 2014), fully exploring the prevalence and nature of memory errors in older adults will only become more imperative in the coming decades.

6.5 Limitations

Any study exploring memories in the autobiographical domain must reach a compromise between experimental control and ecological validity (Levine, 2004), and as such the studies in this thesis are not free from limitations. One limitation lies with the associative condition employed in *Studies 2* and *3*, for which we used a pleasantness judgement task. This task was designed to provide a means of deep encoding without imagination (Gaesser et al., 2013; Jacoby et al., 2005) in order to separate the influence of processing fluency from phenomenological quality in the imagination inflation effect. However, the hit rates when determining source for detail sets presented in the associative condition were at chance for both younger and older adults (consistent with the accuracy rates reported in Gaesser et al., 2013), suggesting that the pleasantness task may not be equal to imagination with regards to evoking increased familiarity over time, and thus may not be an optimal control task. Despite the relatively low hit rate, lures presented in the associative condition were more likely to result in conjunction errors than those in the new condition, speaking in favour of the provocation of a sense of familiarity as a result of the pleasantness judgements. However, a control condition that equates hit rate with the imagination condition may be better suited to fully account for the contribution of fluency to the imagination inflation effect in AM conjunction errors.

Another limitation with the current studies is the difficulty in teasing apart a general bias towards responding “real”, from an influence of familiarity with the individual lure components. The lures presented in the new condition were not completely novel, in that the comprising people, place and object features originate from AM and are thus inherently familiar. Therefore, a higher rate of conjunction errors in the new condition is not necessarily indicative of a liberal response bias, but may instead reflect a heightened sensitivity to this familiarity. In future studies, including a condition in which unfamiliar memory components are used (for instance, taken from another individual's memories) may help disambiguate these two effects (see Castel & Craik, 2003; Giovanello, Kensinger, Wong, & Schacter, 2010; Jones & Jacoby, 2005). Future research may also benefit from exploring the likelihood of conjunction errors forming when different types of memory features are altered. In the current paradigm we used person, place and object details due to their likely consistency across the timeframe of a single event. However, AMs are composed of many other types of features that could be transferred across memory traces, including (but by no means limited to) emotions (Odegard & Lampinen, 2004), activity (Burt et al., 2004), smell and internal thoughts.

It is also possible that the participant's eagerness to please the examiner inflated claims of conjunction errors (Ost et al., 2002; Porter, Birt, Yuille, & Lehman, 2000); for instance, individuals with high compliance have a greater propensity to accept misinformation (Frost et al., 2013). The AI may be particularly susceptibility to such effects; it has been shown that the interacting personalities of the interviewer and participant can alter susceptibility to memory distortions (Porter et al., 2000), and participants may further tailor event descriptions to focus on those details they believe the examiner is most interested in. The prompts used in the AI were purposefully general (e.g., "is there anything else you can tell me?") in order to avoid unduly leading or directing participants' reports in such ways (see Appendix B), though future studies may benefit from including personality measures in order to account for individual differences in willingness to comply with testing procedures.

Lastly, although the neuropsychological tests employed in *Study 4* were informative regarding the contribution of mnemonic and executive functions, they cannot provide a direct measure of cortical functionality. Given these data would provide a more detailed understanding of the neurocognitive changes that contribute to conjunction errors, we have invited participants from *Study 3/4* to complete an additional neuroimaging session, in which we obtain a more direct measure of neural integrity using structural and functional MRI. Data collection is currently underway; consistent with the findings of *Study 4*, we expect structural declines in frontal areas to be related to an increased rate of AM conjunction errors (see Brassen et al., 2009; Marchewka, Jednoróg, Nowicka, Brechmann, & Grabowska, 2009). Employing fMRI will further allow us to examine the functional connectivity between MTL and PFC regions. Individuals displaying lowered inhibition ability and an increased susceptibility to AM conjunction errors are likely to exhibit reduced connectivity of these regions, an effect that may be especially pronounced in the older adults, reflective of a less prominent role of supervisory frontal areas during AM retrieval (Andrews-Hanna et al., 2007; Gutchess et al., 2005; Simons & Spiers, 2003; St Jacques, Rubin, & Cabeza, 2012; but see Fuentemilla et al., 2009)

6.6 General conclusion

The constructive nature of memory, whereby constituent features of a single memory trace are distributed throughout the cortex and are indexed by the hippocampus (Lavenex & Amaral, 2000; McClelland et al., 1995; Squire, 1992b; Yassa & Reagh, 2013), allows for transference of features between memories and the formation of memory conjunction errors that surpass typical reality monitoring checks. This thesis serves to highlight the complexity of AM conjunction errors, illuminating several factors that contribute to their formation, including familiarity with the individual components of the recombination, as well as the fluency, plausibility, and phenomenological characteristics of the associated imagined event. The more that we learn about the nature of memory, the blurrier the line between true and false memory becomes. Our life stories are assembled from fragments of the past and built on a foundation of schematised knowledge about the self and the world; although these reconstructions may not always provide an entirely accurate representation of external reality, they nevertheless form our subjective reality.

