Individuals with amnesia are not stuck in time: Evidence from risky decision-making, intertemporal choice, and scaffolded narratives

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Abstract

This dissertation investigates the supposition that individuals with amnesia are cognitively "stuck in time". In Experiment 1, I used a Galton-Crovitz cueing paradigm to test etiologically diverse amnesic cases on their ability to richly recollect autobiographical episodic memories and imagine future experiences. In Experiment 2, I use two behavioural economics tasks (a risky decision-making task and an intertemporal choice task) to examine whether amnesic cases' judgment and decision-making reflects proneness to risky choices or steep disregard for the future. In Experiment 3, I examine the flexibility of amnesics' intertemporal choice by testing whether cueing them with personal future events increases their value of future rewards as it does in healthy controls. In Experiment 4, I attempt to decrease the severity of amnesic cases' episodic memory and prospection impairment by using structured and personally meaningful cues rather than the single cue words featured in the Galton-Crovitz paradigm. I replicated existing research showing that those with MTL damage have impaired ability to (re)construct rich and detailed narratives of past and future experiences, and I extended this finding for the first time to a lateral dorsal thalamic stroke case (Experiment 1). Despite this impairment in "mental time travel", the same amnesic cases made financial decisions that a) systematically considered and valued the future and b) showed normal sensitivity to risk (Experiment 2). The normalcy of intertemporal choice in amnesia extends beyond basic rates of future reward discounting in intertemporal choice. In controls, cues to imagine future experiences can modulate decision-making by increasing the value one places on future rewards. Here, most amnesic cases also retain this modulatory effect, despite having

impaired ability to generate detailed representations of future experiences (Experiment 3). Finally, I found that the severity of episodic prospection impairment in MTL amnesia is cue-dependent and likely overestimated in current research: specific, personally meaningful cues lead to an appreciable reduction of episodic prospection impairment over single cue words for those with mild-moderate amnesia (Experiment 4). Collectively, results challenge assumptions that amnesic populations are cognitively confined to the present and call for refinement to simple accounts of limited temporality in individuals with amnesia.

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I dedicate this dissertation to the individuals with amnesia who I document in this work, and to their families. Thank you for all of your time.

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General introduction

"And I myself was wrung with emotion - it was heartbreaking, it was absurd, it was deeply perplexing, to think of his life lost in limbo, dissolving. 'He is, as it were,' I wrote in my notes, 'isolated in a single moment of being, with a moat or lacuna of forgetting all round him… He is man without a past (or future), stuck in a constantly changing, meaningless moment.'" (Sacks, 1985, pp. 23 – 42).

In the quote above, neurologist Oliver Sacks reflects on meeting Jimmie G., a densely amnesic individual with Korsakov's syndrome. Jimmie resembled a mariner lost at sea, stuck in a permanent present and unable to recall events from mere minutes past. Like Jimmie, amnesic cases with medial temporal lobe (MTL) damage are often described as mentally confined to the "here and now" (e.g., Corkin, 2013; Dalla Barba & La Corte, 2013; Tulving, 2002). Such individuals lack episodic memory, a distinct kind of memory that relies on the hippocampus and allows one to mentally revisit specific events and to recollect the details of such events (e.g., Bartsch & Butler, 2013; Gilboa et al., 2006; Rosenbaum et al., 2005, 2008; Steinvorth, Corkin, & Halgren, 2006). Recollecting a distant family vacation, a high school graduation, or even a recently had conversation, are all acts of episodic memory.

Upon meeting Jimmie, Sacks surmised that those with amnesia are not only without a past but are in some ways, without a future. Endel Tulving made a similar observation when speaking with amnesic case K.C. K.C, a now well-studied individual, sustained a motorcycle accident that erased a lifetime of episodic memories. He was unable to richly recall a single life experience.   Strikingly, he also seemed unable to imagine a single future experience:

E.T.: Let's try the question again about the future. What will you be doing tomorrow?

[There is a 15 second pause.]

K.C.: I don't know

E.T.: Do you remember the question?

K.C.: About what I'll be doing tomorrow?

E.T.: Yes. How would you describe your state of mind when you try to think about it?

K.C. [a five second pause] Blank, I guess

(Tulving, 1985, p. 4)

Asked to provide an analogy for the blankness of mind when thinking about his future, K.C said, "It's like be (sic?) in a room with nothing there and having a guy tell you to go find a chair, and there's nothing there". Now thirty years after this interview, the ability (or inability) to imagine future experiences, which in this dissertation I refer to as *episodic prospection*, continues to be the subject of prolific investigation (see Atance & O'Neill, 2001; Schacter, Addis, & Buckner, 2008; Szpunar, 2010; Klein, 2013a, 2015 for reviews). There is increasing recognition that this ability affords humans with the evolutionarily advantageous capacity to plan and make decisions for the future (Suddendorf & Corballis, 2007; Boyer, 2008; Klein, 2013a).   At the same time there is parallel recognition that, like any cognitive faculty, this immeasurably adaptive ability can be taken away by injury and disease. Thus, scientists and clinicians alike are motivated to better understand episodic prospection: how is it achieved, what is its relation to episodic memory, and without it, are individuals stuck in time?

Behavioural studies of healthy individuals reveal that episodic memory and prospection share common cognitive and phenomenological features (Szpunar & McDermott, 2008). For example, the capacity for visual imagery enhances sensory experiencing in both past and future episodic thinking while emotional suppression reduces sensory experiencing in both aspects of time travel (D'Argembeau & Van der Linden, 2006). Both abilities require disengagement from the present and "self-projection" into another time (Buckner & Carroll, 2007), and both require the generation of a coherent spatial context (Hassabis & Maguire, 2007). Neuroimaging studies provide a large piece of the puzzle in understanding the relationship between episodic memory and episodic prospection and how these abilities are achieved. Numerous studies show that both activate a common network of brain regions in which the hippocampus is a main component (Okuda et al., 2003; Botzung et al., 2008; see Schacter et al., 2007 and Buckner, 2010 for reviews). This is particularly true during the early stages of recollecting or imagining an event, when the initial event is being (re)constructed (Addis, Wong, Schacter, 2007; but see Weiler, Suchan, & Daum, 2010).

Though largely overlapping, episodic memory and prospection differ in some respects (see Suddendorf, 2010). For example, episodic memory develops ahead of prospection; the latter surfaces at around four years of age (McColgan & McCormack 2008; Busby & Suddendorf, 2009; see Martin-Ordas, Atance, & Caza, 2014 for review), and suggesting that prospection surpasses memory in terms of cognitive sophistication. Recollecting episodic memories also appears to be a more evocative experience, phenomenologically, than its future imagining counterpart. In a behavioural study with healthy adults, memories for past events contained more visual and other sensory details than representations of future events (D'Argembeau, & Van der Linden, 2006)

Consistent with the idea that prospection may be more cognitively demanding, episodic prospection appears to engage the hippocampus to a greater degree than episodic memory (Addis et al., 2007; Weiler et al., 2010; but see Botzung, 2008). But what does it mean for a process to be "cognitively demanding" and what makes it so? Greater hippocampal activation during prospection can simply reflect more of the same processing that occurs during episodic memory. However, an alternate explanation is that the hippocampus is engaging in qualitatively different processes during prospection. For example, additional hippocampal engagement during prospection may reflect the unique cognitive resources needed to generate novel or uncertain events. Gaesser and colleagues (2013) investigated this question and found that increased hippocampal activation in episodic prospection (relative to recollection) reflects distinct but related processes, including construction, encoding, and novelty detection. They further show that subregions of the posterior hippocampus uniquely contribute to construction.

Other research shows that the core network associated with episodic thinking (which includes the hippocampus) is also activated during counterfactual thinking (Van Hoeck, Ma, Ampe, Baetens, Vandekerckhove, & Van Overwalle, 2012) and that subjective likelihood of imagined events during counterfactual thinking appears to modulate the degree of core network activation, including the right hippocampus (De Brigard, Addis, Ford, Schacter, & Giovanello, 2013). Thus, increased hippocampal activation during episodic prospection may reflect the cognitive demand of constructing a low probability event rather than one that is more likely to be available. In this view, prospection may not simply be "more" than memory, but also *qualitatively different* in its cognitive demand.

While imaging studies make a compelling case that prospection exceeds memory in its need for cognitive resources, there remains a critical gap in converging evidence from lesion studies. Specifically, the magnitude of amnesic cases' prospection impairment ought to be greater than that of their episodic memory impairment if the hippocampus is indeed needed more for the former ability. However, several case studies to date have found that cases' episodic memory and episodic prospection impairment are comparable in severity (e.g., Kwan et al., 2010; Race, Keane, & Verfaellie, 2011).

Despite what differences there may be between episodic memory and episodic prospection, it is the similarity between these processes that has captured the interest of scientists. Perhaps the most profound evidence that episodic memory and prospection share a common functional base is the growing body of formal case studies on hippocampal amnesia that confirm Sacks' (1985) and Tulving's (1985) early observations: amnesic populations not only have impaired episodic memory but also mirrored deficits in episodic prospection (e.g., Klein, Loftus, & Kihlstrom., 2002; Kwan et al., 2010; Andelman et al., 2010; Race et al., 2011). This is separate from semantic and conceptual aspects of time, like understanding the temporal asymmetry of causation and the irrevocability of the past, which are relatively preserved in amnesia (Klein, 2013a; Craver, Kwan, Steindam, & Rosenbaum, 2014).

Collectively, findings from behavioural research, developmental research, neuroimaging, and neuropsychological case studies converge to suggest that the MTL and hippocampus in particular is responsible for "mental time travel," which Tulving (2002) conceptualized as the ability to mentally transport one's self to real or imagined personal events in the past or future (see also Ingvar, 1985, Buckner & Carroll, 2007; Dalla Barba & La Corte, 2013). However, the hippocampus-as-a-time-machine account of episodic thinking is likely oversimplified. The model begins to fall apart when one considers that episodic memory and prospection comprise numerous component processes. Episodically (re)constructing events in time requires low-level constructional processes, such as generating details, relating those details to one another, and holding these disparate details to form a cohesive representation (see Addis & Schacter, 2012) – such basic processes do indeed seem independent of time. In contrast, episodically (re)constructing events in time also requires higher-order temporal and phenomenological processes, such as autonoetic consciousness and the subjective feeling of having gone back or forward in time (Wheeler, Stuss, & Tulving, 1997; D'Argembeau, Ortoleva, Jumentier, & Van der Linden, 2010). Many of these processes are believed to have distinct neural substrates, complicating the idea that mental time travel is an ability subserved by a unitary cognitive mechanism. However, these dissociable processes, only some of which appear to be hippocampally-dependent, are confounded with each other in many existing studies. For example, when amnesic populations exhibit an impaired ability to describe a past experience in detail, it is unclear whether this impairment reflects a deficit in the fundamental ability to retrieve, bind, and relate details or in the ability to travel mentally through time to re-experience an event. Some studies hint that the crux of episodic impairment in hippocampal amnesia is the former. For example, Hassabis and colleagues (2007) found that individuals with hippocampal amnesia produced narratives of imagined novel experiences that lacked spatial unity. Rather, their narratives consisted of fragmented images in the absence of a holistic representation of the environmental setting. Hassabis and colleagues thus suggest that the hippocampus is primarily responsible for scene construction, and that disrupted ability to generate coherent spatial scenes is the underlying deficit in hippocampal amnesia (Hassabis & Maguire, 2007).

In another study, amnesic K.C. accurately recognized and discriminated details of well-known bible stories and fairy tales, yet had difficulty using these details to form a rich and cohesive narrative even though the stories were impersonal and atemporal (Rosenbaum, Gilboa, Levine, Winocur, & Moscovitch, 2009). Rosenbaum suggested that amnesia is thus an impairment in the (re)constructive processes of generating and binding details. A related idea is the *constructive simulation hypothesis*, which Addis and colleagues have put forth to explain the relationship among the hippocampus, episodic memory, and episodic prospection. According to this hypothesis, a temporally malleable episodic system

> … can draw on elements of the past and retain the general sense or gist of what has happened. Critically, it can flexibly extract, recombine and reassemble these elements in a way that allows us to simulate, imagine or 'pre-experience' events that have never occurred previously in the exact form in which we imagine them…the constructive nature of episodic memory is attributable, at least in part, to the role of the episodic system in allowing us to mentally simulate our personal futures" (Schacter & Addis, 2007).

The hypothesis also posits that the hippocampus critically facilitates episodic simulation, although mapping specific component processes onto hippocampal subfields is an ongoing endeavor (Addis & Schacter, 2012).

There is also an argument that the deficit in hippocampal amnesia is one of a more basic nature. Using eye-tracking data, Ryan and colleagues (2000, 2004) found that individuals with hippocampal amnesia failed to show implicit memory of constituent elements in a complex scene. Specifically, they were unable to retain the relations among the constituent elements of a scene, such as where an object appeared in relation to the scene or where an object appeared in relation to other objects in the scene. The authors suggest that hippocampal impairment reflects a basic deficit in relational memory (Cohen et al., 1999; Eichenbaum, 1999; Konkel & Cohen, 2009). Additional studies support the relational memory account of hippocampal amnesia, showing that the binding deficit occurs even at short delays (Hannula, Tranel, & Cohen, 2006) and that it extends to all types of relations (Konkel, Warren, Duff, Tranel, & Cohen, 2008).

An elegant imaging study with healthy individuals casts further doubt over whether the hippocampus contributes to time-dependent thinking outside of basic constructional or relational processes. In this study, Nyberg and colleagues (2010) attempted to isolate the neural substrates of subjective temporal consciousness in a task that minimized any demand on detailed construction. Participants repeatedly imagined taking the same short walk in a familiar environment, doing so either in the imagined past, present, or future. As a control condition, they also recollected an instance in which they actually performed the same short walk in the same familiar setting. Thinking about taking a walk in the past or future activated a network of frontal, cerebellar, and thalamic brain regions but did not include the hippocampus. The authors conclude that there is no evidence of hippocampal contribution to subjective time travel. Similarly, Szpunar, Watson, & McDerrott (2007) scanned healthy participants while they imagined themselves in personal past or future events. Participants were required to come up with as vivid an image as they could for the duration of each 10-second trial but were never required to respond - participants simply imagined themselves without having to construct a narrative. The authors did not find hippocampal activation during past remembering or future imagining.

Nyberg and Szpunar's studies raise an important point about time travel – there are numerous ways in which humans can mentally transcend the present and travel through time, with narratives of their recollected or imagined experiences but one type of metric for this ability. Despite widespread acceptance of the idea that episodic amnesia traps individuals in a "permanent present tense," recent findings argue that that this metaphor distorts the true state of temporal consciousness in such populations. Individuals with episodic amnesia actually retain much of their ability to think and reason about the past and future, apparently using non-episodic cognitive systems, when probed with tasks that do not require construction (Klein, 2013a). There is a clear emerging need to re-evaluate and more closely examine the status of time-based thinking outside of basic constructive demand. Perhaps the loss of time in amnesia is misunderstood.

Overview of experiments

In this dissertation I conduct a series of experiments investigating both constructive and non-constructive aspects of time-based thinking in order to understand the underlying deficit in medial temporal lobe amnesia. In Experiment 1, I use a Galton-Crovitz cueing paradigm to test a group of etiologically diverse amnesic cases on their ability to richly recollect autobiographical memories and imagine future experiences. In Experiment 2, I use two well-established behavioural economics tasks (an intertemporal choice task and a risky decision-making task) to examine whether amnesic cases' judgment and decision-making reflects steep disregard for the future or proneness to risky choices. In Experiment 3, I examine the flexibility of amnesics' intertemporal choice by testing whether cueing them with personal future events increases their value of future rewards as it does in healthy controls. In Experiment 4, I examine whether I can decrease the severity of amnesic cases' episodic memory and prospection impairment by using structured and personally meaningful cues rather than the single cue words featured in the widely used Galton-Crovitz paradigm.

Statistical approach

This dissertation features a series-of-case-studies approach. I analyzed all amnesic cases individually using a descriptive neuropsychological approach to quantify the degree of impairment in each case. This approach involves calculating participants' z-scores relative to control groups and then using a standardized psychometric conversion table based on the Wide Range Achievement Test-Third Edition, Administration Manual (WRAT-III, Wilkinson, 1993, Appendix A) to derive quantitative (estimated percentile rankings) and qualitative (diagnostic labels) estimates of impairment.

The neuropsychological approach compares to standard null hypothesis significance testing (NHST) in the following ways: In NHST, “significance” is an all-or-none inference that occurs when an obtained p-value is below a predetermined alpha (i.e., $p < 0.05$). NHST is problematic for neuropsychological studies such as ours, which feature small sample sizes of rare populations and thus lack statistical power to reject the null. NHST also requires averaging patients’ performance to compare a single score to that of controls’. Clinical cases are often averaged in this manner to increase statistical power and reduce unwanted noise, but the average is not always representative of performance in each case (Rosenbaum, Gilboa, & Moscovitch, 2014; Schwartz & Dell, 2010) and this practice potentially obscures clinically informative differences among amnesic cases. Holdstock and colleagues (2008) illustrated the issues that arise in averaging neuropsychological cases’ performance in a study that directly compared two individuals with hippocampal damage. Despite very similar and selective hippocampal lesions, “Patient A.C.” demonstrated surprisingly intact and, on some measures, above average memory performance whereas “Patient P.R.” demonstrated typical impairment on measures of recollection and highly variable performance on measures of recognition. The authors concluded that even seemingly selective hippocampal damage can have highly variable effects on memory.

In contrast, the neuropsychological approach is an alternative method that both quantitatively and qualitatively assesses the degree to which a patient’s score deviates from that of controls’. This approach circumvents the frequent statistical limitations of patient studies that typically feature small sample sizes of rare populations. A neuropsychological approach is sensitive to variability among cases and allows discussion of each amnesic individual in clinically meaningful terms with respect to impairment severity.

This approach adheres to broader statistical guidelines put forth in recently revived efforts to build a more replicable psychological science (i.e. the "new statistics", Cumming, 2013; Eich, 2014; Maner, 2014). These guidelines argue for continuous, estimation-based thinking rather than dichotomous thinking, and for shifting away from p-values as the sole metric of statistical meaning. The movement toward "new statistics" alternatives is particularly relevant in neuropsychological research where small sample sizes and uneven groups push the boundaries and assumptions of standard NHST (Kakzanis, 2001).

Experiment 1

Episodic Memory and Episodic Prospection

1.1 Introduction

The necessity of the hippocampus for episodic memory and prospection is generally accepted, but not without controversy (see Addis & Schacter, 2012 for review). For example, a developmental amnesic case, H.C., had significantly impaired episodic memory and episodic prospection impairment upon initial assessment (Kwan et al., 2010). However, she and other developmental amnesic cases with MTL damage showed intact episodic prospection in subsequent testing using more elaborate, full-sentence scenario cues (e.g., "Imagine you are walking along a busy fishing harbor"; "Imagine how you will spend next Christmas") (Cooper et al., 2011; Hurley et al., 2011). Several explanations exist for the discrepancies in findings. In addition to more elaborate scenario-cues, those with amnesia of developmental origin typically have more circumscribed hippocampal lesions and may have better preserved function than their adult-onset counterparts (see Vargha-Khadem, Gadian, & Mishkin, 2001, for review).

There is greater consensus that hippocampal damage interferes with both episodic memory and prospection among adult-onset cases - several researchers have replicated this finding with different cases (Tulving, 1985; Klein et al., 2002; Andelman et al., 2010; Race et al., 2011). Beyond hippocampal amnesia, other populations with decreased hippocampal function also have impoverished episodic thinking (mild cognitive impairment, Gamboz et al., 2010; healthy aging, Addis et al., 2008). However, some argue that episodic prospection functions independently of the hippocampus. For example, Squire et al., (2010) suggests that lesions outside of the hippocampus may better explain episodic prospection impairments previously attributed to hippocampal damage and that frontal executive rather than medial temporal neuropsychological impairments contribute to episodic impairment. Squire and colleagues further argue that the hippocampus does not critically contribute to basic constructive processes that are independent of time, such as scene construction (Kim, Dede, Hopkins, & Squire, 2015). This debate is in some ways an extension of an old and ongoing controversy over whether the hippocampus is needed for remote episodic memory (see Nadel & Moscovitch, 1997; Frankland, & Bontempi, 2005; Squire & Bayley, 2007 for reviews).

Given the current debate there is a clear need for continued case studies on how or if hippocampal damage affects episodic memory and prospection. The purpose of the present study is to formally assess episodic memory and episodic prospection in a group of etiologically diverse, adult-onset amnesic cases with varied selectivity of hippocampal damage.