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Appendices

Appendix A: List of cues provided to participants to facilitate retrieval of autobiographical memories

Younger adults

- Birthday party
- Family celebration
- Attending a funeral
- Attending a wedding
- Baby shower
- A good or bad babysitting experience
- A heated argument
- Particularly bad weather
- Experiencing an earthquake
- Going to a concert
- Going to a play/opera/ballet
- Visiting a museum
- Visiting a gallery
- Visiting the zoo
- Visiting an aquarium
- Going to a party
- Giving/receiving a gift
- Going to a good/bad restaurant
- Flying in a plane
- Buying something large
- Taking a driving test
- Buying a car
- Getting into or seeing a car accident
- Getting a parking ticket
- Getting a speeding ticket
- A bad experience at the dentist
- Losing/winning money at a casino
- Going on a date
- Having a first kiss
- A good or bad Valentine's Day
- A good or bad New Year's Eve
- A school reunion
- Moving to a new house
- Taking a trip overseas
- Packing for a trip overseas
- Staying in a hostel/hotel
- Goodbye party
- Getting a pet
- Losing a pet
- Meeting a new friend
- Meeting a celebrity
- Giving a presentation
- Performing in a play or concert
- Taking an exam
- Losing your wallet
- Finding something valuable
- Doing something embarrassing
- Being late for something
- Hurting someone's feelings
- Telling a lie
- You or someone you know being ill
- Getting food poisoning
- Having an operation
- Getting a good or bad haircut
- Participating in a sport
- Winning an award
- Bungee jumping
- Surfing
- White water rafting
- Going up the Sky Tower
- Trying something for the first time
- Tramping/camping
- Staying at a bach
- Going on a ferry trip
- Watching a sports game
- Going to the beach
- Whale watching
- Job interview
- First day on a job
- A bad day at work
- Leaving a job
- First day of high school
- Going to a high school dance
- Winning a prize
- High school graduation
- School trip
- Visiting universities
- Acceptance to university
- First day of university
- Moving into residence
- Moving into a flat
- Meeting room/flatmates
- A conflict with flatmates
- Painting a room/house
- Buying textbooks
- Inappropriate cell phone ring times
- Walking into the wrong classroom
- Forgetting/confusing someone's name in conversation
- Cheating on a test
- Receiving a care package
- Participating in an experiment
- Voting for the first time
- Tutoring

Older adults

- Birth of grandchild
- Graduation of child/grandchild
- A recent holiday celebration
- Attending fireworks
- Having a picnic
- Attending/having a birthday party
- Relative/friend visiting
- Visiting a relative/friend
- Attending a family reunion
- Attending a work/school reunion
- Argument with someone
- Attending a retirement party
- Going to a sporting event
- Going to a play
- Going to a movie
- Witnessing an accident
- Losing something important
- Being embarrassed
- Death of a friend/relative
- Being in an accident/getting injured
- Going to a wedding
- Going to a funeral
- Participating in a research study
- Going out to a restaurant
- Telling a lie
- Stealing something
- Getting lost
- Being hospitalized
- Visiting a relative/friend in hospital
- Dentist/doctor’s visit
- Seeing someone famous
- Being in a storm
- Being in/hearing about a disaster
- Going to a christening/baptism
- Going to a party
- Giving a gift
- Receiving a gift
- Buying a new suit/dress
- Buying a new appliance
- Buying a car
- Buying new furniture
- Going to the South Island
- Traveling abroad
- Going to the beach
- Getting robbed
- Getting a new job
- Attending a parade
- Buying a new book
- Buying a new computer
- Family member losing job
- Joining a new organization
- Church/community event
- Writing/updating a last will
- Visit to a museum
- Attending a concert
- Taking a particularly nice walk
- First meeting with grandchild's spouse
- Catching up with an old friend
- Receiving an award
- Rediscovering old pictures
- Finally making "that big purchase"
- Discovering spoiled food in the fridge
- Meeting a new neighbour
- Moving house
- Losing your wallet/phone
- Fixing something that's broken in the house
- Incident while on the motorway
- Staining a well-liked article of clothing
- Encounter with landlord/tenants
- Difficulty at pharmacy
- Winning something
- Preparing a special meal
- Finally finishing a long-term project
- Memorable shopping trip
- Going to an engagement party
- Babysitting the grandchildren
- Trying a new recipe
- Visiting a newly opened store
- Attending a sale
- Being late to an appointment/event
- Doing a good deed/helping someone
- Volunteering event
- Taking a class
- Hearing some news about a friend/relative
- Getting your hair cut/styled
- Applying for/renewing your passport
- Renewing your driver's license
- Losing your luggage
- Being delayed in the airport
- Taking a day trip
- Planting a new garden / harvesting a garden
- Visiting a farmer's market
- Burning something
- Dropping something
- Falling over
- Getting caught in the rain
- Vehicle breaking down
- Trying to find parking