1.2 Methods

1.2.1 Participants

Amnesic cases. The amnesic individuals in our study represent six unique neuropsychological cases that arose from a range of etiologies and differ in the severity of memory impairment (see below for detailed case descriptions). To meet the operational definition of "amnesic" for the purposes of this research, cases were required to meet each of the following criteria: (1) neuroanatomically, damage to the MTLs or other areas in the extended hippocampal system (Aggleton & Brown, 1999; Edelstyn, Hunter, & Ellis, 2006) as verified on MRI, (2) neuropsychologically, documented anterograde memory impairment on measures of delayed free recall (i.e., 1^{st} percentile or less) in at least one modality (visual or verbal) and in the context of otherwise intact overall intellectual functioning (FSIQ = 90 or higher), and (3) functionally, impaired ability to sustain full-time employment as a result of cognitive impairments.

I recruited and tested the following cases to observe whether degree of memory loss would correspond with the magnitude of any observed impairments. The individuals' demographic information, neuropsychological findings, and measures of past and future episodic thought are summarized in Table 1.

K.C. K.C. was 57 years old at the time of testing, was right handed, and had 16 years of formal education. As mentioned, his case is well-documented in the literature. K.C. sustained a closed-head injury from a motorcycle accident in 1981 when he was 30 years old. His MRI scans revealed extensive volume loss in MTL structures, most notably the hippocampal formation and surrounding parahippocampal gyrus, bilaterally (Fig. 1). Additional affected areas include the septal area, posterior thalamus, and caudate nucleus, bilaterally, as well as the left amygdala, mammillary bodies, and anterior thalamus (Rosenbaum et al., 2005).

Despite his widespread damage, K.C. had preserved semantic memory that remained stable after his accident (Rosenbaum et al., 2005). When tested, he exhibited a conservative response bias with no evidence of confabulation. K.C. continued to demonstrate average IQ and relatively preserved cognitive functioning until his passing in 2014. One major exception to K.C.'s intact functioning was his episodic memory. His head injury caused dense amnesia, both retrograde and anterograde, leaving him without episodic memory for any details of personal experiences (see Rosenbaum et al., 2005 for detailed neuroanatomical and neuropsychological profiles).

D.A. D.A. was 59 years old at the time of testing. He is a right-handed man with 17 years of education who contracted herpes encephalitis in 1993 and has been the subject of previous studies on MTL amnesia (Rosenbaum et al., 2008; Westmacott et al., 2004; Roy & Park, 2010). His MRI scans reveal severe damage to MTL structures, affecting the right side substantially more than the left (Fig. 1). His right sided damage includes lesions to the hippocampus (damaged by over 90%), perirhinal, entorhinal, and parahippocampal cortices, as well as the anterior temporal lobe. In the right hemisphere, D.A. has additional volume reductions in regions outside of the MTL, including posterior temporal, ventral frontal, occipital regions, anterior cingulate, and posterior thalamus. Little volume loss was reported in the right dorsal frontal, superior and inferior parietal, and posterior cingulate regions. D.A.'s left sided damage includes hippocampal volume reduction by over 50%, as well as damage to the perirhinal, entorhinal, and parahippocampal cortices (see Roy & Park, 2010).

Like K.C., D.A.'s brain damage was accompanied by a pattern of preserved semantic but impaired episodic memory. He continues to have average IQ and intact cognitive function outside of episodic memory. Within the episodic domain, D.A. has a moderate retrograde amnesia that is temporally graded (better remote than recent memory) and a significant anterograde amnesia for personal experiences (see Rosenbaum et al., 2008 for neuroanatomical and neuropsychological profiles). He is able to talk about some past experiences with apparent vividness, detail, and episodic richness, such as when he proposed to his wife. However, it is likely that many of these experiences have been retold over the years and are now represented in semantic memory, given that D.A. will often re-tell stories of personal happenings to the same person almost verbatim.

D.G. D.G. was 47 years old at the time of testing. He is a right-handed man with 16 years of education. D.G. is a husband and father of two who worked as a civil engineer and was an avid hockey player and golfer until his injury. In 2010, D.G.'s wife awoke in the middle of the night to what she thought was snoring and discovered that D.G. was in cardiac arrest. She initiated chest compressions until an ambulance arrived and worked for an additional thirty minutes during which D.G. was treated by defibrillator. He was then transferred to hospital where he received hypothermic treatment. He arrested twice more while in emergency treatment and was treated by defibrillator each time. He did not regain consciousness until approximately 48 hours after the initial incident. DG shows the characteristic neuropsychological pattern of impairment that typically follows cardiac arrest: he has preserved semantic but impaired episodic memory with accompanying dysarthric motor deficits (Lim et al., 2004). D.G. had an implantable cardioverter-defibrillator inserted following the arrest and is thus unable to undergo MRI.

Upon awakening in the hospital, he estimated that he was 22 years old – half of his actual age at the time. He had no memory of his children, of his home, or of several close friends. In the months following his injury, he recovered personal semantic memory (e.g., recognition of family members and friends, his home address), although there was evidence of sustained episodic memory impairment along with dysarthria and some loss of fine motor control. Neuropsychological testing conducted approximately two and a half years post-injury revealed that he continues to have average IQ and intact cognitive function outside of episodic memory. Within the episodic domain, D.G. has a temporally graded retrograde amnesia and an anterograde amnesia for personal experiences. D.G.'s wife describes his current memory function as "spotty": he is able to describe some experiences in a gist-like fashion but admits that "a lot of it is guesswork because [he is] not very sure". For example, he describes as one of his fondest memories taking a trip with friends to attend the practice round of the Masters

Tournament the year following his injury. However, he reported only having "bits and pieces of the day" and is uncertain about key details of the event, such as who played in the tournament. There are other significant life events that he is completely unable to recall, including his wedding day and moving into his current house.

L.D. L.D. was 61 years old at the time of testing and has 19 years of education. L.D. has a history of complex partial seizures dating back to June 2000, when MRI revealed a left hippocampal lesion. In 2007, L.D. developed a growth in the left parahippocampal region. He underwent a left temporal lobectomy and amygdalohippocampectomy to treat refractory temporal lobe epilepsy in 2011. Surgical resection of the middle temporal gyrus, hippocampus, uncus, and amygdala successfully ameliorated seizures but exacerbated his memory impairment. Neuropsychological testing revealed a stable pattern of average overall intellectual function and low semantic fluency but a steady decline in episodic memory, particularly for verbal material, over repeated assessments. After surgical resection, L.D.'s episodic memory further deteriorated relative to pre-surgical functioning. L.D. currently reports difficulty with day-to-day memory, such as remembering the content of recent conversations.

B.L. B.L. was 52 years old at the time of testing and has 13 years of education. In 1985, B.L. was diagnosed with anoxic brain injury secondary to electrocution and cardiac arrest. He has little recall of the incident. MRI showed clear bilateral lesions in the hippocampus with hyperintensities consistent with hippocampal sclerosis. Hippocampal lesions were primarily limited to the dentate gyrus with relative sparing of the CA1 and CA3 subfields and the surrounding parahippocampal cortices. Cerebral atrophy with mild enlargement of ventricles and cortical sulci also was apparent. Repeated neuropsychological examinations revealed a stable pattern of spared and impaired function. B.L. has borderline-low average memory for verbal material and stark memory impairment for non-verbal material in the context of average intellectual function. Motor speed and dexterity are also affected, and there is evidence of mild executive difficulties affecting planning, mental flexibility, and self-monitoring.

S.N. S.N. was 46 years old at the time of testing and has 12 years of education. In 2011, he suddenly experienced nausea, vomiting, and decreased consciousness, and presented at the hospital with right hemiparesis and right hypesthesia. Initial CT showed a left thalamic hemorrhage likely secondary to acute hypertension. MRI at four months post-stroke revealed a resolving left thalamic hemorrhagic stroke with no obvious underlying vessel malformation. Primary lesions were bilateral in the lateral dorsal thalamus (greater on the left). MRI also revealed a left pontine lesion suspected to be ischemic in nature and smaller lesions in the left pons, right putamen, and left occipital lobe medial to the occipital horn. Within the MTL, there was a localized left hippocampal lesion. The perirhinal, entorhinal, and parahippocampal cortices were intact, as were the fornix and mammillary bodies.

S.N. was initially unable to recognize close family members, including his parents. During the course of lengthy rehabilitation, he recovered personal semantic memory (e.g., recognition of family members and friends, and his home address) but continues to exhibit an episodic memory impairment and anterograde amnesia. For example, he has difficulty recalling recent conversations and tends to repeat questions and retell stories during testing.

Neuropsychological assessment at nine months post-stroke revealed high average overall intellectual functioning but severe, selective impairments in episodic memory, particularly in encoding of verbal information. He showed additional impairments in verbal fluency and inhibitory control.

Each amnesic case gave informed, written consent in accordance with the Human Research Ethics Committees of York University and Baycrest, and received monetary compensation for their time.

Controls. Control data were taken from Addis et al.'s (2008) healthy older adult sample (n = 16, six male, M_{age} = 72.313, SD = 5.003).

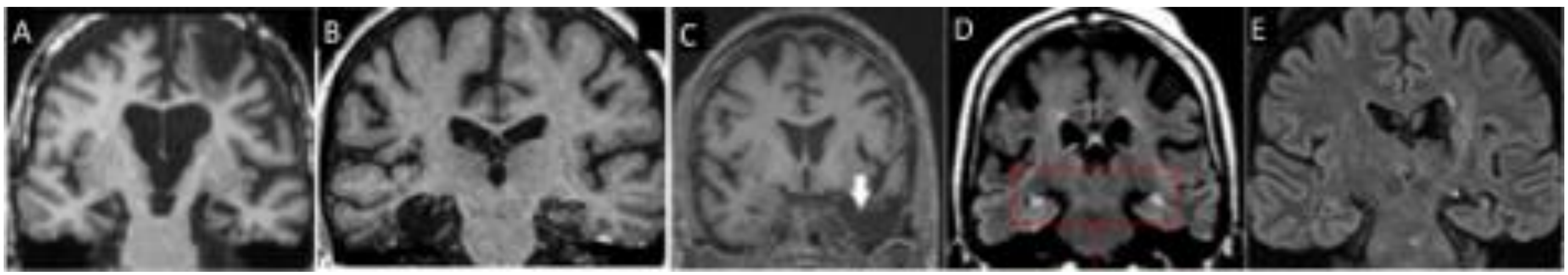

Figure 1.1. Coronal T1 MRI slices of damage for (A) K.C., (B) D.A., (C) L.D., (D), B.L., and (E) S.N. Images are presented according to radiological convention (right hemisphere is presented on left side of image). D.G. could not be scanned because of an implantable cardioverter defibrillator.

Table 1.1 Amnesic cases' demographic and neuropsychological data

	K.C.	**D.A.**	**D.G.**	**L.D.**	**B.L.**	**S.N.**
Age at injury	30	47	44	~48	25	44
Age at testing	57	59	47	61	52	46
Etiology	TBI	Encephalitis	Anoxia	TLR	Anoxia	Stroke
Education (years)	16	17	16	19	13	12
Full Scale IQ	99	117	99	111	92	114
Verbal IQ	99	121	83	117	--	--
Performance IQ	99	106	104	105	--	--
Verbal Learning						
Acquisition	< 1^{st}%	< 1^{st}%	3^{rd} – 6^{th}%	1^{st}%	21^{st} -32^{nd}%	1^{st}%
Short delay free recall	< 1^{st}%	< 1^{st}%	2^{nd} %	< 1^{st} %	< 1^{st} %	2^{nd} -3^{rd} %
Long delay free recall	< 1^{st}%	< 1^{st}%	6^{th} – 7^{th}%	1^{st}%	14^{th} – 19^{th}%	<1^{st}%
Recognition discrimination	< 1^{st}%	< 1^{st}%	16^{th}%	< 0%	50^{th}%	<1^{st}%
Logical passages/memory I	5^{th}%	15^{th}%	--	50^{th}%	25^{th}%	< 1^{st}%
Logical passages/memory II	< 1^{st}%	< 1^{st}%	--	< 1^{st}%	8^{th} – 13^{th}%	< 1^{st}%
Rey Osterrieth Complex Figure						
Copy /36	36	35	30	29	35	30
Delayed recall	< 1^{st}%	< 1^{st}%	< 1^{st}%	21^{st} -32^{nd}%	< 1^{st}%	1^{st}%
Boston Naming /60	57	56	56	36	--	52
Letter Fluency	7^{th} -13^{th}%	21^{st} – 32^{nd}%	7^{th} -13^{th}	21^{st} -32^{nd} %	58^{th} -68^{th}	21^{st} – 32^{nd}%
Wisconsin Card Sort Task /6	6	6	6	6	6	3

Notes: Notes: TBI, traumatic brain injury; TLR, temporal lobe resection; Full Scale IQ, Verbal IQ, and Performance IQ based on Wechsler Adult Intelligence Scale – Revised for K.C., D.A., and D.G., Wechsler Abbreviated Scale of Intelligence–III for L.D. and S.N., and Wechsler Abbreviated Scale of Intelligence –IV for B.L.

Verbal learning is based on California Verbal Learning Test-II for K.C., D.A., D.G., and B.L., Hopkins Verbal Learning Test – Revised for L.D., Kaplan Baycrest Neurocognitive Assessment, Word List Learning for S.N.

Logical passages/memory is based on the Wechsler Memory Scale – Revised for K.C. and D.A., Wechsler Memory Scale III for L.D. and S.N., and Wechsler Memory Scale IV for B.L.

Letter fluency is based on the average number of words produced for the letters F, A, and S in a given minute per letter.

1.2.2 Procedure

A Galton-Crovitz cueing paradigm in which cue words are used to elicit narratives of personal events was administered to participants (Crovitz & Schiffman, 1974; see Addis et al., 2008 for detailed task description). Participants were asked to remember five personal past events (up to five years ago) and to imagine five personal future events (up to five years into the future). The task unfolded as follows: on each trial, participants were presented with a single cue word on a computer screen along with a time condition (past or future). Participants were instructed to use the cue to help generate a personal event that occurred in the past or that could occur in the future, depending on the time condition. I explained that the cue was a tool to help generate an event, and that the event itself need not be related to the cue. For past trials, participants were asked to recall specific, personally-experienced events in as much detail as possible. For future trials, participants were asked to imagine specific novel events that they might personally experience in the future in as much detail as possible. Each trial lasted five minutes, with the cue word and time frame appearing in full view for the duration of the trial. I gave one general probe (i.e., “Is there anything (else) you can remember/imagine?”) when approximately 30 seconds of silence had elapsed. Sessions were recorded using a digital audio recorder and then transcribed.

Scoring. The standard scoring procedure for the autobiographical interview (AI) was used to assess the detail and quality of participants’ past and future events (Levine, Svodoba, Hay, Winocur, & Moscovitch, 2002). All details were segmented and categorized as either internal or external. Internal details refer to specific episodic information about the central event. External details are non-episodic details provided by participants that are tangential or unrelated to the central event, semantic facts, repetitions, or metacognitive statements/editorializing. For each time condition, I tallied and averaged the number of internal and external details to determine an overall index for each type of detail generated by each participant. Given that the task was to produce details of a specific event, internal details were expected to outnumber external details on every trial.

1.3 Results

Figures 1.2 and 1.3 respectively show that amnesic cases both recollect past experiences and imagine future experiences in lesser episodic detail than controls. To statistically assess the magnitude of these impairments, I used the aforementioned neuropsychological approach. As expected, individuals with amnesia showed varying degrees of impairment in both episodic memory and prospection. All scores were at or below the clinical threshold for borderline impairment (i.e., 8^{th} percentile). The only exception was L.D.'s prospection, which was within the low average range.

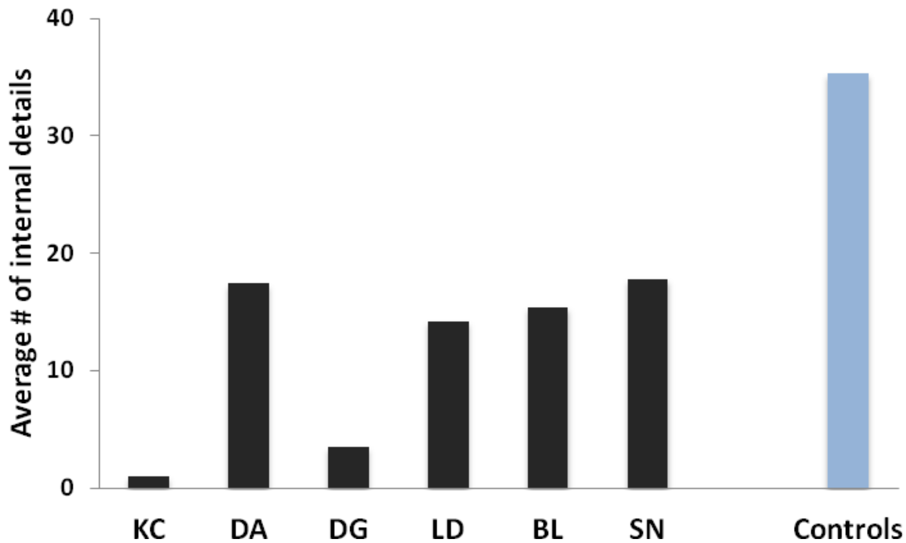

Figure 1.2 Amnesic cases and controls' average number of internal details for remembered past events. Error bar represents standard error of the mean.

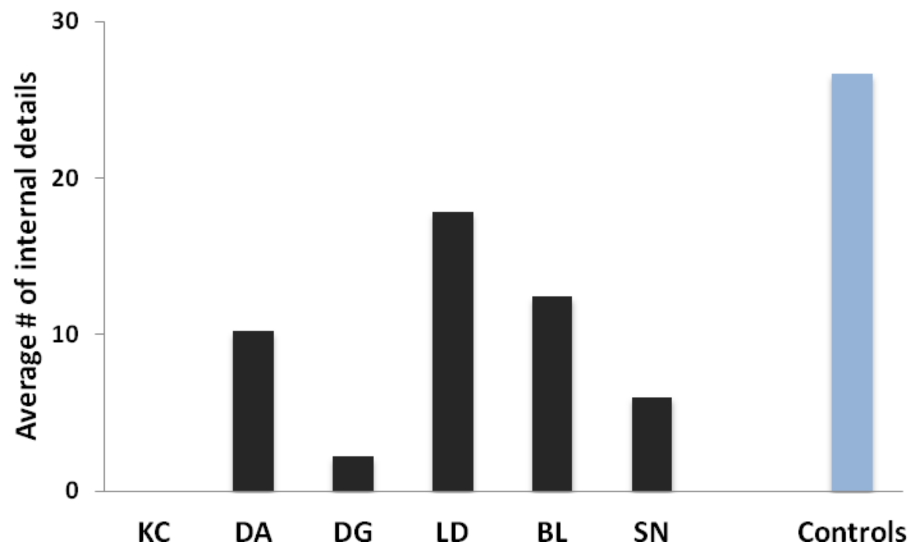

Figure 1.3 Amnesic cases and controls' average number of internal details for imagined prospective events. Error bar represents standard error of the mean.

Table 1.2 *Episodic memory and episodic prospection in amnesic cases*

Episodic Autobiographical Memory						
	Internal details			External details		
Case	*z-score*	*%ile rank*	*descriptive label*	*z-score*	*%ile rank*	*descriptive label*
KC	-3.451	< 1st	Impaired	-1.987	2nd – 3rd	Borderline
DA	-1.802	3rd – 4th	Borderline	-0.490	30th – 32nd	Average
DG	-3.200	< 1st	Impaired	-1.724	4th	Borderline
LD	-2.124	1st – 2nd	Impaired	0.673	75th	High average
BL	-2.003	2nd	Borderline - Impaired	1.022	86th	High average
SN	-1.762	3rd – 4th	Borderline	3.117	>99th	Very superior

Episodic Prospection						
	Internal details			External details		
Case	*z-score*	*%ile rank*	*descriptive label*	*z-score*	*%ile rank*	*descriptive label*
KC	-2.676	< 1st	Impaired	-2.197	1st -2nd	Impaired
DA	-1.653	4th – 5th	Borderline	-0.721	19th - 21st	Average-Low Avg.
DG	-2.459	< 1st	Impaired	-1.850	3rd -4th	Borderline
LD	-0.891	18th – 19th	Low average	0.404	66th	Average
BL	-1.432	7th – 8th	Borderline	1.459	92nd – 93rd	Superior
SN	-2.074	2nd	Impaired	1.230	88th – 90th	High average

Higher ‘External details’ scores indicate an access of details

1.4 Conclusion

I used a series-of-case-studies approach to assess episodic memory and prospection in six adult-onset amnesic cases with varying etiologies and selectivity of hippocampal damage. Both memory of past experiences and simulation of future experiences were either borderline or outright impaired in the assessed cases. The only exception was L.D.'s prospection, which fell within the low end of average range. Results from the current study are consistent with the majority of previously reported cases in the literature (i.e. Race et al., 2011). Amnesic case B.L.'s performance is particularly relevant to the debate over whether the hippocampus is needed for episodic (re)construction. He has highly selective lesions that are circumscribed not only to the hippocampus, but to the dentate gyrus with relative sparing of other hippocampal subfields and the surrounding parahippocampal cortices. However, his lesions sufficiently impaired both recall of remote past experiences and imagination of future experiences. B.L.'s performance is inconsistent with Squire et al. (2010)'s assertion that deficits in remote episodic memory and episodic prospection are an artifact of lesions beyond the hippocampus proper.

While the majority of studies on episodic prospection focus on the MTL, and the hippocampus in particular, less is known about the function of other structures within the extended hippocampal system, including the fornix, mammillary bodies, and parts of the thalamus (see Aggleton & Brown, 1999). The thalamus is often active when healthy individuals engage in episodic prospection (e.g. Szpunar et al., 2007; Viard et al., 2011) yet perhaps due to the rarity of such populations, neuropsychological studies documenting how thalamic lesions may affect episodic (re)construction are lacking. In one such study, an individual with bilateral lateral dorsal thalamic lesions showed impaired recollection on lab-based tests of episodic memory (Edelstyn, Hunter, & Ellis, 2006). More recently two cases with medial dorsal thalamic lesions showed selectively impaired prospection with preserved episodic memory (Weiler, Suchan, Koch, Schwarz, & Daum, 2011). In the present study, amnesic case S.N. demonstrates for the first time that a lateral dorsal thalamic lesion, much like a hippocampal lesion, can also cause episodic (re)construction deficits for both past and future events. This finding further enforces that this area of the thalamus should be considered part of the extended hippocampal system (Edelstyn et al., 2006). It reinforces the consideration of episodic thinking as a system, and highlights the need for continued investigation to establish how the hippocampus and structures within the extended hippocampal system contribute to time-based thinking.

A potential limitation of this study is that the controls used in this study differed from the amnesic cases in that the controls were primarily female and were a mean age of 72 years, which is substantially older than the younger, all-male amnesic cases. There are few direct studies on sex difference in episodic prospection; some studies combine data from male and female participants after finding no effect of sex (e.g. Irish, Addis, Hodges, & Piguet, 2012; Murphy, Troyer, Levine, & Moscovitch, 2008). However, one study specifically investigating sex differences does show that women recollected past events and imagined future events with greater specificity than men (Wang, Hou, Tang, & Wiprovnick, 2011). An implication of this finding for the current study is that the magnitude of impairment in the amnesic cases could be inflated due to the predominately female control group. Conversely, research on aging and episodic prospection makes a counter suggestion: normal aging (as well as age-related disorders) are associated with both reduced episodic memory and reduced episodic prospection (Addis, Wong, & Schacter, 2008; Gaesser, Sacchetti, Addis, & Schacter, 2011; see Schacter, Gaesser, & Addis, 2012, for a review). This well-established finding suggests that the magnitude of amnesic cases' impairment might actually be *underestimated* in light of the older control group.

Experiment 2

Risky Decision-Making and Intertemporal Choice

2.1 Introduction

Results from Experiment 1 established episodic memory and prospection impairments in a group of individuals with MTL amnesia. In the present study, I focus specifically on prospective aspects of time-based thinking and attempt to disentangle temporal from constructive processes using decision-making tasks that require the former but not the latter.

Decisional disregard for the future is often associated with impulsivity. Researchers posit that impulsive behavior might arise from distorted estimations of temporal duration and otherwise altered temporal experience (Barratt, 1983; Takahashi, 2006; Whittmann, Leland, Churan, & Paulus, 2007; Whittmann & Paulus, 2008; but see Lennings & Burns, 1998, Glicksohn, Leshem, & Aharoni, 2006). According to Cottle (1977; cited in Lennings, Burns, & Cooney, 1998), those who are cognitively biased toward the present and who do not integrate the past with the future are also more impulsive than those with a more holistic time perspective. Cottle also conceptualized such individuals' experience of time as a series of discontinuous points rather than as a unified and flowing entity. This description would seem to fit the experience of people with amnesia who are unable to mentally (re)construct their past or future experiences and who lack memory to bridge their experiences across time (Roberts, 2002; Tulving, 2002). However, impulsivity is a multidimensional construct that lacks specificity in describing one's decision-making patterns (see Green & Myerson, 2013 for review). In the next section I discuss two features of decision-making that may differentially respond to changes in one's temporal consciousness.

Probabilistic and Delay Discounting: distinct ways of disregarding one's future

Numerous studies have linked two well-documented behaviours, risk-taking and delay discounting, to distortions in or neglect of future-oriented thinking. For example, college students who view their futures as uncertain and unstable are also more likely to engage in risky behaviour (Hill, Ross, & Low, 1997). Indeed a variety of risk-taking behaviours, such as illicit drug use, risky driving, and even sub-optimal corporate decisions ("managerial myopia"), have been attributed to a cognitive overemphasis on the present and a failure to adequately take the future into consideration (Kahneman & Lovallo, 1993; Petry, Bickel, & Arnett, 1998; Zimbardo, Keough, & Boyd, 1997).

Probability discounting is a widely used measure of risk-taking in which individuals choose between a smaller, certain reward and a larger, risky reward. One's probabilistic discount rate refers to the decrease in the subjective value of an uncertain reward as the odds against receiving it (i.e., the percentage probability of not receiving an award) increases. As such, steeper probabilistic discounting reflects a greater aversion to risk. Although probabilistic decision-making does not require explicit consideration of the future, the research summarized above suggests that one's appetite for risk implicitly reflects attitudes or beliefs about his/her future. It is unknown if amnesic populations with cognitive impairments in episodic prospection show shallow discounting of probabilistic choices, revealing lost sensitivity to risk.

Intertemporal choice is a widely used measure of delay discounting in which individuals choose between a smaller, immediate reward and a larger, delayed reward. One's delay discounting rate refers to the decrease in the subjective value of the future reward as the delay until its receipt increases. As such, shallow delay discounting reflects a higher valuation of the future. In contrast to risky decision-making, intertemporal choice explicitly pits the present against the future and requires one to take temporal delays into systematic consideration.

There are differing ideas about how episodic prospection may influence one's delay discounting. One thought is that the ability to imagine one's future serves an evolutionary purpose in nudging decisions in favour of the future (Boyer, 2008). Based on this hypothesis, individuals with episodic prospection impairment could be biased toward immediate rewards over delayed rewards. Alternatively, Luhmann and colleagues (2008) postulate that imagining one's future in delay discounting is associated with the negative experience of waiting; to avoid that negative experience; individuals are thus biased toward present rewards. Based on these two accounts, it is unclear if or how inability to imagine one's future might influence delay discounting rates in intertemporal choice.

Some argue that processes underlying probabilistic and delay discounting are one in the same (e.g., Rachlin, Raineri, & Cross, 1991). For example, both forms of discounting fit a hyperbola-like function, are positively correlated within subjects, and are correlated with personality measures of impulsivity (Richards, Zhang, Mitchell, & Wit, 1999). This and other studies have led to a conclusion that probabilistic and delay discounting are interchangeable measures of impulsivity. However, subsequent studies show that a single-process account of probability and delay discounting (i.e., impulsivity) is insufficient: the two tasks show differential patterns in psychiatric populations (Crean, de Wit, & Richards, 2000) and respond in opposite ways to manipulations of the reward amount (e.g., Green Myerson, & Ostaszewski,1999; Myerson, Green, Hanson, Holt, & Estle, 2003; see Green & Myerson, 2013 for review).

Given that risk-taking and intertemporal choice may reflect different facets of prospective thinking, I tested amnesic cases on both measures to investigate whether their decisions are abnormal in their sensitivity to risk and time. Such decision-making tasks are non-constructive metrics of future-oriented thinking and provide a window into whether amnesic individuals make decisions as if they are bound to the present.

2.2 Method

2.2.1. Participants

Amnesic cases. The same amnesic cases who participated in Experiment 1 participated in the current study.

Controls. Twenty control participants (12 male; mean age = 69.25 years, SD = 7.00 years; mean education = 17.05 years; SD = 3.20 years) with no known history of psychiatric or neurological disorders participated in this study. Controls were screened for variables associated with deviant discounting behaviour, including smoking, significant alcohol use, and problem gambling. All participants are fluent in English and right-handed. Participants gave informed written consent in accordance with the Human Research Ethics Committees of York University and Baycrest, and received monetary compensation for their time.

2.2.2. Measures and Procedure

Risky decision-making task. Amnesic cases and control participants completed a computerized version of an established measure of probability discounting (Green & Myerson, 2004). Participants were told that the task involved assessing preferences and that there were no correct or incorrect choices. Participants made a series of choices between two hypothetical monetary amounts: a smaller, certain or "sure" reward and a larger, probabilistic reward. For each of two probabilistic amounts ($250 and $2,000), participants made six choices at each of six probabilities (described to the participants as a 90%, 75%, 50%, 20%, 10%, and 5% chance), presented in random order.

For both the $250 and $2,000 conditions, the amount of the certain reward judged equal in subjective value to the probabilistic reward was determined at each probability using an iterative, adjusting-amount procedure. The first choice at each probability was between the probabilistic amount and a certain amount that was equal to half of the probabilistic amount (e.g., a 75% chance at $2,000 or $1,000 for sure). For each of the subsequent choices at that certain amount, the probability of the chance reward was adjusted based on the participant's previous choice. If the participant chose the certain reward, then the probability of the chance reward was increased on the following trial; if the participant chose the probabilistic reward, then the probability on that reward was decreased on the next trial. The size of the adjustment to the probability of the chance reward after the first choice was half of the initial probability.

The size of the adjustment to the probabilistic reward then decreased with each successive choice and was always equal to half of the previous adjustment, rounded to the nearest percentage. For example, in the condition with a 75% chance of receiving $2,000, the choice on the first trial would be between “75% chance of receiving $2,000” and “$1,000 for sure.” If the participant chose “75% chance of receiving $2,000,” the choice on the second trial would be between “50% chance of receiving $2,000” and “$1,000 for sure.” If the participant then chose “50% chance of receiving $2,000,” the choice on the third trial would be between “25% chance of receiving $2,000” and “$1,000 for sure.” This iterative procedure converged rapidly on the certain amount subjectively equivalent to the probabilistic amount (for full details, see Myerson et al., 2003). The certain amount that would have been presented on a seventh trial was used as an estimate of the subjective value of the probabilistic reward at each probability.

Figure 2.1 A sample trial from the risky decision-making task. Participants were presented with two hypothetical rewards and indicated their decision between the smaller sure reward and the larger risky reward.

Intertemporal choice task. Amnesic cases and controls completed a computerized version of an established measure of delay discounting (Green & Myerson, 2004). Participants made a series of choices between two hypothetical monetary rewards – a smaller, immediate amount and a larger, future amount. They were told that the task assesses preferences and that there are no correct or incorrect choices. For each of two future amounts ($100 and $2000), participants made six choices for each of seven delays (1 week, 1 month, 3 months, 6 months, 1 year, 3 years, and 10 years) presented in random order. For both the $100 and $2000 conditions, the amount of the immediate reward judged equal in subjective value to the delayed reward was determined at each delay using an iterative, adjusting-amount procedure analogous to that used in the probabilistic discounting task. Participants were told that the task involved assessing preferences and that there were no correct or incorrect choices.

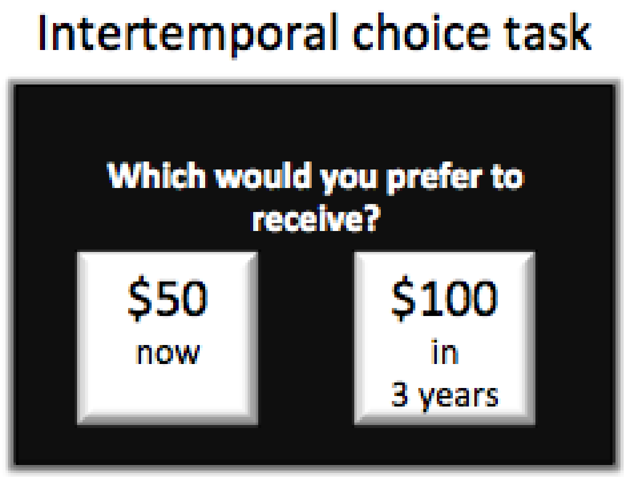

Figure 2.2. A sample trial from the intertemporal choice task. Participants were presented with two hypothetical rewards and indicated their decision between the smaller immediate reward and the larger reward to be received at the same delay.

I randomized the order in which participants completed the risky decision-making task and the intertemporal choice task. All of the rewards in this study were hypothetical, which raises the question of whether decisions would be made differently if rewards were real. Numerous studies have directly investigated this question by comparing hypothetical versus real rewards in financial decision making. These studies find no systematic difference in respective discount rates for delay discounting (Johnson & Bickel, 2002; Lagorio & Madden, 2005; Locey, Jones, & Rachlin, 2011; Madden, Begotka, Raiff, & Kastern, 2003; Madden et al, 2004) or probabilistic discounting (Hinvest & Anderson, 2010). Further, one fMRI study found that evaluating real and hypothetical rewards activated the same brain regions and that the BOLD signals in these regions were indistinguishable by function of reward type (Bickel, Pitcock, Yi, & Angtuaco, 2009). The use of hypothetical rewards in discounting research is thus likely to be valid and generalizable to real monetary rewards.

2.3 Results

Risky decision-making. Figures 2.3 and 2.4 show the mean subjective values of the sure rewards for amnesic cases and controls plotted as a function of risk for $250 and $2,000 rewards, respectively. As may be seen, the amnesic individuals (like the controls) exhibited clear discounting of both the $250 and $2,000 certain rewards: In each case, the subjective value that the amnesic individuals placed on a reward decreased systematically as the odds against receiving the reward increased.

I then calculated participants' area under the curve (AuC) for each sure reward amount. The AuC measure represents the area under the observed subjective values and provides a single, theoretically neutral measure of the degree of discounting (Myerson, Green, & Warusawitharana, 2001). Both subjective value and risk were normalized in order to calculate the AuC that, as a result, can range between 0.0 (maximally steep discounting) and 1.0 (no discounting). I then applied the neuropsychological approach to participants' AuCs to estimate the degree to which their discounting differed from that of controls (Table 2.1). Results show that each amnesic case's AuC was within normal range. In other words, amnesic cases show normally sensitivity to risk.

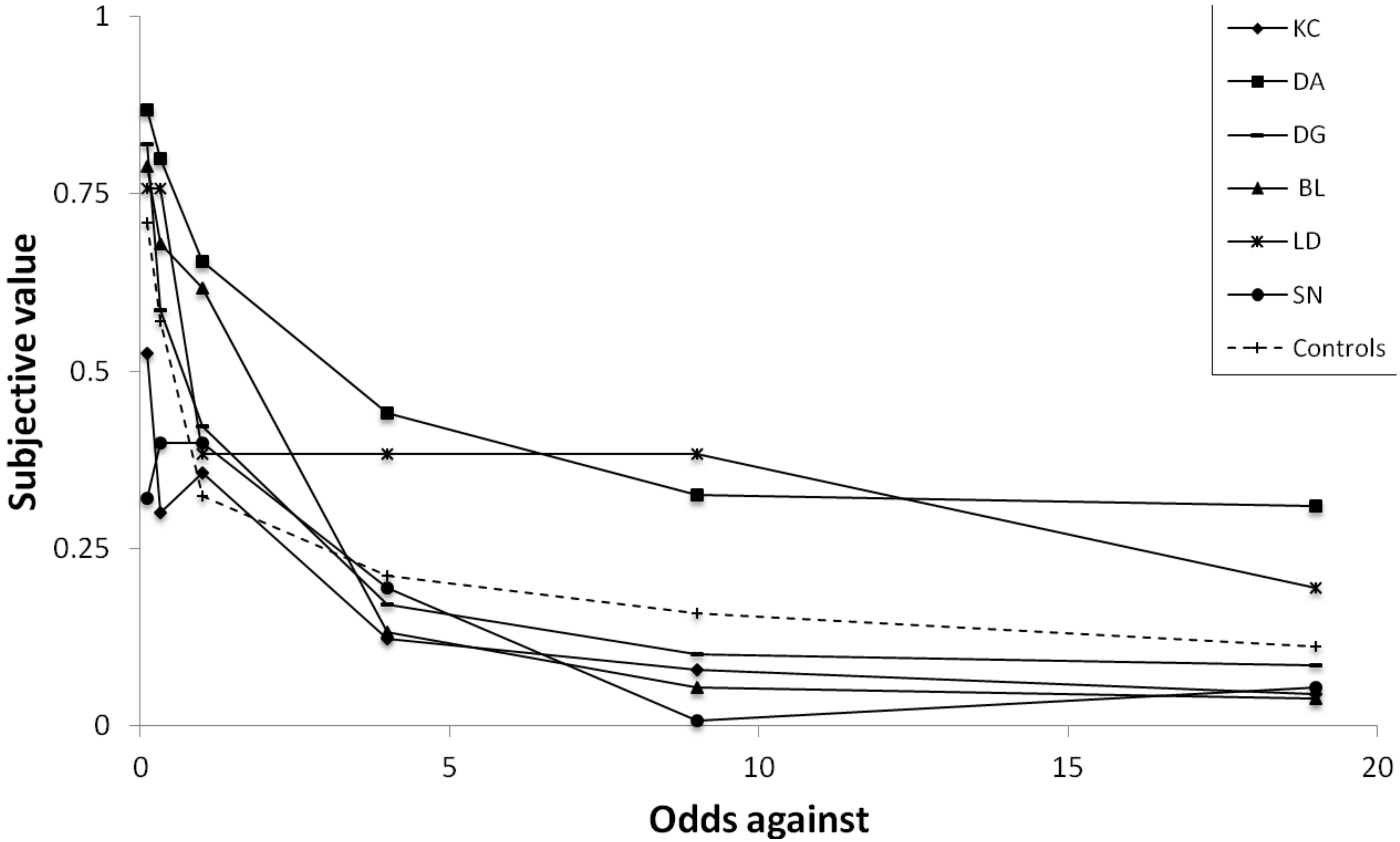

Figure 2.3 Subjective value of a $250 reward as a function of risk.

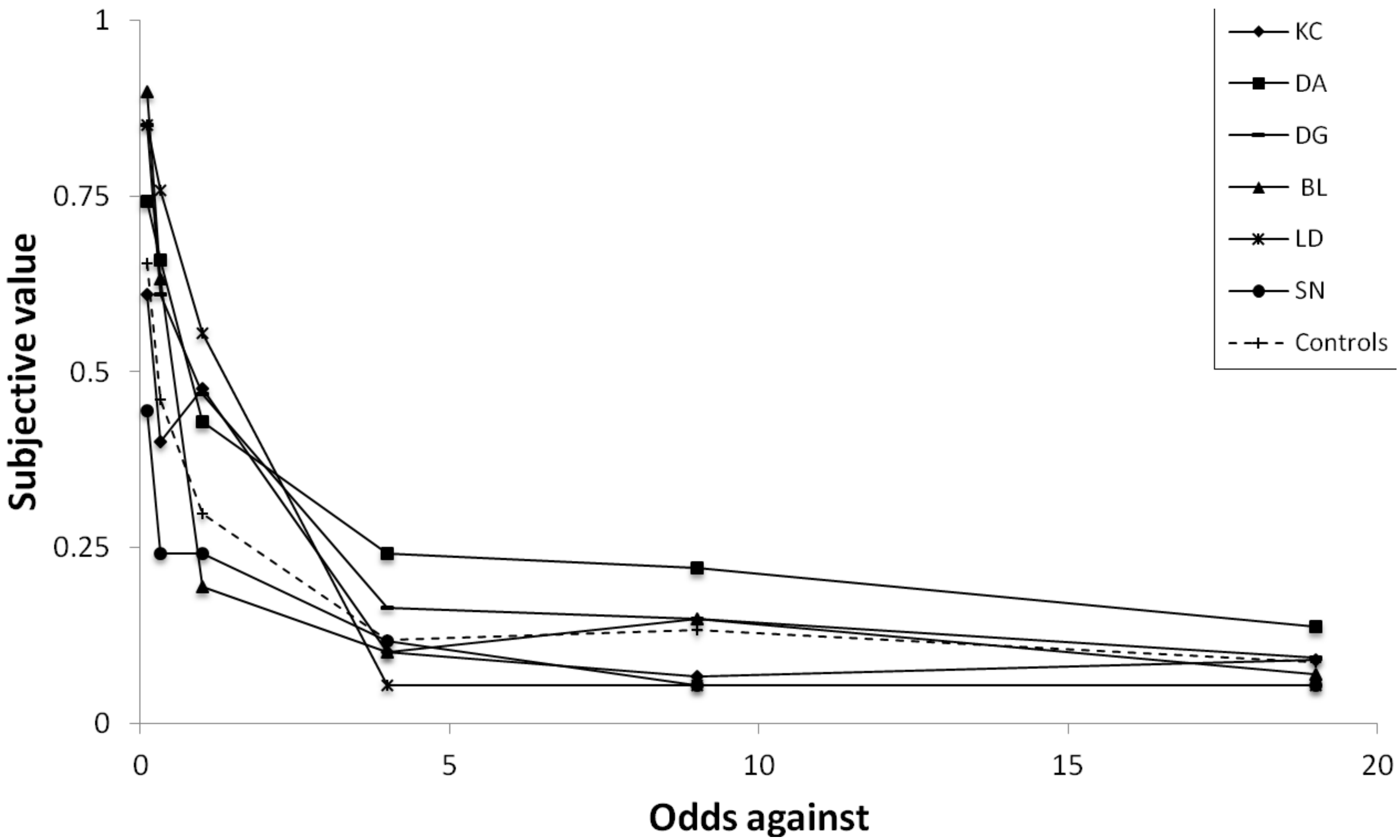

Figure 2.4 Subjective value of a $2,000 reward as a function of risk.