Appendix B: General instructions for Sessions One, Two and Three

Note that some of these instructions were excluded depending on the study.

Session One

In this study we are interested in a particular type of memory called autobiographical memory, which is your own personal memory for things that have happened to you in your lifetime. In today's session, I would like you to recall [number] memories of events that you have experienced within the past 10 years.

Each event should be something that happened on a particular day, in a particular place. In other words, it should be a unique event with a specific time and place. Try to avoid routine events that you do over and over again, for example a general scenario of going supermarket shopping, but not a particular occasion. The events do not have to be important or significant, they can be minor, like a memorable phone call or lunch with a friend.

Each event might have lasted for a couple of minutes, a couple of hours, or as long as a whole day, but no longer than a day. So if you are recalling something which happened over an extended period (e.g., a 3 week holiday), you should report one or more of the mini specific events that happened within this timeframe (e.g., scuba diving, shopping).

Events must be things that you personally experienced. Do NOT give events that you only heard about but weren't actually there. Also, we will be using these events for the rest of the study, so if there is anything you are uncomfortable with, it is best not to include it.

For each event you will report 5 things:

1. A very brief description of the event (so we can be sure it is specific in time and place).
2. The year the event happened.
3. One main person in the event (NOT YOU). It's OK if you cannot remember the person's name, instead describe them in one or two words (e.g. Joe's Dad). If there were multiple people at the event, choose the person who stands out to you as the main person.
4. The location of the event. BE SPECIFIC. For example, instead of "my house", put "my kitchen". Instead of "France", put "Croissant Café in France".
5. A main object in the event. This can be clothing, furniture, food, animals, etc. BE SPECIFIC. For example, instead of "laptop", put "my laptop" or "Joe's laptop". Instead of "jumper", put "my blue cat jumper".

Details should be specific enough that if you were to see that detail alone (without the accompanying memory description or other details), you would be able to form an image of that precise detail in your mind. Try not to duplicate details across events. Think of events that involve as many unique people, places and objects as possible (for example, try not to over use events with your best friend in them). We have a list of cues to help you come up with these events, but please don't feel limited to using only those cues.

Session Two

Last session we were interested in how you remember the past, and in this session we're interested in how you think about the past. What I've done is taken the person, place and object details from the memories you gave me last session, and I've jumbled them all up, or in other words I have recombined them. So you're going to see detail sets on the screen, each with a person place and object, but these details will come from two or three separate memories. So the person might come from one memory, and the place and object from another. Today you will be doing two tasks involving these recombined detail sets.

<u>Imagination task:</u>

For each detail set you will have 30 seconds to imagine a plausible past event involving all three of the details you see on screen. This will be done silently in your own head.

There are a couple of guidelines for the events you will imagine:

- The event must be novel. By that I mean that I don't want you to *remember* something that has happened, I want you to make up a new event that hasn't actually to you before.
- As with the memories last session, try to stick within the past 10 years for the events you imagine. So don't imagine things happening when you were a young child for example. When you are imagining the event try to think what time in your life this could be occurring.
- Try to imagine as plausible an event as possible.
- All three of the details should be included in the imagined event. The person and object should be physically present in the location.
- Try to imagine the event though your own eyes, as if you were actually there experiencing it, rather than from an external vantage point.
- Avoid general events (things that happen over and over again, like going to the supermarket).

Use the entire 30 seconds to add as much detail to the imagined event as possible. Possible things to think about when imagining could be: What do you see? When is this happening? Why is this happening? How are you feeling? Include sensory detail such as sights, sounds, smells, etc. A bell will sound at the end of the 30 seconds and the screen will change.