Table 2.1 *Amnesic cases' risky decision-making*

	$250 reward			$2,000 reward		
Case	*z-score*	*%ile rank*	*descriptive label*	*z-score*	*%ile rank*	*descriptive label*
KC	-0.385	34^{th} – 37^{th}	Average	-0.078	47^{th}	Average
DA	1.068	86^{th}	High average	0.538	70^{th} – 73^{rd}	Average
DG	-0.144	45^{th}	Average	0.226	58^{th} – 61^{st}	Average
LD	-0.240	39^{th} – 42^{nd}	Average	-0.035	47^{th} – 50^{th}	Average
BL	0.819	79^{th}	Average	-0.116	42^{nd} – 45^{th}	Average
SN	-0.413	34^{th}	Average	-0.307	37^{th} -39^{th}	Average

Higher scores indicate riskier decision-making.

Intertemporal choice. Figures 2.5 and 2.6 show the mean subjective values of the delayed rewards for amnesic cases and controls plotted as a function of delay for $100 and $2,000 rewards, respectively. As can be seen, the amnesic individuals (like the controls) exhibited clear discounting of both the $100 and $2,000 future rewards: In each case, the subjective value that the amnesic individuals placed on a reward decreased systematically as the delay until receiving the reward increased.

I then calculated participants' AuC for each future reward amount and applied the neuropsychological approach to estimate the degree to which amnesic cases' discounting differed from that of controls (Table 2.2). Results show that each amnesic case's AuC was within normal range. In other words, amnesic cases show normally valuation of the future.

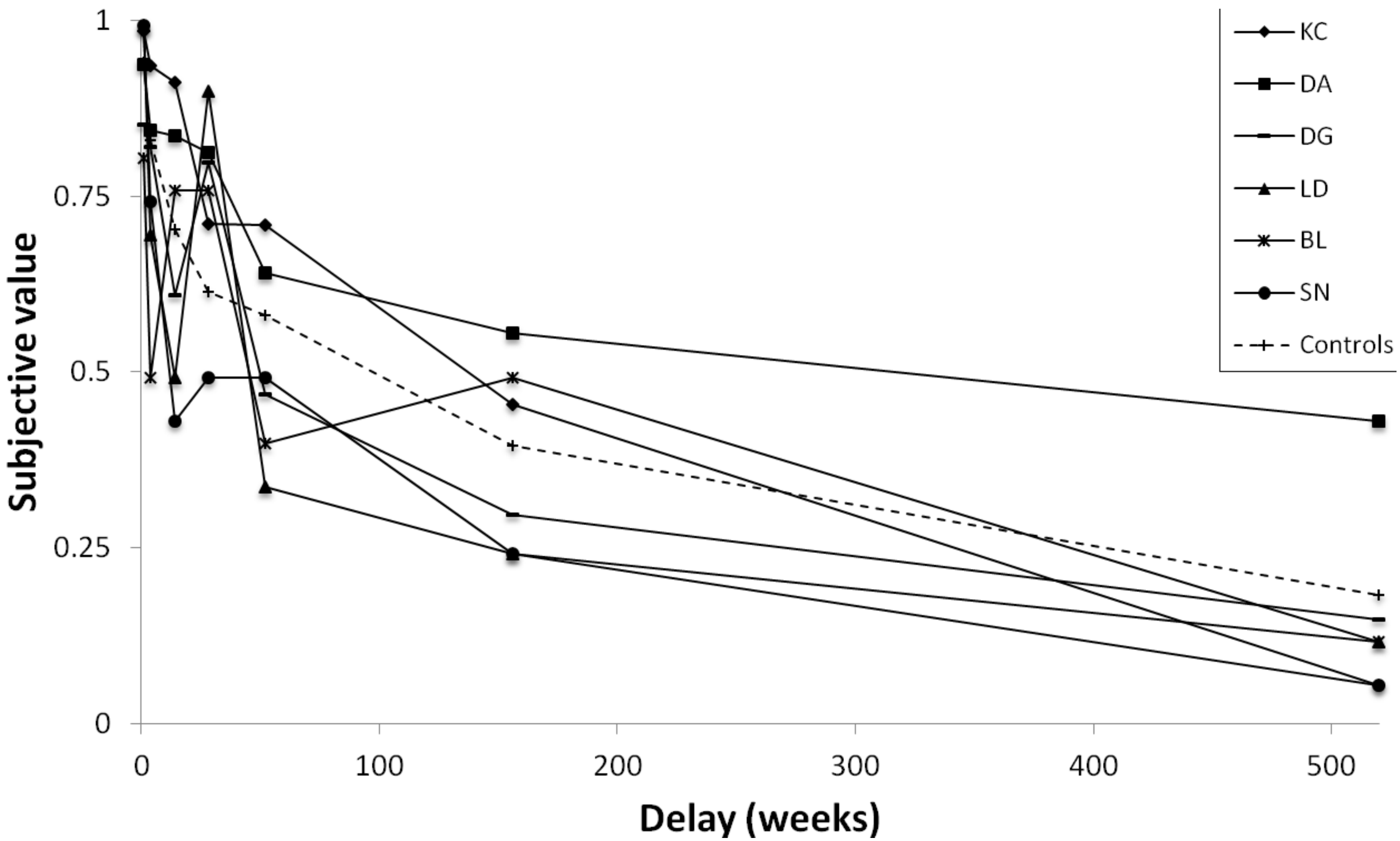

Figure 2.5 Subjective values of a $100 reward as a function of delay.

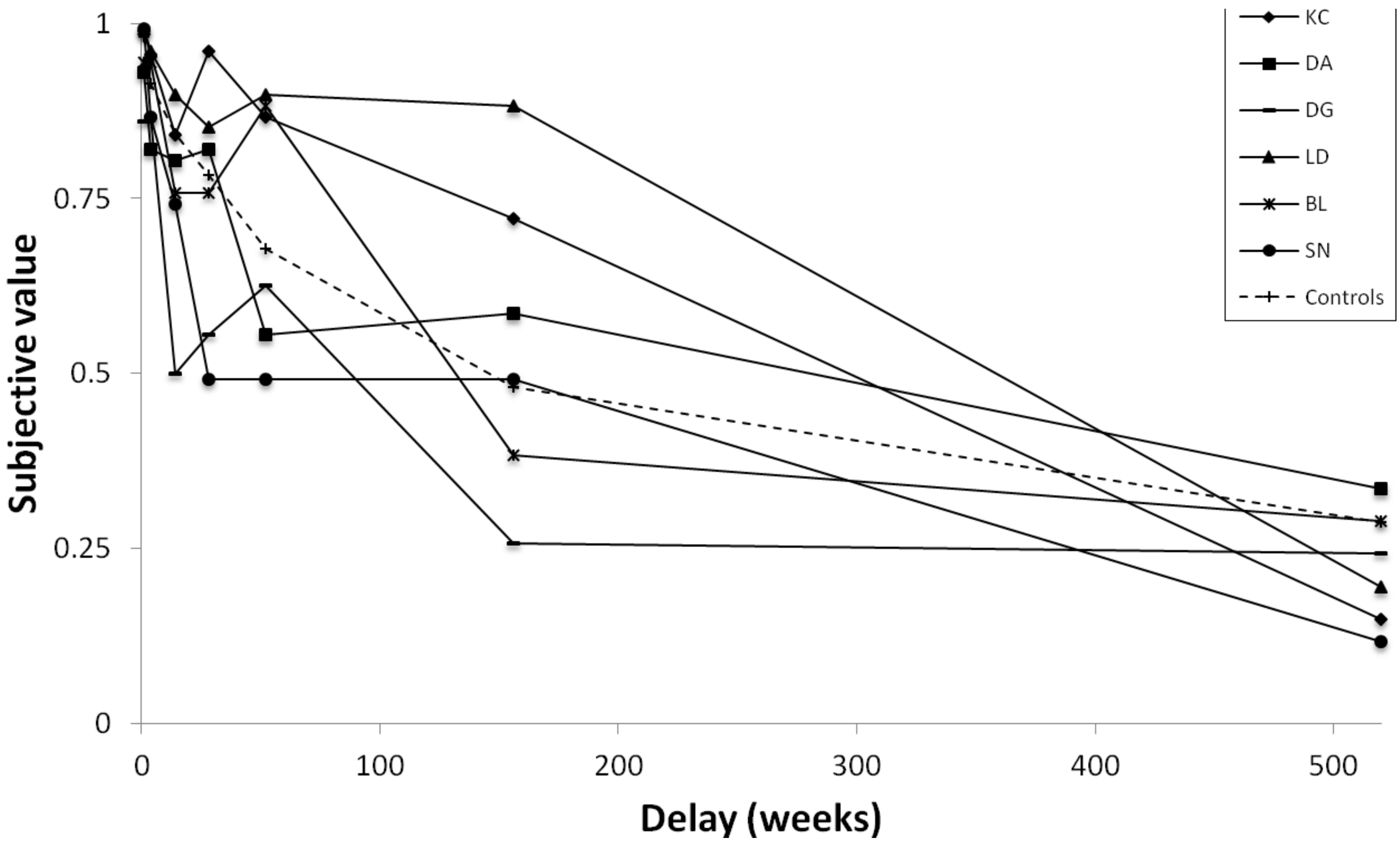

Figure 2.6 Subjective values of a $2000 reward as a function of delay.

Table 2.2 *Amnesic cases' intertemporal choices*

	$100 reward			$2,000 reward		
Case	*z-score*	*%ile rank*	*descriptive label*	*z-score*	*%ile rank*	*descriptive label*
KC	0.024	50th	Average	0.335	63rd	Average
DA	0.841	79th – 81st	High average	0.181	55th – 58th	Average
DG	-0.313	37th – 39th	Average	-0.550	27th – 30th	Average
LD	-0.567	27th – 30th	Average	0.692	75th – 77th	High average
BL	-0.001	50th	Average	-0.081	53rd	Average
SN	-0.655	25th – 27th	Average	-0.353	34th – 37th	Average

Higher scores indicate shallower discounting.

Post-task interviewing. Because intertemporal choice involves explicit consideration of the future, I conducted an informal post-task interview to understand how amnesic individuals made choices during this task. D. A. reported using a strictly economic strategy, specifically estimating inflation and interest rates, but did not expand on how he made his calculations. This strategy capitalized on his premorbid professional background. When probed, D. A. gave vague and general examples of how he might spend the money, such as “going on a vacation.” D. G. simply reported “wondering if [he] could wait that long” when deciding between immediate and delayed rewards. When pressed further, he reported that his decisions were based on a “gut feeling.” Likewise, B.L., S.N., and K.C. also reported relying on a “gut feeling.” K. C. was unable to imagine episodes or ways in which he might spend the hypothetical payout; when probed, K. C. consistently stated that he supposed he would “put it in the bank.” In fact, none of the amnesic cases reported spontaneously engaging in episodic considerations for spending. Though (aside from D.A.) amnesics’ decision-making strategies were vague at best, each was able to take the future into systematic consideration for their economic choices.

2.4 Conclusion

Given that episodic (re)constructive abilities are impaired in individuals with hippocampal amnesia (Experiment 1), I tested amnesic individuals on tasks that reflect future consideration but that do not necessarily involve the (re)construction of events from one's remembered past or in one's imagined future. The objective was to determine whether there are functionally dissociable forms of prospective thinking, some of which may depend on hippocampal episodic memory, and some of which may not. Six amnesic cases with impaired episodic prospection completed a risky decision-making task involving monetary rewards, varying the likelihood of their receipt. Despite the potential for those with impairments in prospection to be risk-prone, all cases systematically discounted the value of probabilistic monetary rewards as the odds against their receipt increased, performing within the range of their respective controls. The same cases also performed an intertemporal choice task, varying the delay until reward receipt. Amnesic cases again performed within the range of healthy controls, systematically discounting the value of future monetary rewards as the delay until their receipt increased. Taken together, these findings demonstrate that decisional aspects of prospection that do not require episodic construction are spared in those with extensive hippocampal damage and despite deficits in episodic prospection.

The current findings indicate a need to fractionate prospection into distinct underlying parts in order to understand the (potentially limited) role that the hippocampus occupies. In those with hippocampal damage, I propose that the crux of the deficit is in basic, constructive processes in the retrieval and binding of details, which are common to episodic memory, future imagining, and imagining in general. It may also be that the well-established dissociations between semantic and episodic elements in memory are true of prospection (Klein et al., 2002). Notably, the discounting tasks used in the current study, and on which people with hippocampal damage showed apparently normal function, capture predominately semantically mediated aspects of future thought. Thus, these findings support Klein et al.'s (2002) assertion that semantic memory alone can support a host of future-thinking abilities so long as they do not require temporal awareness of one's own experience. Klein et al. (2002)'s report, and the collective results from the dissertation thus far, indicate that prospection is not a unitary construct. There is emerging evidence that MTL and frontal lobe regions make distinct contributions to forms of prospective thinking. MTL structures and the hippocampus in particular, appear to occupy a central role in atemporal aspects of prospection such as those mentioned in the Introduction. In contrast, medial prefrontal cortex appears to be selectively important for subjective, conscious, experiential aspects of future thinking, and time-based thought in general (e.g., Fellows & Farrah, 2005; Wheeler et al., 1997; Nyberg et al., 2010).

Recent fMRI studies demonstrate that hippocampally-mediated episodic prospection occupies a role in financial decision making (Peters & Büchel, 2010; Benoit, Gilbert, & Burgess, 2011) but it is unclear whether this role is necessary or merely modulatory; the current findings suggest the latter. Further, the fact that I found no significant difference in delay or probability discounting between amnesic individuals and healthy controls indicates that such modulatory effects are relatively slight. The apparent discrepancy between the current data and studies that show an effect of prospection on decision making support a multiple systems approach to decision making. In a multiple systems approach, automatic and controlled processes can work in tandem to produce a decision (see Sanfey & Chang, 2008; Johnson & Weber, 2009 for reviews). There are likely multiple concurrent mechanisms that enable intertemporal choice and episodic prospection may be just one of several such mechanisms.

This approach explains why the current findings and those implicating a role for the hippocampus in discounting (i.e., Peters & Büchel) are not mutually exclusive. Amnesic individuals' intact performance on the present tests does not rule out the possibility that distortions in their temporal experience (i.e., impaired episodic prospection) could have more subtle effects on their decision-making. It remains an open question whether experimental manipulations of episodic prospection would have the same attenuating impact on the amnesic cases' discounting as they have on that of healthy adults.

Other questions that arise from this study include: What subjective strategies are reported by amnesic individuals? Do the strategies reported differ systematically from those reported by controls? The post-task interview in this study was informal because it was not part of the original task; only partway through data collection did it become apparent that the approaches to the task taken by individual participants were highly variable. A follow-up study that includes a formal post-task interview would help clarify individual differences in decision-making strategies and determine if subjective reports inform behavioural results.

Experiment 3

Flexible Intertemporal Choice

3.1 Introduction

Results thus far show that amnesic cases with hippocampal damage have impaired episodic (re)construction (Experiment 1) yet their decisions do not reflect a lost future: they avoid risky choices as much as controls and they value the future systematically when deciding among delayed rewards (Experiment 2).

It is unclear how to reconcile amnesic cases' apparently normal rates of delay discounting with the hippocampus' purported role in general decision-making (Ernst et al., 2002; Gupta et al., 2009) and particularly in intertemporal choice (Cheung & Cardinal, 2005; McHugh, Campbell, Taylor, Rawlins, & Bannerman 2008; Kurth-Nelson, Bickel, & Redish, 2012). One possibility is that amnesic populations have nuanced decision-making impairments not readily detected in standard measures of intertemporal choice. Specifically, their decision-making may lack adaptive flexibility. Flexible decisions are responsive to new information, are modulated by environmental cues, and are constructed in real time when presented with choice (Fellows, 2006). Although the ability to bend and shift choices is broadly associated with frontal lobe function (Fellows, 2006; Mitchell et al, 2009), researchers now posit that the hippocampus and episodic prospection also contribute to this hallmark of human decision-making (see Johnson, van der Meer, & Redish, 2007; Labudda et al., 2009).

In Experiment 2, amnesic cases may have made seemingly normal intertemporal choices using a rigid, non-episodic heuristic such as rejecting every offer below a certain threshold. One way to further investigate the normalcy and limits of decision-making in amnesia is to test whether, like healthy controls, individuals with damage to the MTL memory system and impairments retain adaptive flexibility in their decision-making. For example, healthy individuals flexibly modulate their delay discounting (i.e., place greater value on the future) when they are first cued to imagine specific future experiences temporally contiguous with the reward. fMRI analyses show that this cueing effect is predicted from both the amount of self-reported mental imagery during decision-making and the degree of coupling between hippocampal/MTL and frontal lobe regions (Peters and Büchel, 2010; Benoit et al., 2011). These findings suggest that individuals with damage to these systems, or reduced coupling among them, will not be able to modulate the value of future rewards when they are cued to think of personal future experiences.

The current study tests the hypothesis that hippocampal amnesia impairs prospective decision-making disabling the cueing effect – that is, flexible modulation toward the future when cued to imagine future experiences. Does this modulatory effect require intact episodic prospection, or can alternative mechanisms facilitate the adaptive effect of cueing without detailed episodic prospection?

3.2 Methods

3.2.1 Participants

Amnesic cases. The same amnesic cases who participated in Experiments 1 and 2 participated in the current study. Participants again received monetary compensation for their time.

Controls. The same controls who participated in Experiment 2 participated in the current study.

Participants gave informed written consent in accordance with the Human Research Ethics Committees of York University and Baycrest, and received monetary compensation for their time.

3.2.2 Procedure

At least one month after participants completed the standard intertemporal choice task in Experiment 2, they performed a second intertemporal choice task that included personal future event cues. Although carry-over effects from this design cannot be ruled out, our previous research shows that they are unlikely: repeated testing does not systematically change rates of discounting in amnesic cases or controls (Kwan, Craver, Green, Myerson, Boyer, & Rosenbaum, 2012). This design also ensured that any benefit from future event cueing did not carry over into participants' baseline discounting rates.

Amnesic and control participants identified planned or plausible personal future events (e.g., appointments, anniversaries, outings) for each of the seven delays in the discounting task. To minimize the possibility of inducing anticipatory anxiety or distress, participants were asked to include only emotionally neutral or positive future events. Perhaps unsurprisingly, the amnesic cases had greater difficulty generating events in comparison to controls, and for this reason, all participants were permitted to refer to personal calendars and electronic devices, which greatly facilitated cue collection. When participants encountered difficulties providing an event, the experimenter probed with the following questions: "Might there be any events with family or friends that may take place in <insert delay>?" and, "Is there something you could possibly see yourself doing in <insert delay> or want to do in <insert delay>?" In the case of S.N., his mother provided several distant future events when he was unable to provide cues.