(Study 1 only) If a combination of details reminds you of a real memory that also involved those three details, please press the 'R' button (for remember) while the details are still presented onscreen, and for both ratings.

After you've imagined an event for 30 seconds you will be asked to make some ratings about the event. You will be using the numbers on the keyboard to indicate your ratings.

- *(Study 3 only)* Has an event involving these 3 details actually occurred? This is asking whether the combination of details (not necessarily the event you imagined) is similar to anything that has truly happened to you in the past. Yes = Y, No = N. Only say yes if ALL THREE details were involved in the past event *(note for Study 2 this is a rating scale of similarity to previous events).*

- VIVIDNESS: How vivid was the event, or how detailed is it when you picture it in your mind? This is on a scale of 1-5, 1 being you didn't imagine anything, 5 being the event was clear and detailed and plays out like a movie in your mind.
- PLAUSIBILITY: How plausible was the event? Again on a scale of 1-5, 1 being the event would never happen in a million years, 5 being the event is really plausible, and is something that could have happened.

Lastly you will type a brief sentence about what you imagined. I am getting you to do this because the imagination part was done silently in your head, so this gives me an idea of what you imagined.

(For the practise instruct the participants to do the imagination aloud so that you can make sure they understand the instructions. Emphasise that for the real task they will do this part silently.)

(Study 2 and 3) Pleasantness judgement:
For each detail set I want you to rank the details in order of pleasantness, from highest to lowest. This judgement is entirely subjective; put them in order according to how pleasant (or unpleasant) they feel to you. Once you have made this decision, think about *why* you have made this decision for the rest of the 30 seconds.

A bell will sound after 30 seconds, the screen will change and you will be making some ratings.

- *(Study 3 only)* Has an event involving these 3 details actually occurred? This is asking whether the combination of details is similar to anything that has truly happened to you in the past. Yes = Y, No = N. Only say yes if ALL THREE details were involved in the past event *(note for Study 2 this is a rating scale of similarity to previous events).*
- DIFFICULTY: How difficult was it to put them in order? This is on a scale of 1-5, 1 being low difficulty, meaning it was easy to decide what order to put them in, 5 being so hard you couldn't decide on an order.
- AVERAGE: If you took the average pleasantness of the three details, where would it fall on a scale of pleasantness? Again this is on a scale of 1-5, 1 being all three details were unpleasant, 3 is the average is neutral, and 5 is all details are very pleasant.

Lastly you will write a sentence, letting me know what order you put the details in, (highest-lowest).

(For the practise instruct the participant to do the pleasantness judgement aloud so that you can make sure they understand the instructions. Emphasise that for the real task they will do this part silently.)

<u>Imagination screens</u> *(shown to participants)*

30 seconds

Imagine a past event Sally Field My office Purple high heels

<u>Example response</u>

"I imagine Sally Field meeting me at my office a few months ago, she was meeting me for lunch. She was wearing a red dress with purple high heels. Her heels were really high, so she tripped over the ledge in the door and nearly fell over, but grabbed the table to support herself. We both ended up laughing."

Has an event involving these 3 details together actually occurred before? Y=Yes, N=No

Rate VIVIDNESS low 1 2 3 4 5 high

Rate PLAUSIBILITY low 1 2 3 4 5 high

Write a short sentence about the event that you imagined.

"Sally met me at the office, wearing heels and tripped."

Pleasantness screens *(shown to participants)*

30 seconds

Order by pleasantness

Henry Head
Library
Banana skin

Example response

"Henry Head is a bit too loud for my liking. I love the library much more than Henry, because I like reading and it is a quiet place to study. I hate bananas, so the banana skin would be unpleasant. So the order I would put them in is library, then Henry, then banana skin."

Has an event involving these 3 details together actually occurred before?

Y=Yes, N=No

Rate DIFFICULTY

low 1 2 3 4 5 high

Rate AVERAGE PLEASANTNESS
low 1 2 3 4 5 high

Write a short sentence indicating pleasantness order (highest-lowest).

"Library then Henry then banana skin."

Session Three
Today is split into two parts. The first task you'll be doing is a memory test on the computer. After that I am going to ask you to talk about a few of your remembered and imagined events.

Source test:

On the computer screen you will see sets of details – person, place and object – similar to last session. These detail sets are going to come from 3 different sources.

1. They will correspond to a memory you gave me in Session One.
2. They will be a recombined (jumbled up) set that you saw in Session Two, for which you imagined an event or made a pleasantness judgement.
3. They will be a recombined set that you haven't seen before. The details will still come from your memories, but will be in a combination you didn't see last session.