As depicted in Figure 3.1, the discounting task in the cued condition proceeded as in the standard (non-cued) condition, except that each delay-interval block was preceded by the prospective cue associated with that delay. Upon viewing a cue word, participants were instructed to imagine in as much detail as possible the personal future event associated with the cue and to press a button indicating they had the event in mind. The button press triggered the decision-making screen and participants then completed the same intertemporal choice task as in the baseline condition. The event cue remained at the top of the screen until the end of the delay block to keep the future event 'activated' in participants' minds and to reduce demands on memory.

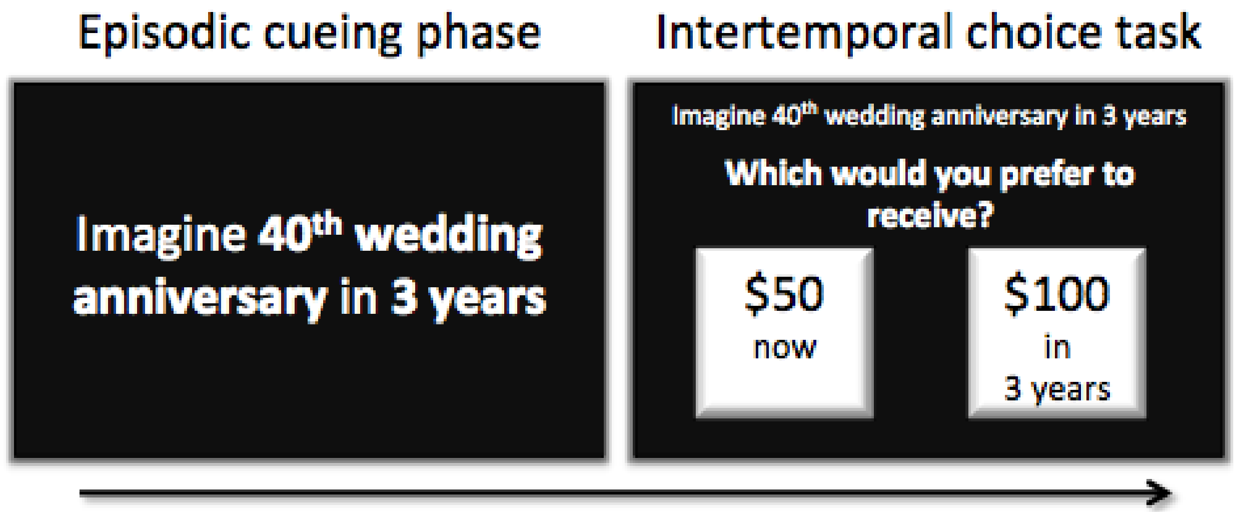

Figure 3.1 A sample trial from the cued intertemporal choice task. Participants were presented with an episodic cue and imagined a personal future experience occurring at a specific delay (e.g., 3 years). They were then presented with two hypothetical rewards and indicated their decision between the smaller immediate reward and the larger reward to be received at the same delay.

3.3 Results

Figure 3.2 shows participants' mean subjective values plotted as a function of delay for the standard and cued conditions. Subjective values are given as proportions of the reward amount, averaged across the two delayed amount conditions. Note that the control data from replicates the cueing effect (Peters & Büchel 2010; Benoit et al., 2011): Future rewards were discounted less steeply in the cued condition. As may be seen in Figure 3.2, a few of the amnesic cases, most notably D.G. and B.L., also demonstrated this effect.

Next I calculated AuCs for each reward amount ($100, $2000) and for each condition (standard, cued). To measure the cueing effect for each reward amount, I took the difference scores between AuCs in the cued condition and those in the standard condition. I then averaged these difference scores across the two reward amounts to derive a single measure of the cueing effect (see Table 3.1). Contrary to my hypothesis, the current results establish that cases with low or even outright impaired episodic prospection can show cueing effects that fall within the range of controls.

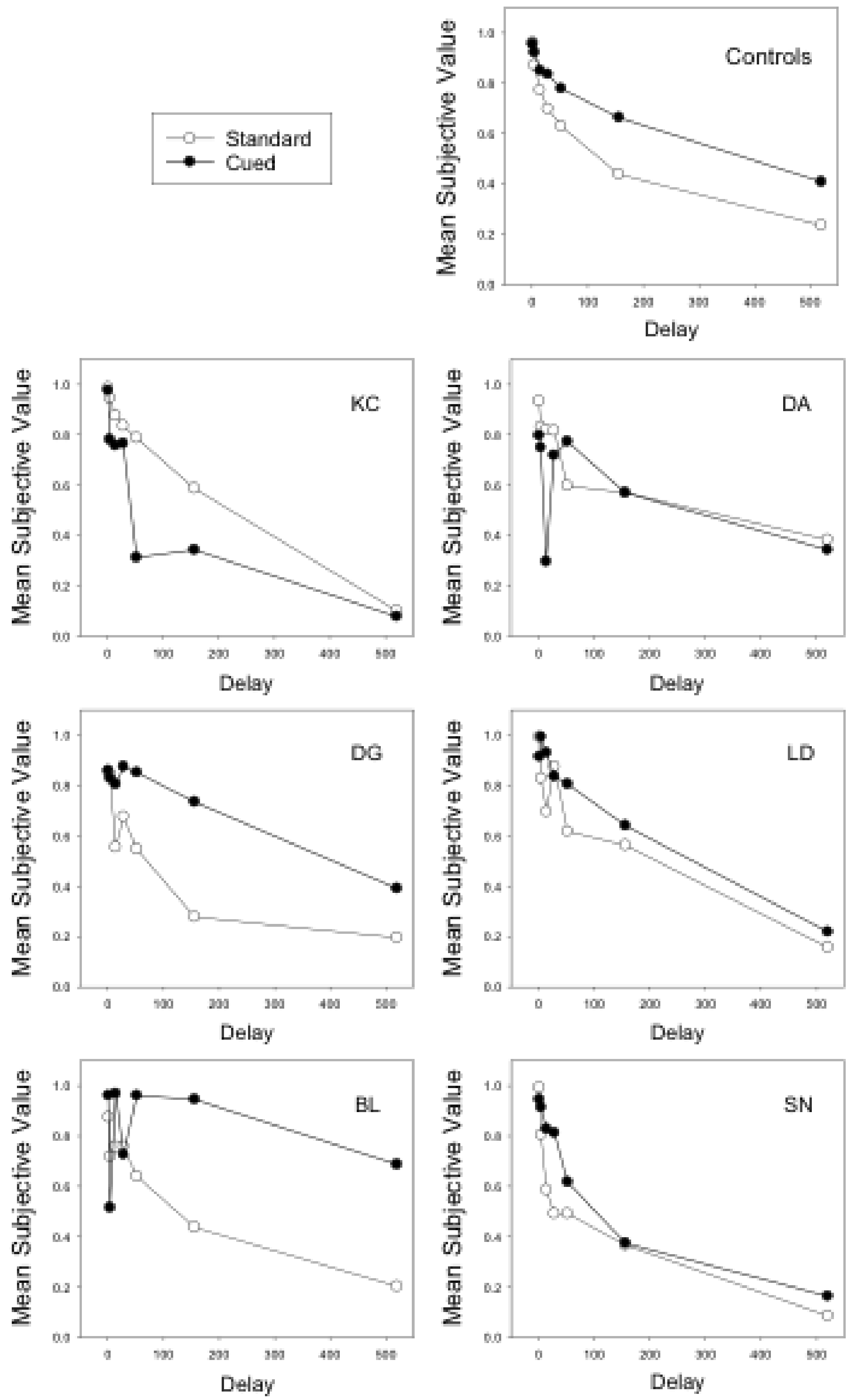

Figure 3.2 Subjective value as a function of delay. Lines represent choices averaged across both reward amounts.

Table 3.1 *Amnesic Cases' Cueing Effect*

	Average Cueing Effect		
Case	*z-score*	*%ile rank*	*Descriptive label*
KC	-1.76	5th	Borderline impaired
DA	-0.93	18th	Low average
DG	0.66	73rd - 75th	High average - Average
LD	-0.49	30th - 32nd	Average
BL	1.20	88th - 90th	High average
SN	-0.59	27th - 30th	Average

3.4 Conclusion

The present results shed light on the limited contributions that the hippocampus and the extended hippocampal system, which support episodic memory and episodic prospection, make to intertemporal choice. Experiment 2 established that hippocampal damage does not impair standard intertemporal choice: Individuals with such damage discount the value of delayed rewards no more steeply than do healthy controls. The current study extends this research by investigating whether damage to the hippocampal memory system affects the tendency for cueing future experiences to modulate the value of future rewards.

The amnesic group and controls performed an intertemporal choice task with cues that prompted participants to imagine personal future events expected to occur at the time the delayed reward would be received. The amnesic cases' choices in the cued task condition were also surprisingly similar to those of controls, indicating broadly preserved ability to reduce the degree of discounting when first cued to consider future experiences. Indeed, low episodic prospection (z-scores between -2.00 to -0.74) or even outright impaired episodic prospection (z-scores below -2.00) did not completely remove the cueing effect. These results call into question a simple account that assumes a direct relation between episodic prospection and the modulation of delay discounting and suggests the need for a more nuanced account. Not only do amnesic cases' decision-making show preserved regard for the future, their choices can remain flexible and responsive to environmental cues. Their preserved function is likely achieved through gist or semantic representations of possible personal future events, and raises the possibility that such representations, rather than or in addition to episodic prospection, underlie typical human intertemporal choice.

Amnesic cases individuals varied widely in both the magnitude of episodic prospection impairment (Experiment 1) and the magnitude of cueing effects (current experiment), but variability in the former did not predict the latter, raising the question of what other factors may account for variations in the cueing effect among amnesic cases. One factor affecting the effectiveness of cueing may be the extent of damage within the extended hippocampal system that includes the hippocampus proper and surrounding MTL tissue, as well as the fornix, mammillary bodies, and parts of the thalamus (Aggleton & Brown, 1999). Individual analyses revealed that the two individuals who were least responsive to cueing, K.C. and D.A., are those with the most widespread and bilateral neurological damage within the MTL. On the other end of the spectrum, the two cases who were most responsive to cueing, D.G. and B.L., are the only cases who suffered anoxia, an etiology that can produce more circumscribed, incomplete hippocampal lesions (Cummings, Tomiyasu,, Read, & Benson, 1984; Allen, Tranel, Bruss, & Damasio 2006) with relative sparing of surrounding MTL tissue. Indeed, B.L.'s lesions are selective to the dentate gyrus of the hippocampus and he has spared surrounding MTL tissue. Unfortunately, I am unable to assess D.G.'s lesions due to contraindications that prevent him from entering an MRI.

Those with more circumscribed damage may have residual hippocampal tissue that remains functional. In other studies, researchers proposed that activation of residual tissue may explain why some amnesic cases nevertheless retain certain functions thought to be hippocampally dependent (Maguire, Vargha-Khadem, & Hassabis, 2010; Mullally, Hassabis, & Maguire, 2012). Follow-up fMRI research with the present sample of amnesic cases to assess the functional status of their remaining hippocampal tissue would give additional insight into neurological processes that might explain how their intertemporal decision-making is similar or dissimilar to that of controls.

There is, however, an alternative explanation for why the amnesic cases varied in their degree of responsiveness to cueing that is independent of explanations relating to residual hippocampal activation, integrity of the extended hippocampal system, and episodic prospection. Intertemporal choice is inherently high in individual variability, even among healthy adults (Myerson & Green, 1995; Peters & Büchel, 2011), and the cueing effect is also likely subject to this variability. Indeed, the controls in this study show an overall discounting reduction in cued choices when scores are averaged, yet the current analyses show that individuals varied widely in this regard. A few control participants even shifted their cued choices in the opposite direction, discounting delayed rewards more, rather than less steeply. It is thus not surprising, and actually expected, that the amnesic cases would show cueing effects of varying magnitudes. What is surprising, and possibly of fundamental theoretical significance, is that the cueing effect was not altogether abolished despite these individuals' neurological damage and memory impairment.

In a recent study Palombo et al. (2015a) reported that although amnesic cases with MTL lesions showed intact standard discounting, they failed to attenuate their discounting in response to episodic prospection cues. This latter result differs from what was observed in the current study, despite the fact that the amnesic groups in both studies were similar in age, neuropsychological profile, and episodic prospection impairment. If multiple processes beyond episodic prospection can facilitate the cueing effect, it is not immediately clear why the amnesic cases in Palombo et al.'s study did not benefit from cueing. One possibility is that the discrepancy in findings may be due to differences in how each study cued the personal future. Following Benoit et al.'s paradigm (2011), the participants in Palombo et al.'s study were probed to imagine future events using cues drawn from a set of standard scenarios (e.g., attending a street fair or going to a bar). Each participant received cues that corresponded to events for which they had given ratings of high familiarity and liking in a pre-experimental session, and was instructed to imagine spending a specific amount of money in the given scenario. In contrast, participants in the current study generated their own future event cues, sometimes referring to existing future plans, and they were not required to imagine doing anything specific.

Because cues in this study were self-generated, personally meaningful, and highly plausible for each individual, they may have more readily recruited alternate cue-facilitating processes such as gist representation or personal semantic prospection than the standard event cues used in Palombo et al. (2015a). Indeed, it is possible that amnesic individuals in general would show benefits in episodic prospection if given specific personalized and meaningful future event cues like the ones used in the cued discounting condition of the current study, rather than the individual cue words that are typically used to assess episodic prospection (i.e., Galton-Crovitz cueing). Moreover, because the cueing instruction in the present study was quite broad (e.g., "Imagine your granddaughter's birthday party in 1 month"), it may have facilitated activation of relatively intact gist-like, semantic representations. In contrast, the specificity with which amnesic cases were instructed to imagine the future in Palombo et al.'s study (e.g., "Imagine spending $42 at a theatre in 2 months") may have loaded more heavily on their impaired episodic prospection ability (see Palombo et al., 2015b for commentary). Further research will be needed to identify the conditions in which individuals with episodic amnesia show preserved versus impaired decision-making and to clarify the processes contributing to future decision-making in general.

Experiment 4

Scaffolding Episodic Memory and Episodic Prospection

4.1 Introduction

Results thus far show that amnesic cases with hippocampal damage have impaired episodic (re)construction (Experiment 1) yet they retain intact future oriented decision-making (Experiment 2) and in some cases even retain flexible and adaptive responsiveness to cues of future experiences (Experiment 3). The results collectively distinguish basic constructive processes in episodic thinking that are impaired in MTL amnesia from other forms of prospective thinking that are relatively intact in the same amnesic cases. In the present experiment I reconsider original assessments of memory and prospection in amnesic cases (i.e. Experiment 1). I investigate whether magnitudes of impairment may in part be a function of using Galton Crovitz cueing as the method of assessment and whether more structured or ecologically valid cues can act as a cognitive scaffold to improve episodic memory and prospection impairments in individuals with amnesia.

There is considerable work in the autobiographical memory literature demonstrating that the different aspects of recollection depend on the cue used to elicit a memory. For example, the Proust phenomenon asserts that olfactory stimuli are more effective in eliciting memories than stimuli presented via any other sensory modality (see Chu & Downes, 2000, 2002); moreover, such memories are particularly emotional in nature (Herz, Eliassen, Beland, &

Souza, 2004; Willander & Larsson, 2007) and more strongly evoke the subjective experience of being "brought back" to the event (Herz & Schooler, 2002). The ease with which a cue can elicit an image – a quality sometimes referred to as imageability – also has implications for the process of autobiographical memory retrieval and the content that is retrieved. Rubin & Schulkind (1997) found that cues that are more concrete and imageable elicited autobiographical memories with shorter latencies and older autobiographical memories. Williams, Healy, and Ellis (2010) manipulated three characteristics of verbal cues – imageability, frequency, and predictability – and found that visual imageability uniquely predicted how well participants could recollect autobiographical events.

Galton-Crovitz cueing (Crovitz & Schiffman, 1974), in which participants are given a single, generic cue word (e.g., "lemon") as a starting point for an episode, is widely used to elicit narratives in neuropsychological studies of episodic past, and more recently, future thinking (amnesia, Race et al., 2011; bipolar disorder, King et al., 2011; amnestic mild cognitive impairment, Gamboz et al., 2010; Parkinson's disease, de Vito et al., 2012; post-traumatic stress disorder, Brown, Root, Romano, Chang, Bryant, & Hirst, 2013, etc.). This method prevails in popularity for several reasons. First, it is a long-standing method for cueing autobiographical memories (Galton, 1879; see McDermott, Szpunar, & Christ, 2009), and the overlap between episodic memory and prospective imagining makes it an obvious option for cueing prospection. Second, it is relatively easy to construct and administer, with the same cue words applied uniformly to each participant. Third, cue words can be matched on variables such as imageability and frequency of use, allowing for better experimental stimulus control.

Galton-Crovitz cueing also has methodological drawbacks. For example, Maguire and

Hassabis (2011) suggested that individual cue words can elicit semantic bias and erroneously inflate amnesics' episodic prospection scores, thereby masking potential deficits. They also proposed that cueing with full sentence descriptors is more valid because it encourages rich prospective visualization, which they argue is the foundation of any imagined episode (Hassabis & Maguire, 2007). In contrast, Hurley et al. (2011) suggested that constructing a detailed representation of a future experience from a single word places high cognitive demands on neuropsychological populations and may, instead, result in overestimating the magnitude of a participant's actual impairment. Rosenbaum and colleagues made a similar point based on discrepant episodic memory findings in H.C., a rare case of developmental amnesia (see Rosenbaum et al., 2014 for detailed neuroanatomical profile). H.C.'s episodic memory was impaired when assessed with single Galton-Crovitz cue words (Kwan et al., 2010), yet appeared to improve when she was provided with a list of event topics (e.g., high school graduation) from which to choose cues (Rosenbaum et al., 2011). Rosenbaum et al. (2011) suggested that H.C.'s greater difficulty with single cue words might have been due to the constraints placed on her memory search.

As with studies of episodic memory, there are variations in the types of cues that researchers have used to elicit future events. These differences have led to debate over how best to measure the construct and interpret discrepant results across studies (Klein, 2013b; Schacter, Addis, Hassabis, Martin, Spreng, & Szpunar, 2012). Nevertheless, systematic research on how such differences may affect performance is only beginning to surface (Rasmussen & Berntsen, 2014).

The main objective of the present study is to test whether specific, personally meaningful cues can yield richer episodic memory and prospection in amnesic individuals over typically used single Galton-Crovtiz cue words. The secondary objective is to capitalize on the series-of-case studies approach in order to investigate the degree to which each individual amnesic case benefits from cueing, along with the factors that lead to cue-related gains in a given case.

4.2 Methods

4.2.1 Participants

Amnesic cases. With the exception of amnesic case K.C., the same cases who participated in Experiments 1-3 also participated in this study.

Controls. Control data for episodic prospection using Galton-Crovitz cueing were the same as in Experiment 1. For the current study I tested a separate sample of older adults (N = 30, 16 male; M_{age} = 68.233, SD = 6.027). Participants gave informed written consent in accordance with the Human Research Ethics Committees of York University and Baycrest, and received monetary compensation for their time.

4.2.2 Procedure

Approximately one year after completing Experiment 1, each amnesic case returned to complete the current study. The amnesic cases could not recall the contents of the first test session, or even of having previously participated. I also tested a new group of healthy older controls. Before beginning the task, amnesic and control participants first identified six past personal events (up to five years ago) and six planned or plausible future personal events (up to five years in the future). Examples of events included specific appointments, anniversaries, and outings. During the cue collection phase, participants identified the event with a brief tag (e.g., "40th wedding anniversary") and did not elaborate on the event.

The amnesic cases had greater difficulty than controls in generating topics, and all participants were permitted to refer to personal calendars and electronic devices, which assisted the cue collection. When participants encountered any difficulty providing an event, I probed with the following questions: "Might there be any events with family or friends that took place/may take place in <insert delay>?" and, "Is there something you possibly did/could see yourself doing in <insert delay>?" In the case of S.N., his mother provided several possible future events when he was unable to provide cues. The experimental task and scoring then followed exactly the same procedure as in Experiment 1.

4.3 Results

Episodic memory. Figure 4.1 shows the performance of each amnesic case in response to specific, personal cues relative to Galton Crovitz cues. Autobiographical episodic memory benefited from personal cueing in some but not all of the cases. Three of five amnesic cases (D.G., L.D., B.L.) showed improved internal detail generation in response to personal cues, whereas two of the cases (D.A. and S.N.) did not show an appreciable change in internal detail generation across cue type. Specific cueing did not have any consistent effect on the amnesic cases' external detail generation during autobiographical recollection. These findings are summarized in Table 4.1, which includes z-scores, estimated percentiles, and diagnostic labels corresponding to the number of internal and external details of future events that was generated by each amnesic case.