It is your task to decide which of these categories each detail set belongs – a memory, a recombined set you saw in Session Two, or a new recombination.

You will be using the numbers on the keyboard to indicate your decision; press 1 if you think it is a memory from Session One, press 2 if you think it is a recombined set you saw last session (either imagined or pleasantness judgement), and press 3 if you think it is a new recombination you haven't seen before. It will remind you on each screen which number corresponds to which answer.

After you've made each decision, you will then make a rating of how confident you are in your answer. Like last time, this is on a scale of 1-5, 1 being you have no idea, you made a total guess, and 5 being you are absolutely sure of your answer. Once again you'll be using the keyboard to indicate your rating.

You will have 5 seconds for each detail set to make your decision, and another 5 seconds for the confidence rating. Keep in mind that the program runs on its own time, so if you don't answer within the 5 seconds the screen will automatically change, and if you do respond the screen won't change until the time is up.

(Run practise task. Repeat if necessary until participant is comfortable with the speed.)

Memory task screens

MEMORY (1), OLD (2) or NEW (3)? Susan Slurp Cafe Ham sandwich	CONFIDENCE low 1 2 3 4 5 high

Autobiographical Interview *(Study 2 and 3)*
Now I am going to ask you to describe some of the events you remembered or imagined. To help with scoring, we will be audio-recording your response, but your responses will be kept completely confidential and only your participant number, not your name, will be linked to the recordings.

I will be presenting some detail sets corresponding to either remembered or imagined events. For each event, you will have up to three minutes to tell me as much detail as you can about them. Please tell me everything you remember about the event – what happened, what you can visualise, what you thinking or feeling, and so on. These descriptions are the only way I know how well you remember an event, so tell me everything you think is relevant. Please also speak clearly, since we will be transcribing these audio recordings later on.

For imagined events, stick to what you originally imagined in Session Two, try not to add any new information, as for this session I am not interested in how well you can imagine an event, but rather how good your memory is for the imagined events. After the three minutes is up you will hear a bell, at which point I may have to stop you – not because I'm not interested in what you're staying, but just because we have to stick to the three minute time limit. If there is anything you don't want to share, let me know and we will skip it.

Once you have finished describing the event, I will ask you some questions about it (provide sheet of rating scales). Firstly, I will ask you to tell me whether the event was a memory of something that actually happened to you, or whether it was something you imagined in Session Two. Next, what year the event happened, or if it was an imagined event, what year could it have happened. Then I will ask you to rate how detailed or vivid the event was, from 1 to 5. If it was vague, give it 1, or up to a 5 if it was vivid and detailed and plays out like a movie in your mind. Then you will rate how emotional it makes you feel now to think about this event (regardless of how you may have felt at the time of the event, or the specific type of emotion). Give it a 1 if it does not make you feel emotional at all, up to a 5 it is very emotional for you. Next, you will rate how personally significant the event it, that is how important or life-changing this event was or might have been. Give it a 1 if it is not important and makes little difference to your life, up to a 5 if is an important and life-changing event. Finally, you will tell me from what perspective you saw the event. There are two ways we remember or imagine events; either looking out through our own eyes, similar to what you are doing right now, or from an external or third-person perspective.

General probing if they finish before the 3 mins:
- Is there anything else you can tell me?
- Are there are other details that come to mind?

If the participant provides a vague description of an event:
- Can you tell me more about it?
- What else do you remember about it?

Appendix C: Adapted Autobiographical Interview Scoring Manual

(Version: April 2014)

From: Addis, DR, Wong, AT, Schacter, DL (2008). Age-related changes in the episodic simulation of future events. *Psychological Science, 19,* 33–41.

Adapted from: Levine, B, Svoboda, E, Hay, J, Winocur, G, Moscovitch, M. (2002). Aging and autobiographical memory: dissociating episodic from semantic retrieval. *Psychology and Aging, 17,* 677-689.

Overview

The Adapted Autobiographical Interview quantifies elements of descriptions of specific events from the subject's personal past (i.e., recollections) and events which may occur in the subject's personal future (i.e., simulations). In each trial, a cue word (e.g., "DOG") and a time period (e.g., "Next Few Weeks"; "Past Few Years") is shown. The subject must think of a specific event in the time period that the cue makes them think of, and describe as much detail as possible within 3 minutes. The events must be specific to a particular time and place. When describing events, general probes may be used by the interviewer to focus the subject on a specific event and to encourage full description (e.g., "Can you tell me more about that? Can you describe a specific incident relating to that event?")