Episodic prospection. Figure 4.2 shows the performance of each amnesic case's performance on episodic prospection in response to specific, personal cues relative to Galton Crovitz cues. As can be seen, the five amnesic cases showed varying degrees of benefit from personal cueing. Episodic prospection impairment in three of the five amnesic cases (L.D., B.L., S.N.) was significantly alleviated by personal cues, such that they generated a greater number of internal details when given personal cues compared to the number generated in response to generic cue words. The number of internal details generated by D.A. and D.G. was significantly lower than that of controls for each cue type and did not differ in response to personal cues.

In contrast, specific cueing had widely variable effects on external detail generation, with no clear pattern in external detail generation as a result of personal cueing. These findings are summarized in Table 4.2.

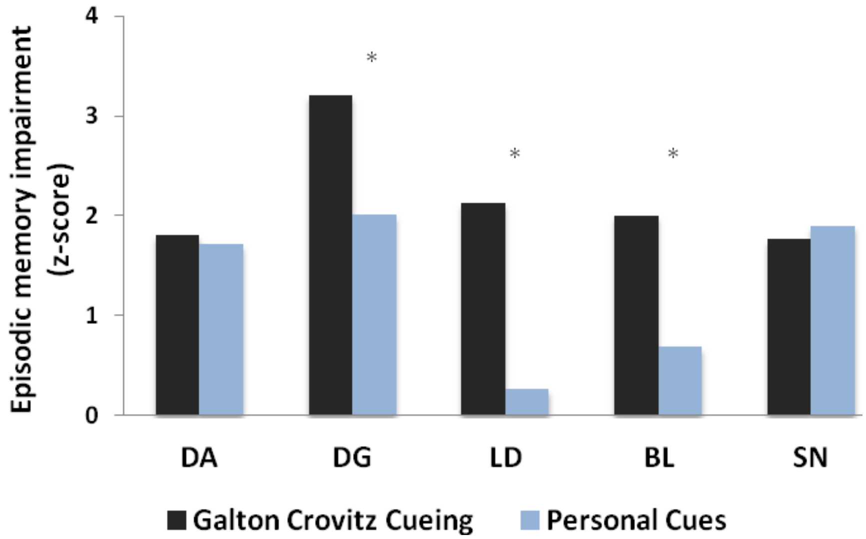

Figure 4.1 Amnesic cases' episodic memory using Galton Crovitz cueing and using personal specific cueing. Z-scores are reversed so that higher numbers indicate greater impairment. Asterisks denote clinically significant improvement, defined as improvement by at least one diagnostic level according to a standardized psychometric conversion table.

Table 4.1 *Episodic memory with Galton-Crovitz cues and specific, personal cues*

Internal details						
	Galton-Crovitz cue words+			Personal specific cues		
Case	*z-score*	*%ile rank*	*descriptive label*	*z-score*	*%ile rank*	*descriptive label*
DA	-1.802	3^{rd} – 4^{th}	Borderline	-1.715	4^{th} – 5^{th}	Borderline
DG	-3.200	0.07^{th}	Impaired	-2.005	2^{nd}	Impaired – BL*
LD	-2.124	1^{st} – 2^{nd}	Impaired	-0.261	39^{th} – 42^{nd}	Average*
BL	-2.003	2^{nd}	Borderline - Impaired	-0.684	23^{rd} – 25^{th}	Low average – A*
SN	-1.762	3^{rd} – 4^{th}	Borderline	-1.899	3^{rd}	Borderline

External details						
	Galton-Crovitz cue words+			Personal specific cues		
Case	*z-score*	*%ile rank*	*descriptive label*	*z-score*	*%ile rank*	*descriptive label*
DA	-0.490	30^{th} -32^{nd}	Average	-0.765	21^{st} – 23^{rd}	Low average
DG	-1.724	4^{th}	Borderline	1.164	88^{th}	High average
LD	0.673	75^{th}	High average	-0.185	42^{nd} – 45^{th}	Average
BL	1.022	86^{th}	High average	0.316	62^{nd}	Average
SN	3.117	99.91^{st}	Very superior	2.786	99.7^{th}	Very superior

Higher “External details” scores indicate an access of details.
BL = Borderline, A = average, “superior” performance indicates an excess of details
+ Galton-Crovitz data taken from Experiment 1: Episodic Memory and Episodic Prospection
* indicates significant clinical improvement

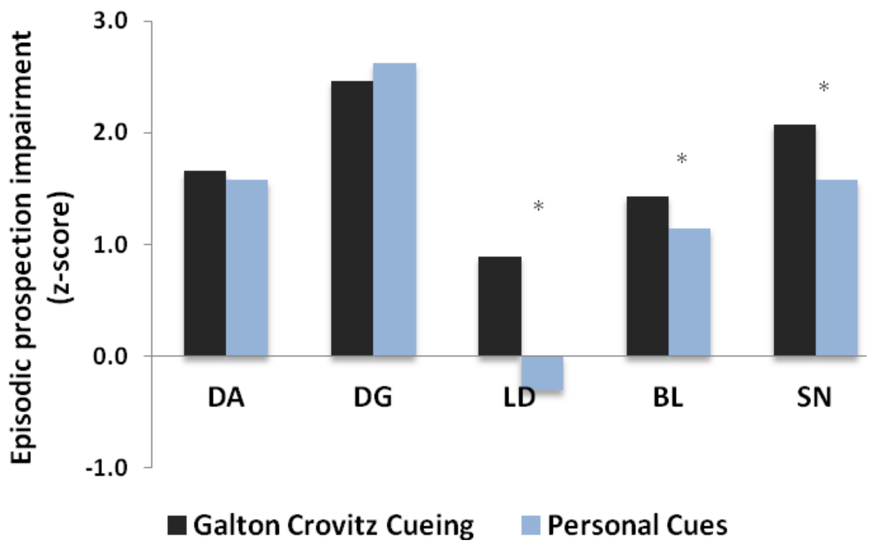

Figure 4.2 Amnesic cases' episodic prospection using Galton Crovitz cueing and using personal specific cueing. Z-scores are reversed so that higher numbers indicate greater impairment. Asterisks denote clinically significant improvement, defined as improvement across diagnostic labels of function in a standardized psychometric conversion table.

Table 4.2 *Episodic prospection with Galton-Crovitz cues and specific, personal cues*

Internal details						
	Galton-Crovitz cue words+			Personal specific cues		
Case	*z-score*	*%ile rank*	*descriptive label*	*z-score*	*%ile rank*	*descriptive label*
DA	-1.653	4th -5th	Borderline	-1.574	5th – 6th	Borderline
DG	-2.459	0.7th – 0.8th	Impaired	-2.622	0.4th – 0.5th	Impaired
LD	-0.891	18th -19th	Low average	0.308	61st – 63rd	Average*
BL	-1.432	7th – 8th	Borderline	-1.144	12th – 13th	Low average*
SN	-2.074	2nd	Impaired	-1.574	5th – 6th	Borderline*

External details						
	Galton-Crovitz cue words+			Personal specific cues		
Case	*z-score*	*%ile rank*	*descriptive label*	*z-score*	*%ile rank*	*descriptive label*
DA	-0.721	19th – 21st	Average – Low average	-1.226	10th – 12th	Low average
DG	-1.850	3rd – 4th	Borderline	-0.718	23rd – 25th	Low average
LD	0.404	66th	Average	-0.059	47th – 50th	Average
BL	1.459	92nd – 93rd	Superior	1.241	88th – 90th	High average
SN	1.230	88th – 90th	High average	2.653	99.6th	Very superior

Higher “External details” scores indicate an access of details.
“Superior” performance indicates an excess of details
+ Galton-Crovitz data taken from Experiment 1: Episodic Memory and Episodic Prospection
* indicates significant clinical improvement

4.4 Conclusion

The present study investigated whether impaired episodic memory and prospection improves when specific, personally meaningful cues are provided rather than standard, generic, Galton-Crovitz cue words. I found that personal cues benefited the generation of internal details in 3 of the 5 cases, in both past and future conditions. The current finding that some MTL amnesic cases benefit from specific, personally meaningful cues suggests that basic constructional processes in episodic memory and prospection may be compromised. This is consistent with fMRI studies of episodic prospection that show increased hippocampal activation during the initial construction phase of prospection, and subsequently decreased activation as participants elaborate on the constructed event (Addis et al., 2007; see also Rabin, Gilboa, Stuss, Mar, & Rosenbaum, 2010).

The role of the hippocampus in initial event construction indicates the importance of having some scaffold or framework to help structure event details in at least some individuals with hippocampal amnesia. Identifying potential scaffolds is of theoretical and clinical interest. For example, a memory schema, defined as an associative network structure based on multiple episodes that is adaptive and lacks detail (Ghosh & Gilboa, 2014), may serve as such a scaffold. A schematic cue to scaffold episodic prospection might be, “Imagine how you would make lemonade in the future,” as this draws on scripted and generic conceptual knowledge on how to make lemonade. In contrast, a specific personal cue to scaffold episodic prospection, as in the current study, might be, “Imagine your granddaughter’s lemonade sale next summer.” Both types of cues likely afford greater episodic (re)construction than the Galton-Crovitz cue equivalent, “lemonade.” Relatedly, Irish and colleagues suggest that semantic memory in particular can act as a schema for prospective thinking (i.e., “Semantic Scaffolding Hypothesis,” Irish, Addis, Hodges, & Piguet, 2012; Irish & Piguet, 2013), while Klein (2015) suggests that autonoetic consciousness, a unique experiential awareness of the self across time, scaffolds the ability to travel through mental time into one’s future. Thus, specific personal cues may be just one of many ways to scaffold episodic memory and prospection.

At the same time, results from this study also show that even scaffolding narratives with rich cues does not altogether extinguish impairments in memory and prospection. Such cues reduce but do not remove constructive demand and providing a basic structure still requires individuals to “fill in the blanks” or elaborate, a process that requires MTL integrity, albeit to a lesser degree than initial event construction (Addis & Schacter, 2008). Indeed, recent neuroimaging studies of the neural underpinnings of event construction show that the role of the hippocampus may be more nuanced than originally believed. For example, McCormick and colleagues (2013) used a multivariate approach to assess functional connectivity between hippocampal and neocortical regions as healthy participants constructed and elaborated on autobiographical memories. Results showed that only the left anterior hippocampus was activated and that it interacted with frontal areas during the construction phase; bilateral posterior hippocampi were activated and interacted with visual perceptual areas during the elaboration phase. Another neuroimaging study suggests that medial temporal lobe structures are critical only during the *elaboration* of autobiographical events when modulated by the PFC. Findings from this study instead identified two other networks – a frontoparietal network and a cinguloperculum network – as facilitating the construction of autobiographical recall (St. Jacques, Kragel, & Rubin, 2011).

Delineating the roles of the hippocampus and other regions in episodic memory and episodic prospection continues to be an active area of investigation, and the current study may inform some discrepancies in findings from past studies on this topic. For example, patient H.C. demonstrated significant episodic prospection impairment when she was first assessed using Galton-Crovitz cueing (Kwan et al., 2010). However in subsequent testing using more elaborate, full-sentence scenario cues (e.g., "Imagine you are walking along a busy fishing harbor"; "Imagine how you will spend next Christmas"), H.C. and other developmental amnesic cases with MTL damage showed intact episodic prospection (Cooper et al., 2011; Hurley et al., 2011). The current results suggest that H.C.'s impaired episodic prospection on some measures but not others is due to differences in the level of scaffolding built into the non-descript cue words versus elaborate scene/scenario cues.

Comparing episodic memory with episodic prospection in the current study provides insight into the well-documented neurocognitive overlap between the two processes. Specific, personal cues benefited both episodic memory and prospection in three of five cases. I expected that amnesic cases who benefited from personal cueing on episodic memory would be the same cases who benefited in episodic prospection. This was true of B.L. and L.D. but not D.G, who showed improvement (albeit modest) only for past memories, or S.N., who showed improvement only for episodic prospection. These initial findings may speak to individual differences in amnesia or may point to distinct subcomponents of the shared core network underlying past and future episodic thought (Addis, Pan, Vu, Laiser, & Schacter, 2009). Further research is needed to determine whether episodic memory and prospection are similarly influenced by rich cues. I discuss individual differences more thoroughly in the General Discussion.

The results show that the frequently used Galton-Crovitz cueing paradigm (Crovitz & Schiffman, 1974) may be too restrictive and does not promote the level of detail that patients are capable of producing. Tasking MTL amnesic individuals with generating detailed episodes from non-descript everyday nouns puts them at a particular disadvantage given that hippocampal damage impairs a host of related abilities including representational generation (Duff, Kurczek, Rubin, Cohen, & Tranel, 2013), generative free-association (Sheldon, Romero, & Moscovitch, 2013), detail generation and binding (Rosenbaum et al., 2009), and open-ended problem solving (Sheldon, McAndrews, & Moscovitch, 2011).

Table 5.1 *Summary of amnesic cases' performance*

	K.C.	D.A.	D.G.	L.D.	B.L.	S.N.
Experiment 1						
Episodic memory	Impaired	Borderline	Impaired	Impaired	B-I	Borderline
Episodic prospection	Impaired	Borderline	Impaired	Low average	Borderline	Impaired
Experiment 2						
Intertemporal choice ($100)	Average	High average	Average	Average	Average	Average
Intertemporal choice ($2,000)	Average	Average	Average	High average	Average	Average
Risky decision-making ($250)	Average	High average	Average	Average	Average	Average
Risky decision-making ($2,000)	Average	Average	Average	Average	Average	Average
Experiment 3						
Flexible intertemporal choice	Borderline	Low average	Average – HA	Average	High average	Average
Experiment 4						
Scaffolded episodic memory	--	Borderline	B-I	Average	LA-Average	Borderline
Scaffolded episodic prospection	--	Borderline	Impaired	Average	Low average	Borderline

B-I: impaired –borderline impaired; HA: high average; LA: low average

General Discussion

5.1 Summary of experiments

Through a series of experiments I used constructive and non-constructive tasks to examine whether people with amnesia are truly “stuck in time”. In the first experiment I examined episodic memory and prospection abilities in a group of etiologically diverse amnesic cases using a Galton-Crovitz cueing paradigm. In Experiment 2 I investigated whether the same amnesic cases exhibited disregard for the future by ways of probabilistic discounting in a risky decision-making task or steep delay discounting in an intertemporal choice task. In Experiment 3 I examined whether amnesic cases retained flexible decision-making by examining whether they modulated rates of delay discounting when cued to imagine future experiences. In Experiment 4 I retested amnesic cases’ episodic memory and prospection to examine whether minimizing constructive demand in episodic thinking could act as a cognitive scaffold and reduce magnitudes of impairment. The overall pattern of results suggests that MTL amnesia interferes with basic episodic (re)constructional processes involved in memory and prospection, but does not support the notion that such individuals are robbed of time.

5.2 Comparisons across studies

Neuropsychological research with small samples is particularly vulnerable to the skewing that can result from a few or even one extreme case, increasing the likelihood of misinterpreting individuals’ actual abilities. One advantage of treating each case individually using an estimates-based approach is that it provides a finer-grained view of individual capacities, facilitating the ability to detect whether and to what degree each case demonstrates various impairments. Table 5.1 summarizes each amnesic cases' performance on each task in this dissertation.

Gross consistencies across and within individual cases

Amnesic cases' performance in Experiments 1 and 2 shows a clear and consistent pattern: they have grossly impaired episodic memory and prospection, yet uniformly intact decision-making on measures of both risky and intertemporal choice. Performance in Experiment 3 shows that with the exception of K.C., amnesic cases also demonstrate a cueing effect within the broadly average range. Yet for all amnesic cases, Experiment 4 shows that improving episodic memory and prospection even with personal, specific cues to scaffold narratives proved more challenging than decision-making.

The finding that performance in Experiment 4 was higher than in Experiment 1, but lower than in Experiments 2 and 3 is consistent with the idea that MTL amnesia impairs basic narrative processes while leaving a range of prospective decision-making abilities intact. In short, generating narratives is most difficult but can improve with scaffolding cues: decision-making is unaffected and even retains flexible responsiveness to prospective cues.

There are also some notable consistencies at the individual case level. For example, D.A. resembled other cases with impaired performance in Experiment 1 and intact performance in Experiment 2. In fact for smaller rewards, D.A. demonstrated *high average* ability to consider risk and the future for his decision-making, perhaps reflecting his previous professional experience in the field of finance. Yet D.A.'s cognitive abilities appear less malleable than other cases and he had consistent difficulty improving decision-making, episodic memory, and episodic prospection. Specifically, his cueing effect was at the low end of average and personal specific cues did not improve his ability to recollect past or imagine future experiences. One reason for this may be due to his response (or lack thereof) to specific cues. While specific cues are generally thought to act as a scaffold to ease the construction process, a comprehensive meta-analysis showed that the interaction between cue-specificity and hippocampal engagement may be a more nuanced one. Viard, Desgranges, Eustache, & Piolino (2012) conducted a meta-analysis on 58 neuroimaging studies that determined the factors that modulated MTL engagement during episodic thinking. They found that specific cues actually activated the right anterior hippocampus *more* than generic cues, arguably because of the personally meaningful, individualized nature of the events that specific cues can evoke. Given that D.A. was the only case with predominately right hippocampal damage, perhaps he was particularly disadvantaged when given specific cues.

Likewise, in amnesic case K.C., who had extensive bilateral hippocampal damage, specific cues did not have the standard effect on his intertemporal choices, despite him showing consistently average standard decision-making in Experiment 2. Sadly, K.C. passed away in 2014, and it is unknown whether narrative scaffolding via personal specific cues would have improved his memory and prospection.

In Experiment 3, I suggest that D.A.'s and K.C.'s relatively low ability to modulate intertemporal choice is due to the extent of their neurological damages and here I extend this point to also explain D.A.'s lack of improvement in Experiment 4. D.A. and K.C. have the greatest degree of neurological damage of the amnesic cases in this dissertation. Unlike other cases whose lesions are unilateral and/or relatively circumscribed to the hippocampus, bilateral damage in D.A. and K.C. extends beyond the hippocampus into parahippocampal cortices and outside the MTL. Although the hippocampus is the focus of the dissertation, other MTL cortices including the parahippocampal gyrus also contribute to episodic memory and prospection (Addis et al., 2007; Szpunar, Chan, & McDermott, 2009) and are active during the episodic prospection phase of cued discounting (Benoit et al., 2011). It is thus likely that K.C. and D.A.'s extensive neurological injury left these cases with reduced ability to modulate their decision-making and episodic thinking even relative to other amnesic counterparts.

K.C. and D.A.'s performance present an important caveat to findings of broadly preserved cognitive function in amnesia: damage occurs along a continuum and severity matters. There may be a point of damage or impairment beyond which manipulations such as those in Experiments 3 and 4 have little ability to shift one's function. Classification of amnesic cases in terms of clinical severity is challenging and somewhat subjective given that severity can imply extent of damage within the hippocampus, MTL, and/or beyond as well as degree and type of functional memory and/or cognitive impairment. A further complicating factor is that severity of neural insult does not always correspond to severity of cognitive deficit. I nonetheless believe that it is informative, and at times necessary, to consider clinical cases along a continuum of severity, whether in relation to neurological or cognitive compromise, which is not always possible at the group level.

On the other end of the performance spectrum are amnesic cases L.D. and B.L. These cases showed not only a cueing effect in Experiment 3, but also made the greatest and most consistent cue-related gains in Experiment 4, improving in both episodic memory and episodic prospection. Again, severity or, in these cases, lack thereof, may underlie this pattern of performance. Although L.D.'s lesions include the hippocampus as well as parahippocampal gyrus, middle temporal gyrus, uncus, and amygdala, they are completely unilateral to the left side. B.L.'s lesions are bilateral, but highly circumscribed to the dentate gyrus of the hippocampus with sparing of residual hippocampus and surrounding tissue in the MTL cortices. Although formal investigation is needed, the pattern of results in this dissertation suggests the following: what may best facilitate preserved function and successful intervention in hippocampal amnesia is not age, general IQ, or recency of injury/illness – L.D. and B.L did not have an advantage on any of these variables (see Table 1). Rather, selectivity of neurological damage within the MTL may be the most predictive clinical factor.

Nuanced variability within individual cases

Both D.G. and S.N.'s benefit from personal, specific cues in Experiment 4 was inconsistent across episodic memory and episodic prospection. This intra-individual variability was unexpected. Given the known neurocognitive overlap between these two abilities (Okuda et al., 2003; Botzung et al., 2008; see Schacter et al., 2007, and Buckner, 2010 for reviews), I anticipated that any cue-related improvement in one temporal end of episodic thinking would parallel the other. Even more surprisingly, D.G. and S.N. showed opposite patterns of benefit:

personal, specific cues improved S.N.'s prospection, but not his memory whereas they improved D.G.'s episodic memory but not his prospection.