The interview is recorded digitally and transcribed. For each event, the scorer isolates or defines the main event, then divides the entire response (including information external to the main event) into small segments (details). These details are categorized as either "internal" or "external" to the main event. This will be explained in more detail below.

Isolating and defining the event

Although the test instructions request specific events, many subjects give more than one event or events that are difficult to define (i.e., non-specific events). It is therefore necessary to be clear what the event is before any scoring takes place. This will come into play when categorizing segments, as segments that are not part of the event (external details) are tallied separately from those that are part of the event (internal details).

Subjects are instructed to provide an event in which they were personally involved and that is singular (not repeated) and specific to a time and place. The event should be restricted in time, no more than a few hours in duration. If an event extends over days or weeks (e.g., a vacation), the scorer must restrict scoring to the best time-restricted event available. If more than one exists, choose the time-restricted event which is described in most detail. In such cases, the examiner will have tried to focus the subject on a single event in the probing conditions.

One of the most difficult scoring situation is when the event is very impoverished or non-existent (e.g., only factual information is given, or an event that was repeated). In such cases, it may be possible to select some details as *probably* specific to an event and to score them accordingly, but qualitative ratings cannot be assigned.

Text segmentation and categorization

A segment, or detail, is an information bit; it is a unique occurrence, observation, fact, statement, or thought. This will usually be a grammatical clause -- a sentence or part of a sentence that independently conveys information (i.e., a subject and a predicate), although a single clause may contain more than one detail. For each clause, consider whether its constituent parts convey additional information. If so, the parts can be separated and scored as separate segments. For example, the statement “he had an old, brown fedora” would be segmented into three details: a “fedora” is different from a “brown fedora”, which in turn is different from an “old brown fedora”. Each of these details adds information that significantly alters the meaning of “fedora”, which on its own would receive one detail.

The main categorical distinction for details is internal or external to the event. To be categorized as **Internal**, a detail must pertain directly to the main event, isolated as defined above. Internal details can include the following:

1) **Event details**. Overall, event details describe the unfolding of the story. They are usually happenings (e.g., "I fell down"), but also include who was there (1 point per name/person up to a maximum of 5), reactions/emotions in others, the weather, one’s clothing if it is part of the action, physical occurrences and actions of others, *temporal sequence* or information about the sequence of events (“Mary came later than Sam”, where “Mary came” is an event detail, and “later than Sam” is a duration/temporal sequence detail). If an item qualifies to be in another category (e.g., perceptual richness), then priority is given to that more specific category. An item cannot be scored as an event detail if it is in another category. *e.g., He jumped out of the chair; It was sunny; My sister Sue was with me; She was jealous/angry/happy; We went to the hotel; It was my birthday.*
2) **Place details**. Any information that involves localization in space, including countries, bodies of water, provinces, cities, streets, buildings, rooms, and locations within a room.
3) **Time details**. Life epoch ("My twenties"), year, season, month, date, day of week, time of day, or clock time. It has been argued that one cannot directly encode or retrieve temporal information (i.e., when an event occurred), but only infer it from other information. That is, it is not possible to re-experience a given point in time without reference to some related episodic thought, feeling, or other detail. Therefore, when scoring time information, people should not be penalized for making inferences (which are usually scored as "other" details), because this is the normal way to figure out when something occurred.
4) **Perceptual details**. Perceptual details include auditory, olfactory, tactile/pain, taste, visual details. More information on some particular aspects of perceptual details:
   Visual (but non-spatial). Object details, colours, clothes. In the case of objects, it can be difficult to distinguish between a perceptual and an event detail. Objects that are directly involved in the unfolding of an event are considered event details ("We lit the candles") whereas objects that are part of the visual landscape are considered visual details ("There were lit candles everywhere").
   Duration. Duration information ("We were there for 20 minutes")
   Spatial orientation. Details about positions, distances, and orientations in allocentric/egocentric space, e.g. one's own orientation in space ("I was to the right of Edgar").
5) **Emotion/Thought details**. Any detail that pertains to the mental state of the subject at the time of the event. These include feeling states, thoughts, opinions, expectations, or beliefs. Thoughts expressed in retrospect (either at the time of the interview or at any time after the event occurred - "I found out later I was wrong") are tallied as external. Beliefs or opinions that are long-standing (not specific to the event - "I never believed in ghosts") are

also external and are scored as semantic details. Inferences about other people's mental state ("She was sad") are considered event details, unless these inferences reflect the subjects' own mental state at the time ("I thought he was angry with me"), in which case they are internal thought details.