There are likely multiple reasons why an individual may perform poorly on a task that requires generating a narrative of a specific personal event. For example, those with MTL amnesia may be impaired because of disruption to basic constructional processes known to be hippocampally dependent (see Maguire et al., 2011; Verfaellie, Race, & Keane, 2012). However, impairment can also arise from a breakdown in executive processes: a decline in strategic search is argued to underlie prospection impairments Parkinson's disease (de Vito et al., 2012) whereas a decline in the inhibition of off-task speech is argued to underlie prospection impairments in normal aging (see Schacter et al., 2013 for review). In those with semantic dementia, a lack of semantic scaffolding is argued to interfere with one's ability to integrate details of a future experience (Irish et al., 2012). Interestingly, these individuals dissociate episodic memory and prospection, demonstrating preserved ability in the former and selective impairment in the latter. Given the multitude of processes that contribute to episodic memory and prospection, and the finding that the abilities are clinically dissociable, it is not altogether surprising that memory and prospection could respond differently to personal specific cues. The pertinent question that D.G. and S.N. collectively raise is, what factors could cause one amnesic case to benefit only in memory and another to benefit only in prospection? I explore this question by comparing the cases more thoroughly in the following section, with the caveat that these are speculative discussion points based only on two cases and that warrant systematic investigation.

D.G.'s amnesia resulted from an anoxic event secondary to cardiac arrest. His implantable cardiodefibrillator precludes his ability be scanned in MRI; however, D.G. shows the characteristic neuropsychological pattern of impairment that typically follows cardiac arrest: he has a primary memory impairment with accompanying dysarthric motor deficits (Lim et al., 2004). Although his verbal fluency was in the borderline – low average range, this likely reflects a motor issue rather than a true executive impairment. Neither neuropsychological nor behavioural observations hint at any executive dysfunction. He completed all categories on the Wisconsin Card Sort Task and shows no behavioural signs of perseveration, disinhibition, or marked changes in personality.

Yet despite otherwise intact cognitive function, the clinical severity of D.G.'s baseline memory and prospection impairment is evident and second only to amnesic case K.C. (Experiment 1). D.G.'s localized but severe cognitive impairment in episodic (re)construction may explain why, in Experiment 4, he showed cue-related improvement in episodic memory but not novel episodic prospection. This is because novel episodic prospection is generally considered the more cognitively demanding than episodic memory, recruiting the hippocampus to a greater extent (Köhler et al., 2005; Addis, Cheng, Roberts, & Schacter, 2011).

An additional possibility is that D.G.'s localized but severe cognitive impairment was associated not only with episodic prospection, but also with semantic prospection. While overall semantic prospection is believed to be spared in MTL amnesia (Klein et al., 2002), more recent research shows that subtle aspects may nevertheless be impaired (Race, Keane, & Verfaellie, 2013). If a bank of semantic details can provide the scaffolding for episodic prospection (Irish & Piguet, 2013), perhaps D.G. has both impaired semantic and episodic aspects of prospection, making it particularly difficult to construct a novel future experience. Since I did not directly assess semantic prospection, continued research with additional amnesic cases will allow us to better explore how the extent of neurological damage and/or cognitive impairment affects the ability to elaborate on personal episodes after cues reduce the need for event construction.

In contrast to D.G., S.N.'s amnesia appears qualitatively different. He suffered a thalamic stroke which caused bilateral damage to the lateral dorsal thalamus and left pons, and smaller lesions in the right pons, right putamen, and left occipital lobe medial to the occipital horn. He has a localized left hippocampal lesion but otherwise intact MTL cortices, fornix, and mammillary bodies. Strokes to the lateral dorsal thalamus are rare and its effects on cognition are sparsely documented in the literature. The lateral dorsal thalamus is sometimes considered part of the anterior group of thalamic nuclei, functioning in concert to form the limbic thalamic nuclei (see Schmahmann, 2003 for review). Carrera & Bogousslavsky (2006) identified distinct patterns of impairment associated with anatomically distinct strokes and found that infarcts to the anterior thalamic region were associated with a unique pattern of behaviour that includes apathy, amnesia, and perseveration. This pattern also features speech that is marked by disorganization, "the superimposition of unrelated information", and the "intrusion of themes previously discussed". This description certainly captures current observations of S.N., as well as family reported concerns. His mother's primary concerns are his disinhibition, angry emotional outbursts, and frequent use of inappropriate language in public settings. More recently, he started exhibiting additional perseverative behaviours including hoarding various household items. S.N.'s neuropsychological data provides further evidence of concurrent memory impairment and executive dysfunction. He is impaired across all memory measures. Although his verbal fluency was within the low end of average, he was only able to complete three categories on the Wisconsin Card Sort Task while the all of the other amnesic cases in Experiment 4 completed all six categories.

D.G. and S.N.'s differences are apparent even in baseline episodic memory and prospection using standard Galton-Crovitz cueing (Experiment 1). Although they were both impaired in both memory and prospection; D.G.'s profile was characterized by an overall paucity of internal and external details, likely reflecting the generative deficits associated with MTL (and in particular, hippocampal) damage (Rosenbaum et al., 2009). In contrast, S.N.'s profile was characterized by a paucity of internal details coupled with a dramatic elevation in external details, likely reflecting concurrent MTL-related deficits in specific detail-generation alongside executive deficits in monitoring and inhibition (see Appendix B for samples of prospective narratives).

In summary there is reason– etiological, neuroanatomical, cognitive, and behavioural – to believe that D.G. and S.N.'s amnesias are indeed different. I hold to the interpretation that D.G.'s selective cue-related benefit in memory but not prospection is ostensibly due to the added difficulty that generating a novel, not-yet-lived experience imposes and the degree to which this taxes the hippocampus beyond autobiographical recollection. The question that remains is why S.N. showed selective cue-related improvement only in prospection, or stated differently, why he failed to show improvement in memory. Perhaps episodic memory reconstruction requires greater inhibitory control or is more susceptible to task-irrelevant speech than constructing a new prospective event. Future studies can continue to use unique neuropsychological cases to parse episodic thinking by respective MTL and frontally-mediated processes.

One rationale for including amnesic cases of varying etiologies and profiles was to observe whether degree of memory loss would correspond with the magnitude of any observed impairments. Based on findings of previous studies, the severity of episodic prospection impairment was expected to have (1) been consistently greater than severity of episodic memory impairment and (2) corresponded with severity of MTL damage. The heterogeneity in cognitive impairment and neurological damage across the patients provided an opportunity to test these hypotheses. Instead, findings showed that the amnesic cases' performance on various non-constructive measures of prospection did not appear to correlate with either their episodic prospection or extent of hippocampal damage. This finding bolsters the argument that the various measures used here are indeed distinct forms of prospection, not all of which are hippocampally dependent.

5.3 Neuropsychological case studies inform behavioral economics

Hippocampal-dependent memory has long been studied in cognitive psychology, but its application to understanding decision behavior is a relatively new endeavor. The current findings provide insight into the strategies and processes underlying widely used economic judgment tasks such as delay discounting and probability discounting (i.e., intertemporal choice and risky choice measures).

There are several other theories in the behavioural economics literature that implicate a role for mental construction and memory in decision making, although the precise cognitive mechanisms are unclear. For example, preference construction postulates that decisions are not made according to pre-determined, rational preferences but rather are constructed at the moment of decision. Moreover, the construction of preferences is context-dependent and vulnerable to a range of biases (see Slovic, 1995). An extension of preference construction is Query Theory, which argues that people draw on memory processes to construct preferences (Weber et al., 2007). The framing of decision parameters affects the order in which people retrieve relevant contents from memory; the order in which people retrieve contents from memory ultimately biases their decisions such that initially retrieved contents are weighted more heavily. Amnesic cases are thus useful resources on which to qualify or test assumptions of Query Theory. Given patterns of impaired episodic memory but relatively intact semantic memory in hippocampal amnesia, such future studies would give insight into the nature of the “memory retrieval processes” (i.e., output interference) that according to Query Theory, underlies features of normal decision making (i.e., endowment effects, Johnson, Häubl, &

Keinan, 2007; asymmetric discounting, Appelt, Hardisty, & Weber, 2011, Weber, et al., 2007; and framing effects, Hardisty, Johnson, & Weber, 2010).

This dissertation addresses the fundamental issue of how people choose between immediate and delayed rewards. One mechanism that is frequently assumed to underlie intertemporal choice is episodic prospection. Boyer (2008) proposed that imagining future experiences provides a motivational "brake" that steers people away from short-term, "myopic" decisions and toward decisions that give more weight to long-term outcomes. A related suggestion regarding the neural mechanism involved is that hippocampally mediated representations of decision outcomes evoke anticipatory reward-related activity in downstream reward-prediction systems (e.g., basal ganglia; Laurent, 2013). However, the hypothesized role of episodic prospection in making future-oriented choices is called into question by the finding that hippocampal amnesic individuals with impaired episodic prospection nevertheless value and discount future rewards to the same degree as do healthy controls (Experiment 2, Palombo et al., 2015a).

A related hypothesis is that episodic prospection is needed for *flexible* future decision-making. Thus, although amnesic individuals' ability to make intact intertemporal choices appears to be intact under standard conditions, it is hypothesized that because of their impaired episodic prospection, they will not respond as readily to environmental cues such as reminders of future experiences. However, results from Experiment 3 contradict this idea. Amnesic individuals' responsiveness to cueing in this study suggests that their decision-making retains a level of adaptive flexibility comparable to that of controls. This is particularly surprising given that the hippocampus arguably serves a critical role in flexible episodic representations in general (see Buckner, 2010; Eichenbaum, Otto, & Cohen, 1994; see also Duff et al., 2013; Rubin, Watson, Duff, & Cohen, 2014) and in flexible decision-making in particular (Wimmer & Shohamy, 2011). Although it still is possible that, as Wimmer and Shohamy's (2011) work suggests, the hippocampus contributes critically to decision-making, it may do so only under circumstances where decisions build on previously learned associations (Wimmer & Shohamy, 2012).

Multiple processes can facilitate the cueing effect

Findings from Experiment 3 call into question the possibility that episodic prospection is necessary for the cueing effect. Despite the intuitive appeal of this account, the data suggest that episodic prospection is not necessary. I found no systematic relation between degree of episodic prospection impairment and magnitude of the cueing effect. For example, L.D.'s episodic prospection score was the highest among the amnesic cases, with his score falling in the low average range, yet he demonstrated what is, at best, an average cueing effect. Further, B.L.'s episodic prospection was more impaired than that of L.D., yet B.L. showed a high average cueing effect.

One possible explanation for the pattern of results observed here is that cueing can elicit a gist representation of an imagined future experience via personal semantic memory. In support of this account it should be noted that amnesic cases were able to generate cues of future events even with compromised ability to describe the event contents, suggesting that their personal semantic prospection might be intact and sufficient to affect decision-making.

Moreover, although the amnesic cases' prospective narratives were relatively impoverished, other than K.C., they were not at floor and retained sparse, gist-like content. In this sense, episodic prospection in amnesia mirrors amnesic individuals' abilities in episodic or spatial memories in which detail and specificity are compromised, whereas broad, gist-like representations tend to be better preserved (see Rosenbaum et al., 2001;). Thus, it is possible that presentation of future event cues activates gist representations of future experiences that are sufficient to modulate decisions regarding the future, even in the absence of detailed event construction.

The nature of gist representations and its neural underpinnings has become a popular area of research. Some studies point to the vmPFC as a principle area associated with gist representations, at least for episodic material. In a recent review, Moscovitch, Cabeza, Winocur, & Nadel (2016) clearly summarize the process by which recent, detailed episodic information might be transformed into gist-like representations: the posterior hippocampus represents detailed spatiotemporal information about recent episodic events, then the anterior hippocampus (acting as a bridge between detailed episodic representations and gist) captures global aspects of an event, and finally episodic information is transformed into gist representations that rely on the vmPFC, along with the anterior temporal lobes. This hypothesis is in part supported through fMRI findings that the vmPFC is active during autobiographical recall and its activity is temporally graded; that is, recalling remote memories recruits the vmPFC more than recent memories (Bonnici, Chadwick, Lutti, Hassabis, Weiskopf, & Maguire, 2012). Others suggest that the vmPFC supports episodic memory in others ways, for example, by providing schemas that are essentially event templates not specific to any particular experience (Ghosh & Gilboa, 2014; Lewis & Durrant, 2011). Given the current amnesic cases' relatively intact vmPFCs, it is possible that the peripheral aspects of episodic thinking that it subserves sufficiently facilitated the cueing effect.

Recent work on semantic processes in prospection suggests another possible avenue by which cueing may reduce discounting. Klein and colleagues note that prospection is actually comprised of several distinct components, some of which do not require the MTL. They distinguish between temporal components based on *lived* time, which is experientially based, and *known* time, which is knowledge-based (see Klein, 2013a). Others have referred to the latter "known" future time as *semantic prospection*, a type of future-oriented thinking that is "…voluntary and not stimulus-bound… and is restricted in that it builds on a knowledge base that is impervious to particularities of the learning event itself" (Suddendorf & Corballis, 2007; see Szpunar, Spreng, & Schacter, 2014, for a review).

The distinction between episodic and semantic prospection in many respects parallels the distinction between episodic and semantic memory. Osvath & Osvath (2008) summarize Suddendorf & Corballis's (2007) conceptualization of semantic versus episodic prospection in the following way: "Semantic prospection is rule-based and thereby only sensitive to regularities of potential future events, as opposed to the episodic system that by pre-experience pick out particularities of the possible future events." Several recent studies further divide time-based episodic thinking into semantic, episodic, and strictly episodic subtypes, where only strictly episodic events are unique to a particular time and place, and possess associated subjective and phenomenological qualities, such as emotion, details, visual imagery, vividness, personal significance and autonoetic consciousness. In an extensive neuroimaging meta-analysis, authors investigated these three forms of time-based thinking (semantic, episodic, and strictly episodic) and found distinct neural correlates underlying each form of time based thinking, with strictly episodic events more strongly activating the left posterior hippocampus than either episodic or semantic events (Viard et al., 2012)

These episodic and semantic components of prospection have distinct neural substrates (Abraham et al., 2008) but are difficult to disentangle experimentally. There is, however, one neuropsychological case study demonstrating a dissociation between these aspects of prospection. Manning, Denkova, & Unterberger (2013) tested an individual (JR) with temporal lobe epilepsy who had significant left (but not right) hippocampal volume loss. The individual underwent a left anteromedial temporal lobectomy that removed the hippocampus, amygdala, parahippocampal gyrus and an anterior portion of the middle inferior temporal gyrus and the occipito-temporal lateral gyrus. Experimental post-operative testing showed that JR had selectively impaired ability to recall past and imagine future public events while his ability to recollect personal past or imagine future personal experiences was preserved. The researchers then ran a follow-up fMRI study with JR, which showed the absence of neural activation for impersonal public knowledge and the presence of activity in the autobiographical memory network for personally significant public knowledge. This is the first study demonstrating that episodic and semantic components of prospection are indeed dissociable by combining both case study and fMRI methods.

In the currently study, I predicted that at least some of the amnesic cases (particularly those with extensive bilateral damage or left, unilateral hippocampal damage) likely also have subtle semantic prospection impairments that could have contributed to the apparent degree of their episodic prospection deficit. However, in the absence of a separate control task exclusively measuring semantic prospection, I am unable to assess the magnitude of this contribution.

Among neurologically intact populations, one's bank of semantic knowledge is thought to support episodic simulation of future events by providing the necessary scaffold for integrating episodic details (Irish et al., 2012). Episodic and semantic subcomponents of prospection are also presumed to work in concert to facilitate "flexible anticipation," a term Suddendorf & Corballis (2007) use to describe all cognitive operations that represent the particularities of a future event. To illustrate constituent episodic and semantic elements of prospection in the context of cueing, consider the following example. When the cue "40th Wedding Anniversary" appears prior to an intertemporal choice trial, a participant may (as instructed) simulate a detailed representation of the actual event— he or she may imagine the people who will attend, the speeches that will be made, the food that will be served, and the feelings of celebration that will be experienced. This type of detailed episodic prospection is usually assumed to underlie the cueing effect: it makes abstract, personal future events concrete by representing their spatial, temporal, and emotional features. As a result, episodic prospection nudges preferences toward future rewards.

However, the cue "40th Wedding Anniversary" likely also activates generic schemas or scripts involving gifts and celebratory events semantically associated with anniversaries, and these might also prompt one to save or plan for such future events. In normal decision-making, episodic and semantic components of prospection likely work in tandem when "future thinking" influences everyday choices. Yet, as the current example illustrates, (personal) semantic prospection alone may be sufficient to modulate one's future-oriented choices independent of episodic prospection. I did not directly assess the status of semantic prospection in the amnesic cases tested in the current study, but future studies will help determine whether and to what extent it can replace or facilitate episodic prospection during future-oriented decision-making. The idea that multiple processes can facilitate the cueing effect is in line with a multiple systems approach to intertemporal choice (Peters & Büchel, 2011) and to decision-making more generally (Frank, Cohen, & Sanfey, 2009; Kahneman, 2011; Sanfey & Chang, 2008; Weber & Lindemann, 2007).

Multiple systems in decision-making

Weber and colleagues propose that multiple decision modes co- exist, ranging from increasingly affect-based to increasingly analytical (Weber & Lindemann, 2007). An extension of this idea is that decision making may consist of redundant processes and can presumably withstand selective compromise of one system, such as with focal brain injury, if other systems are preserved. An application to the current study is that while deliberate, slow, conscious, cognitive processes (i.e., episodic future thinking, Kahneman's System 2) impacts decision making, automatic, fast, unconscious, affective processes (i.e., affective reaction to choice options, Kahneman's System 1) can still carry out decision making when System 2 processes are impaired. The current amnesic cases reported a range of strategies that reflect both rapid, affective processes (e.g., decisions based on a "gut feeling") and slow, cognitive processes (e.g., decisions based on financial calculations).

The redundancies that result from having multiple systems may make it possible for intertemporal choice to withstand selective compromise to one of those systems (e.g., impaired MTL-mediated episodic prospection) as long as other systems are preserved. Moreover, studies of intertemporal choice in healthy individuals provide clues as to what those other preserved systems might be. Both Peters & Büchel (2010) and Benoit et al. (2011) found that the cueing effect was associated with increased coupling between activity in the hippocampus and activity in regions of medial prefrontal cortex. The observed coupling with the anterior cingulate cortex (ACC) in particular prompted Peters & Büchel to suggest that the ACC dynamically adjusts the values assigned to future rewards based on hippocampally represented episodic predictions. Further, Benoit et al. found that the medial rostral prefrontal cortex (mrPFC) was involved in modulating assigned reward value based on hippocampal representations of imagined future episodes.

Peters & Büchel (2011) outlined three distinct but interacting systems that may underlie intertemporal choice: episodic prospection, which relies on the MTL; valuation, which relies on the orbitofrontal cortex (OFC); and cognitive control, which relies on the anterior cingulate cortex (ACC). Of the three systems, only damage to the valuation system appears to impair standard intertemporal choice (Sellitto, et al., 2010). Thus, individuals with MTL damage can make and modulate future-oriented decisions in the absence of detailed hippocampally mediated representations via the valuation (OFC) and cognitive control systems (ACC). Such neuropsychological findings illustrate the fact that multiple processes typically are involved in decision-making and are consistent with the idea that not all of the systems involved in intertemporal choice are necessary for making adaptive future choices

5.4 Clinical considerations

Interpreting internal and external details in narratives

Because internal details are taken as the measure of episodic strength in AI scoring (Levine et al., 2002), I expected to find a cue-related increase in internal details if personal cueing scaffolds past and prospective narratives relative to Galton-Crovtiz cueing (Experiment 4). Although I did not have specific predictions regarding the effect of personal cues on external detail generation, it is important to note how internal and external details may differentially inform the clinical picture of episodic prospection impairment in a given disorder. Patients diagnosed with Parkinson's disease, amnestic mild cognitive impairment, and healthy aging exhibit impaired internal detail generation and elevated external detail generation (de Vito et al., 2012; Gamboz et al., 2010; Gaesser, Sacchetti, Addis, & Schacter, 2011, respectively), whereas those with post-traumatic stress disorder show selective elevation of external details with internal details in the normal range (McKinnon et al., 2014). However, it is not always the case that the generation of fewer internal details is accompanied by a greater number of external details. For example, individuals diagnosed with bipolar disorder and even cases of MTL amnesia have been found to produce prospective narratives that are significantly impoverished in terms of number of internal details, yet the number of external details produced was found to be similar to that of controls (King et al., 2011 and Race et al., 2011, respectively).

A paucity of internal details and increased number of external details may reflect two distinct clinical features. Specifically, a low number of internal details may be suggestive of a basic deficit in detail construction and/or binding and may be the source of the episodic prospection deficit in MTL amnesia (Rosenbaum et al., 2009; Mullally et al., 2012; Verfaellie et al., 2012). In contrast, an abnormally high number of external details may reflect executive difficulties involving inhibitory cognitive control, suppression of task-irrelevant thought, or sustained attention (McKinnon et al., 2014), or may simply reflect age-related changes in narrative style, especially in the case of healthy aging (see Schacter et al., 2012 for discussion). As noted, there are conditions in which both low internal and high external detail generation co-occur, but distinct patterns among clinical populations suggest that they reflect a simultaneous breakdown of dissociable processes.

In Experiment 1, narratives in response to Galton-Crovitz cues led to highly variable external detail generation in the amnesic cases, ranging from borderline impaired (a low number of details) to very superior (an elevated number of details). Experiment 4 showed that external detail generation was also highly variable in response to personal specific cues, with some cases showing reductions in the number of external details generated, others showing increases, and still others showing no change. For example, both D.G. and S.N. are impaired in both memory and prospection; however, DG's profile is characterized by an overall paucity of internal and external details, likely reflecting the generative deficits associated with MTL and in particular, hippocampal damage (Rosenbaum et al., 2009). In contrast, S.N.'s profile is characterized by a paucity of internal details coupled with a dramatic elevation in external details. S.N.'s unique profile likely reflects concurrent MTL-related deficits in specific detail-generation alongside executive deficits monitoring and inhibition.

Even among controls, external details ranged from an average of 6.25 to 46.25 details (SD = 11.38) with Galton Crovitz cue words, and from 6.83 to 40 details (SD = 8.85) with specific personal cues. It is unclear why there was such variability in external detail generation. As mentioned earlier, one reason may be that external details include *any* part of the narrative that is not central to the imagined episode, including repetitions, editorializing, and even attempts at engaging the experimenter in conversation. Taking this into consideration, it is perhaps not surprising that the amnesic cases vary so widely in the number of external details produced, regardless of cue condition. Some cases complete detail generation within a short period of time and speak little during the remaining time, whereas others may switch to an unrelated topic or attempt to initiate conversation in order to fill the silence. External details can thus reflect overall verbosity or conversation seeking in addition to semantic details.

In any case, dichotomizing details as either internal or external has limited ability to paint a full clinically descriptive picture of amnesic narratives. Until recently, researchers paid little attention to the external details of a narrative and instead focused on internal details (or lack thereof) as the main clinical marker of autobiographical memory/prospection impairment. Yet in light of recent findings that an excess of external details can predict the onset of post-traumatic stress disorder (McKinnon et al., 2014), I believe that a shift is underway to better explore the clinical significance of elevated external details as a distinct clinical feature.

Practical clinical implications for goal-setting and rehabilitation

The current results indicate that assessment and rehabilitation tools for MTL amnesic populations should attempt to minimize broad, open-ended questions. Instead, structured diagnostic tests and compensatory aids may provide the best measurement and later support of cognitive ability. This is particularly important for future planning and future goal setting, two common practices for patients in rehabilitation settings. Occupational therapists often use open-ended questionnaires that require patients to identify future goals with great detail and specificity (e.g., the S.M.A.R.T. method; see Wade, 2009; Bovend'Eerdt, Botell, & Wade, 2009). Researchers have attributed patients' lack of responsiveness during goal setting to low insight into one's own neurocognitive deficits or to low motivation (Fleming, & Strong, 1995; Fischer, Gauggel, & Trexler, 2004; Bouwens, Van Heugten, & Verhey, 2009). In the case of memory impaired populations, which span a range of clinical conditions, I offer an additional interpretation for why individuals may exhibit low engagement in rehabilitative goal-setting: the act of open-ended goal setting taxes existing cognitive deficits in narrative construction. Although the hippocampus and memory are classically considered separate from speech and language abilities, there is a growing body of research documenting subtle language deficits in amnesic populations with hippocampal damage. This includes decreased flexibility and creative use of language (Duff, Hengst, Tranel, & Cohen, 2009), decreased cohesiveness in speech (Kurczek & Duff, 2011), and decreased ability to maintain and integrate verbal information even over a short duration (Kurczek, Brown-Schmidt, & Duff, 2013). Thus rather than asking unstructured questions such as, "What is a goal for the future?" results from Experiment 4 provide evidence-based suggestions for creating more effective ways to structure questions for memory-impaired populations. Cues and questions should be specific rather than broad, personally meaningful rather than generic, and detailed rather than sparse. Including a greater degree of narrative scaffolding in questions and conversation will provide structure onto which amnesic cases can build concerns and goals.

Rehabilitative clinicians may consider assistive technology to help amnesic populations compensate for deficits in basic processes needed to construct a narrative – generating details, holding them in relation to one another, and binding them to produce a cohesively articulated thought. For example, Talking Mats® are symbol-based communication tools that facilitate deeper and more effective communication among different populations who exhibit difficulties with expressive speech. This tool greatly minimizes the need to construct, maintain, and relate disparate pieces of information for real-time conversation. Talking Mats® improve the clinical goal-setting process (Bornman, & Murphy, 2006) and are shown to effectively facilitate communication among those with dementia (Murphy, Gray, & Cox, 2007), Huntington's disease (Ferm, Sahlin, Sundin, & Hartelius, 2010), and among the elderly (Murphy, Tester, Hubbard, Downs, & MacDonald, 2005). Our case-by-case analysis suggests that clinical populations with more circumscribed hippocampal / MTL damage or milder episodic memory and/or prospection impairment, as occurs in amnestic mild cognitive impairment, may gain the most from these compensatory strategies and aids. In the clinical endeavor to rehabilitate amnesic patients with impaired episodic prospection, current results show that framing and scaffolding the question is a promising starting point.

5.5 Concluding remarks

There is a need to reconsider the mental life of individuals with amnesia and whether they are indeed, as Oliver Sacks (1985) put it, "…stuck in a constantly changing, meaningless moment". Drawing from neuropsychology, cognitive neuroscience, and behavioural economics, I demonstrated that time is not the essence of impairment in hippocampal amnesia and considering such individuals to be trapped in a moment grossly underestimates their preserved abilities. Although it is true that damage to the hippocampus and within its extended system impairs episodic (re)construction, it is equally important to recognize that there are other aspects of prospective cognition that are left relatively intact. Amnesic individuals' decision-making provides a window into how they value their futures; through it, we see that their choices are not bound to the present.

Appendix A

Psychometric conversion table

Standard Score, Z-Score and Percentile Equivalents

Standard Score	Percentile	T-Score	Z-Score	Scaled Score	Label	Standard Score	Percentile	T-Score	Z-Score	Scaled Score	Label
45	0.02	13	-3.54	0	Impaired						Average
46	0.03	14	-3.43	0		101	53	51	0.08	10	
47	0.04	14	-3.35	0		102	55	51	0.13	10	
48	0.05	15	-3.29	0		103	58	52	0.20	11	
49	0.06	16	-3.24	0		104	61	53	0.28	11	
50	**0.07**	**17**	-3.19	**0**		**105**	**63**	**53**	0.33	**11**	
51	0.08	17	-3.16	0		106	66	54	0.41	11	
52	0.09	18	-3.12	0		107	68	55	0.47	11	
53	0.1	18	-3.09	0		108	70	55	0.52	12	
54	0.2	19	-2.88	1		109	73	56	0.61	12	
55	**0.3**	**20**	-2.75	**1**		**110**	**75**	**57**	0.67	**12**	High
56	0.4	21	-2.65	1		111	77	57	0.74	12	Average
57	0.5	21	-2.58	1		112	79	58	0.81	12	
58	0.6	22	-2.51	2		113	81	59	0.88	12	
59	0.7	22	-2.46	2		114	82	59	0.92	13	
60	**0.8**	**23**	-2.41	**2**		**115**	**84**	**60**	0.99	**13**	
61	0.9	24	-2.37	2		116	86	61	1.08	13	
62	1	25	-2.33	3		117	87	61	1.13	13	
63	1	25	-2.33	3		118	88	62	1.17	14	
64	1	26	-2.33	3		119	90	62	1.28		
65	**1**	**26**	-2.33	**3**		**120**	**91**	**63**	1.34	**14**	Superior
66	1	27	-2.33	3		121	92	64	1.41	14	
67	1	28	-2.33	3		122	93	65	1.48	14	
68	2	29	-2.05	4		123	94	65	1.55	14	
69	2	29	-2.05	4	Impaired	124	95	66	1.64	15	
70	**2**	**30**	-2.05	**4**	Borderline	**125**	**95**	**66**	1.64	**15**	
71	3	30	-1.88	4		126	96	67	1.75	15	
72	3	31	-1.88	5		127	96	68	1.75	15	
73	4	32	-1.75	5		128	97	69	1.88	16	
74	4	33	-1.75	5		129	97	69	1.88	16	
75	**5**	**33**	-1.64	**5**		**130**	**98**	**70**	2.05	**16**	Very
76	5	34	-1.64	5		131	98	70	2.05	16	Superior
77	6	34	-1.55	5		132	98	71	2.05	16	
78	7	35	-1.48	6		133	99	72	2.33	17	
79	8	36	-1.41	6		134	99	73	2.33	17	
80	**9**	**37**	-1.34	**6**	Low	**135**	**99**	**73**	2.33	**17**	
81	10	37	-1.28	6	Average	136	99	74	2.33	17	
82	12	38	-1.17	6		137	99	74	2.33	17	
83	13	39	-1.13	6		138	99	75	2.33	17	
84	14	39	-1.08	7		139	99.1	76	2.37	18	
85	**16**	**40**	-0.99	**7**		**140**	**99.2**	**77**	2.41	**18**	
86	18	41	-0.92	7		141	99.3	77	2.46	18	
87	19	41	-0.88	7		142	99.4	78	2.51	18	
88	21	42	-0.81	8		143	99.5	78	2.58	18	
89	23	42	-0.74	8		144	99.6	79	2.65	19	
90	**25**	**43**	-0.67	**8**	Average	**145**	**99.7**	**80**	2.75	**19**	
91	27	44	-0.61	8		146	99.8	81	2.88	19	
92	30	45	-0.52	8		147	99.9	81	3.09	19	
93	32	45	-0.47	8		148	99.91	82	3.12	20	
94	34	46	-0.41	9		149	99.92	82	3.16	20	
95	**37**	**46**	-0.33	**9**		**150**	**99.93**	**83**	3.19	**20**	
96	39	47	-0.28	9		151	99.94	84	3.24	20	
97	42	48	-0.20	9		152	99.95	85	3.29	20	
98	45	48	-0.13	9		153	99.96	85	3.35	20	
99	47	49	-0.08	10		154	99.97	86	3.43	20	
100	**50**	**50**	0.00	**10**		155	99.98	86	3.54	20	

Note. Percentile Rank and Scaled Scores are estimates of the true value (except when in bold).

Appendix B

Sample prospective narratives

Cue word: "Stain"

K.C.

[no details given]

D.A.

Next few weeks, stain. Well stain has two possible meanings of applications, we do have the problem occasionally of people coming in out of the pool especially if it was early in the year you might come in dripping chlorine but that's not the problem now the chlorine is burnt off now its just the bromine now which doesn't bleach anything. Um, if you see some of the old carpet, you see the drops there on that carpet? That's from when the pool's been first open and a wet suit or towel dripping a little water and it's enough chlorine in it that it creates little spots.

[probe]

Um, probably won't have to worry about that. But what we do have to with our anniversary coming up, we might have a party at a restaurant but we will probably be bringing in family and friends in here and there's we've replaced the carpet in the family room twice, and that's usually from coffee, tea, or some kind of soft drink spills, so it's kind of expected that that will possibly happen again.

D.G.

Hopefully we get that stain out of the carpet because that's fairly new (long pause, followed by experimenter probe). If we have to get a new carpet we won't have much money for Christmas.

L.D.

Um the only thing that I can think of that creates a stain is anything dropped on my shirt. Um and that depends on kind of a couple of things. Um one of the areas that I..I work out all the time and I'll go to the gym sometimes and I'll sweat like a pig. And my if

I have a shirt that was really weighed one pound, with by the time I get worked out, it would be two pounds at least, if not..it would be soakin wet. And sometimes as you're doing that, um if you don't wash the shirt right, somehow it just seems to be..there's a line that seems to appear from the salt that's in your body. And it's not all the way through but it's on one section and if you don't wash it right away, um you get that line, you get uh I don't know what you call it..it's uh..it's a mark, either dry, looks like it's dried out or a white stain and..and then all of a sudden uh you have a nice shirt that looks like hasn't been clean, hasn't been washed and you can't get it out. So that's something that does occur. Um and..and how I get out of it many times is um or how I deal with it many times is I'll bring two shirts. So here I am working out, I'm soakin wet, in great shape. I've got my heart rate up and everything's going like you're supposed to go and the shirts soakin wet and I'm thinking ah ha! Now what I'll do I'm just gonna go into the washroom or locker and take this shirt off, I'm gonna throw it in some water, put some soap on it and this only takes thirty seconds, rinse it out a little bit, put it back in..to a wet spot in the..by the locker and put on a dry shirt and I'm very happy and I've done that..and that's how I'm gonna continue doing it when I work out like that. So um this..the stain in your shirt is a pain in the butt, believe me. The other that sometimes occurs is and I don't know why this happens sometimes and I think it's because I'm getting older and slowing down. If I had um a pasta dinner or something like that and if..ever anything spilled off the sauce, hot sauce spilled off on me, which it can do, guess what it causes? It causes a red mark. I was gonna say stain but it doesn't and that means you have to go right away, clean it up, do it and you come back and you're nice and clean but you look like you've spilled water all over you cause you've cleaned your friggen shirt. So one of the things that you know, when I grow older, I hope I can eat more properly and..and avoid the stains but sometimes it just happens anyway. Um so between the two of those things, those are the only times I get stains on myself, never happens and it's..I have tons of clothes, always look good but all of a sudden it can happen and it can happen twice in one week and I'm goin holy smokes, I can't believe this is happening! And I take care of myself, I do everything I'm supposed to do and guess what? There's a stain and if it's a good shirt opposed to a work out shirt, you can't really use it again. Now do I stain my pants? No. Do I wet my pants? No. I don't do anything else in my pants but those are the only stains I ever have and it's kind of sad kind of funny kind of goofy that all of a sudden you could be eating properly, you could be doing you're supposed to do and something falls off of something and causes a stain in your shirt. And so I don't know what else to say.

B.L.

Stain, stain, stain..I wish my landlord would stain my deck. Um stain, stain, stain..

No it's my landlord's responsibility and uh I don't like <name of landlord> *a lot but the gaps bugs* <name of landlord> *constantly, he's my landlord. So I guess if I wanna get something done, I make it a problem for* <name of neighbour> *upstairs and then he'll make it a problem for* <name of landlord>*. I'm not that concerned about it myself. Um I got some..I have some uh patio furniture that's between the shed and the fence. It's probably gonna make a stain on the fence for ever put together or like it adds..it needs a lot of work. I'm gonna put it on the street or take it to the dump before it stains anything.*

[experimenter probe]

Oh just hauling the stuff out of the backyard…finding somebody with the proper vehicle to take it to the dump. Yeah..and then it's gone. I'm not thinking about putting it together again or anything like that..that was my original plan. And uh and when I have the time and the money and inclination, I can..I can..I can buy new stuff rather than try to put together this lump of crap that was on the side of the road. I kind of get this from my dad cause my dad once got an aluminum boat? on the side of the road. And it was fine..he strapped it to the top of his van, took it..?and my uncle still has it. It's called a pick up day in <name of city> *a, once a year they did a bigger put anything you want garbage day..and uh my dad got a boat once year from my uncle and this kind of funny..nothing to do with stains really but I was still will my ex at the time. So my mom and dad were out again, and me and* <name of former spouse> *with* <name of child> *in the car, we were looking. Apparently there's a statue of Jesus but he's broke..with fingers broken off and uh my parents went out..I didn't know of this but they wanna pick him up and mom said, "Nah, leave it there" so dad left it there. Meanwhile, me and* <name of former spouse> *and* <name of child>*were out, I saw it and we can't leave Jesus on the street like that. So I brought him back, I put him in the garage, closed the garage, meanwhile mom and dad are still out and in the meantime, well me,* <name of former spouse>*, and* <name of child> *are still out, they came back home and saw two finger Jesus in the garage and mom said she just about pooped herself. And now they took it out to* <name of other city> *and set him on like a cutoff log and now there's a big shrine there. People that built the big..it's like a big rainbow with French words, I forget what they said..I have pictures of it. Dad often this..it's called two finger Jesus because his fingers are broken off eh, it's terrible.. It's a true story. I should carry that picture around with me cause I tell people that story before and well I think they believe me but it is true and it is pretty weird. But yeah, mom said, "You can't take that"..mm you know. Yeah..*

[redirection]

I will stop feeling guilty about..not guilty..I'm not..I'm not gonna be picking up as much garbage off the street unless it's another two finger Jesus. No, I just like for few years there, especially when I first got separated, I was..been to the bank..I was hired up for cash so I would grab things I didn't really need, just something and trying to fix it up and make it good. And sometimes I was successful and sometimes I wasn't. But this time it was just, it was just the last time I'm doin' that. And uh..once I get rid of that..once it's perfect, still in the box from the store, I'll pick it up from the street.

S.N.

I'll guarantee it. I spill a coffee on something. I drink too much of it. I wreck another pair of Diesel jeans. $350 dollar jeans, wrecked. Should I show you a picture, or do I show you the pair of jeans? Torn knee, Diesel jeans, wrecked. Oh. Um, I'll stain something. Doesn't matter. Stains, it's a part of life. It's like death and taxes, they're all gonna happen, it's just a matter of when. Oh yeah, I want Looney Tunes Spotlight Collection 2 and 3. Remember that. And try to find me another jacket, I think that's the only one in Canada, but I want another, that's as special as that one. I try to tell people that it's worth $2000 dollars. Do you believe that? Well, it's $750 dollar shoes are in there. I know I'm wearing pajamas right now, but that's a $2000 dollar jacket. That's the best movie ever. I remember at Baycrest, 'cause I had to go there a lot, um, they were always very nice. The only people…there's a couple of people that I didn't like. There was one lady, I forget her name, did they physio, she was just like (makes sounds). I said, you're the one that needs physio, not me. But anyways, but everything else was great, um, at Baycrest. They were excellent. Good coffee, eh. Oh yeah. I want Looney, Looney Tunes Spotlight Collection 2 and 3. Yeah, about my iPod. I don't, how do I get it rebooted. It won't boot up. Like it's, it's like, it won't, its power's out, but it won't start. Like it won't, there's things I have to go through that don't do a thing. And I had to go to Baycrest, to go see (neuropsychologist's name), *that's when I had my stroke, right? So I'd go in, and I'd always visit there, and I had to go through all that, and get to each different place, and I'd always go up to* (neuropsychologist's name). *And, because you have to go, when you go to do your iPod training there, it's a specialty course… it's called Memory Link, right? Um, I was the fastest one ever to complete the course, and it drives me crazy cause I have no wifi here, and it place, it drives me a little nuts. Like some of the stuff I have is nice, but there's a lot of stuff here, like, I just look at the walls, and I go, "am I in a jail cell" like, come on guys. Can I add a little bit? I said to my brother, he's, cause he paints for a living, right? Can you put like a taupe and a beige, a little two tone? You know where the sun hits it can be a little darker and where the sun doesn't hit, make it lighter. You know, just so it, makes the place look like it gets lived in by a human being. And look,* *I don't know what somebody did to this wall, looks like somebody smacked through it in the middle, or something. I don't know what they did. There's my fake Monets. [pause, followed by experimenter probe] Oh, it's guaranteed I'll put a stain on something. I don't know. Look. I got a stain here, a stain here. Eh, and I want another replayed jacket like that. I think that's the only one in existence in Canada. Oh yeah. I want Looney Tunes Spotlight Collection 2 and 3. Have you ever seen those? Marvin the Martian. He's the best. The guy who has the little broom in his head. He's excellent. Marvin the Martian is the best. This guy, right here. I guarantee it's a coffee spill. I don't eat pomegranate.*

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