External details events that are not part of the main event or factual (semantic) information that is not specific to the main event. These can include the following:

1) **Semantic details**. Semantic details involve general knowledge or facts. They can represent general knowledge ("Paris is the capital of France") or be specific to the person ("I always hated yams." "I worked as an engineer"). The distinction between semantic and other kinds of details can depend on the context. For example, "Paris fell to the Germans" would be semantic if it is described as a historical fact ("We couldn't go to Paris because it was in German hands") or an event detail ("We watched in disbelief as Paris fell to the Germans.") In general, details that reflect a long-standing state of being or without a clear beginning or end are considered semantic. Semantic information can be "brought in" to episodic recollection (and scored as an internal detail) if it becomes an integral aspect of the episode: "Arizona is hot" is semantic, but "Arizona was hot when we went there" is episodic. Note that the richness of the description is independent from the episodic/semantic distinction; very richly described factual information is still semantic, and impoverished, minimal details can still be episodic.
2) **Repetitions**. A detail is a repetition if it is an unsolicited repetition of a prior information-containing detail. It does not have to be a verbatim repetition, but it should not add any new information to the prior detail ("I hoped for the best. I kept my fingers crossed" -- second sentence is a repetition). Score all repetitions, even if they are part of normal discourse, except for repetitions that are clearly prompted by the examiner, which may occur if the examiner queries a detail that was given earlier**.** Repetitions must convey information (as opposed to just words that are repeated). In the example below, "… and stuff" is repeated, but there is no information in this utterance, so it is not considered a repetition. As well, only score repetitions when they convey the <u>same</u> information as in an earlier detail. In the example below, "They really really liked me" is not a repetition of "They were happy with my work." Similarly, "I was a carpenter's helper", "I helped them", and "They could depend on me" are all different. "They liked what I did" however is the same as "They liked my work." Then he repeats this repetition straight away.
3) **Other details**. This category is for details that do not reflect recollection and do not fit into other categories. It includes meta-cognitive statements ("Let me see if I can remember that"), editorializing ("That doesn't matter." "That's amazing."), inferences ("I must have been wearing a coat because it was winter"), or other statements that convey verbosity but are not related to the main event. Replies to a query that are clauses (E: "Do you remember any more about that day? S: No, right now I don't. I don't remember anymore") are also scored as "other", although simple reflexive replies such as "No" are not scored. Do not score an "other" detail for any utterance - only those that contain information. Generally an "other" detail will be a clause of some sort. Fragments such as "um" are not scored.
4) **External episodic details**. Episodic events that are secondary to the main episodic event, e.g. if the person is imagining the birth of their first child (as the main event), but <u>also</u> talks about going to the pharmacy to buy prenatal vitamins a few months before.
5) **External generic events/routines**<u>.</u> Semantic details that refer to events (and not general knowledge), but events that are repeated or routine, e.g. "I always go to the dairy down the road."

The **sums of internal and external details** are important measures of a subject's performance. With experience, a scorer will be able to simultaneously segment and categorize a response.

In some cases it can be difficult to distinguish internal from external details. The rule of thumb in these cases (the "benefit of the doubt" rule) is that if a detail could reasonably be internal, it is scored as such. This rule, however, should not be applied to all details that could possibly be internal; only those that could reasonably be internal.

Scoring example

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         EXT1                 EXT2              EXT3        EXT4
It was a company / out of New Bedford / that was building / & did the
shelves and

           EXT5     EXT6                              EXT7
EXT8
that,/ the rough /carpenter work /& then there was another company/ that

came in/

          EXT9             EXT10                EXT11
and did the finish work /but they were all happy /with my work and stuff
/and

         EXT12                  EXT13                          EXT14
saw that I listened and stuff /and I was a carpenter's helper / and I

helped /

        EXT15                         EXT16
when they needed something /and they could depend on me /and the company
really

EXT17             EXT18              REP(of EXT18)
really liked me / what I did /and the work I did and stuff./
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Categorization: All details are classed as external as there is no specific, time-limited event described. The subject is describing the company he worked for and his role. However, this is somewhat open to interpretation. Another scorer might decide that the description of another company coming in (i.e., "*another company came in and did the finish work but they were all happy with my work and saw I listened*") is a single episode rather than a matter of due course on every job. This is an example of a judgement call. Many scoring decisions are judgement calls. Scorers will be somewhat influenced by their own knowledge and experience with the subject matter. Score according to your knowledge. If two people could reasonably score a detail more than one way, simply score it the way that seems best rather than agonize over it.

Segmentation: The clause *"It was a company out of New Bedford that was building"* contains three details, *a company,* from *New Bedford,* that does *building.* Thus, *"company"* can stand alone (i.e., he works for a *company,* and not, for instance, himself) but the subject tells us something about what type of company it is (i.e., they do *building*). The second detail is a place detail, telling us that the company was based in *New Bedford*. This clause illustrates that one cannot always find the dividing line between details. The dividing of segments can be somewhat arbitrary. Where one places the dividing lines is not as important as the number of information bits one scores.

The "shelves … and rough carpenter work" can be segmented into three details: "*doing shelves*" (a type of building), "*carpenter work*" (another description of the type of work), and then further refining the carpenter work (as *"rough"*). Next, another company comes in. This instance of *"company"* is not a repetition of the first, as it is a *different* company. The *"coming in"* was scored as a separate detail because it implies a happening, something this other company did. Their being happy is a state of being/emotion; the cause of the happiness (i.e., the subject's work) is a further detail. Likewise, the subject imparts a number of details about his role: a "*carpenter's helper"*; the task was to *help*; but not just whenever, but *"when something was needed"*; he was dependable (*"they could depend on me"*); the *company liked him*; and they also liked the work he did (*"what I did"* and repeated in *"the work I did"*)

We have come up with some other **segmentation rules**, given scoring dilemmas which have arisen:

- **Time details**: The location of the event in time (e.g., *"next few weeks", "in a couple years", "yesterday"*) should not be segmented as this usually reflects the time period given as part of the cue; SCORE=1
- **Relationship details**: The relationship of the subject to someone else (e.g., *"boyfriend", "last boyfriend", "uncle", "great uncle", "friend", "best friend", "Donna's friend"*) should be SCORE=1 if this is used as a pronoun. Often, as the subject doesn't know the examiner, they will just consistently refer to someone as "*my best friend*". However, if they have used the name and are using the phrase to describe the relationship, then it can be segmented accordingly (e.g., "*she was my best friend*" is SCORE=2 as she's not just a friend, but a *best* friend.)
- **Activities**: *"I was sitting on the couch"; "I was driving to the market"* are SCORE=2 phrases, as *"I was sitting"* and *"I was driving"* are activities in of themselves. The subject doesn't need to provide the location of sitting (*"couch"*) or the destination of driving (*"market"*) for it to make sense. However, *"I went to the market"* is a SCORE=1 phrase, as *"went"* is not a stand-alone activity.
- **Senses**: *"I saw the tower", "I heard a noise"* are all SCORE=1 phrases as the sense description is part of the experience of the content (i.e., you can't see a noise or hear a tower). Also, the sense verbs cannot stand alone (e.g., *"I saw."*)
- **Dialogue**: Whether the dialogue is external (speech) or internal (thoughts), each statement/thought represents one detail (i.e., it is one happening) and so it is not segmented (e.g., "I thought, blah blah blah" or "She said, 'blah blah blah'" are both SCORE=1 phrases). If there are masses of dialogue, then divide it up reasonably, by phrases.
- **Emotions**: If a feeling is followed by the cause or target of the feeling (e.g., "I was happy that he came over"), then it is a SCORE=2 phrase. This is because "I was happy" can stand alone, and more information is provided by describing the reason.
- **Metacognitive**: "I remember", "let me see if I remember", "I can envisage" SCORE=1 (External)
- **Quantities**: "There were skins" SCORE = 1; "there were all these skins" SCORE = 2; "there were 500 skins" SCORE = 2

Other segmenting and scoring tips

- "Negative" events, or the absence or failure of something to occur ("Bob wasn't there") are still scoreable, as they reflect the subject's recollection.
- External details include both external episodes and semantic details. In cases where the two are difficult to distinguish, apply the benefit of the doubt rule.
- Do not give credit for information that is not there. "We went to a place where we could

swim with the dolphins" contains one descriptive event detail, but the actual location is not mentioned, so it is not scored under place details. The place is implied, but is not scored until it is mentioned.

- Scoring of fragmented sentences should allow for natural speech patterns even when they do not appear fluent in the transcription. The scorer should attempt to interpret fragmented sentences in a way that would be transparent to others.
- Repetitions should be segmented as finely as internal and other external details

Remember: Segmentation of details should be consistent regardless of whether the details are internal or external.