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A new method for assessing the impact of medial temporal lobe amnesia on the characteristics of generated autobiographical events

Ariella Lenton-Brym [a], Jake Kurczek [b], R. Shayna Rosenbaum [c,d], Signy Sheldon [a,*]

[a] Department of Psychology, McGill University, Canada
[b] Department of Psychology, Haverford College, United States
[c] Department of Psychology, York University, Canada
[d] Rotman Research Institute, Baycrest Health Sciences Centre, Canada

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ABSTRACT

Constructing autobiographical events involves an initial phase of event selection, in which a memory or imagined future event is initially brought to mind, followed by a phase of elaboration, in which an individual accesses detailed knowledge specific to the event. While considerable research demonstrates the importance of the medial temporal lobes (MTL) in the later phase, its role in initial event selection is unknown. The present study is the first to investigate the role of the MTL in event selection by assessing whether individuals with MTL lesions select qualitatively different events for remembering and imagining than matched control participants. To do so, we created "event captions" that reflected the type of events selected for an autobiographical event narrative task by four individuals with MTL amnesia and control counterparts. Over 450 online raters assessed these event captions on qualitative dimensions known to vary with autobiographical recall (frequency, significance, emotionality, imageability, and uniqueness). Our critical finding was that individuals with MTL amnesia were more prone to select events that were rated as more frequently occurring than healthy control participants. We interpret this finding as evidence that people with impaired episodic memory from MTL damage compensate for their compromised ability to recall detailed information by relying more heavily on semantic memory processes to select generalized events. We discuss the implications for theoretical models of memory and methodological approaches to studying autobiographical memory.

1. Introduction

In everyday life, we are repeatedly reminded of autobiographical events. Reminders can come in the form of questions ("What did you do for your birthday last year?"), conversations ("The best part of my vacation to India was visiting the Taj Mahal"), or self-directed thought ("What did I serve last time I planned a dinner party?"). Similarly, we are often required to imagine autobiographical events that might happen in the near or distant future ("How do you imagine the party will be?"). To answer these questions, we must undergo a process of "event construction", whereby we generate past memories or plausible future instances relevant to the self, first selecting those events and then recalling them in detail.

In this paper, we focus on better understanding the selection phase of event construction. Considerable research has examined the processes that support the generation of specific event details once they have been brought to mind. However, there is a comparative lack of work on the neurocognitive processes that determine the type of events that individuals initially select when prompted to recall autobiographical events. Determining the underlying processes that allow for event selection and understanding how they relate to detailed remembering and future imagining is necessary to gain a richer understanding of autobiographical memory, how it breaks down in conditions including healthy and unhealthy aging (Irish et al., 2011; Levine et al., 2002; Murphy et al., 2008; Seidl et al., 2011; Sheldon, et al., 2015; Shing, et al., 2010), and the adaptive functions that remembering serves in daily life (Gerlach et al., 2014; Schacter et al., 2008; Sheldon et al., 2011; Szpunar et al., 2013).

The processes that support recalling event details during event construction have been assigned to episodic memory, specifically the medial temporal lobes (MTL) and the hippocampus (Eichenbaum, 2001; Moscovitch et al., 2016; Moscovitch et al., 2006; Nadel and Moscovitch, 1997). MTL amnesia has been particularly useful in explicating the role of these processes in autobiographical memory and future imagining (Rosenbaum et al., 2014). For example, studies have documented how MTL damage

* Corresponding author.
E-mail address: signy.sheldon@mcgill.ca (S. Sheldon).

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affects the ability to describe past personal events with procedures that score the type and amount of detail used to describe these events (Rosenbaum et al., 2011). These investigations have shown that MTL damage results in a selective and substantial deficit in the ability to retrieve episodic event details (e.g., "I wore a *red dress* to the restaurant") and, consequently, to vividly remember autobiographical memories and experience related mental scenarios (Hassabis et al., 2007; Mullally et al., 2014; Race et al., 2011; Rosenbaum et al., 2011, 2008; Steinvorth et al., 2005).

In this study, we investigate the initial stage of event construction, in which the individual selects an event (e.g., "My birthday party last year"; Dalgleish et al., 2007; Williams et al., 2007), which is only later elaborated upon by recalling specific episodic details relevant to that event (e.g., "My living room was filled with balloons"; "We ate chocolate cake"). Dissociating these processing stages of autobiographical retrieval is reminiscent of early models of memory. These models suggested that autobiographical recall begins with a retrieval specification stage in which the to-be-described memory is selected, and moves on to processes that support recalling that memory (Burgess and Shallice, 1996; Norman and Bobrow, 1979). More recent work has indicated that such pre-retrieval memory processes are present during standardized laboratory tests and can distinctly influence the way memories are recalled (Halamish et al., 2012). Thus, it is likely that particular event selection processes exist for naturalistic memories and that these processes are important for establishing some aspect of "quality control" when we select events (Koriat and Goldsmith, 1996; Shimizu and Jacoby, 2005).

To investigate the link between event selection processes and those that support detailed event elaboration, we seek to investigate how these two aspects of event construction are dependent on the integrity of MTL-mediated episodic memory processes. Determining that both processes rely upon the MTL is necessary to specify the nature and extent to which MTL damage affects autobiographical memory. In addition, the finding that event selection also depends on intact MTL structures would also raise important methodological considerations for memory assessment.

To do so, we analyzed how MTL damage affected event selection. We looked at both past and future autobiographical events given the documented overlap between remembering and future imagining (Addis et al., 2009; Klein, 2015; Rubin and Umanath, 2015; Schacter et al., 2008; Suddendorf et al., 2009). We developed a new experimental design that makes use of Mechanical Turk (mTurk, Buhrmester et al., 2011), an online method for collecting large samples of unbiased ratings, as a means of characterizing the quality and type of events selected by individuals with MTL damage and age-and education-matched healthy controls when they were asked to elaborate upon various autobiographical events during a remembering task. This autobiographical task was initially designed to measure the processes that support event elaboration by scoring the amount of detail found in elaborated event narratives generated by the participants. To gather these narratives, participants were asked to self-select events from their lives with the help of several aids and no time pressure. They were later given five minutes to describe each event in as much detail as possible. Because the participants self-selected events without any external pressure, this dataset establishes naturalistic tendencies of event selection in the tested samples (Kwan et al., 2015). We can therefore use this data set to investigate processes relating to the selection phase of event generation.

We made use of the "brief event tags" that participants generated to identify their events in tandem with the elaborated event narrative to form complete "event captions" – titles that summarized the single main event discussed in the memory or imagined future event (e.g., "Going to the San Francisco Zoo"). We gave these captions to unbiased raters who judged the quality of each event caption along a series of dimensions known to vary with event generation (Levine et al., 2002; Rubin et al., 2003). The dimensions of each event included in our ratings were frequency (frequency of event occurrence in one's life), personal significance (how personally significant an event would be to an individual), imageability (the ease with which an image of the event comes to mind), emotional content (the positive or negative emotional content of the event), and uniqueness (whether such an event would occur similarly across individuals).

We were interested in testing the specific prediction that, when constructing events, individuals with MTL damage will select events that are more generic and that occur more frequently in daily life when compared with control participants. This prediction is based on the understanding that MTL-mediated episodic memory processes are typically recruited to generate events. Thus, when the episodic memory system is impaired due to MTL damage, individuals will compensate by relying on the intact semantic memory system for event selection. We based this hypothesis on a prominent model of autobiographical knowledge, which holds that knowledge relating to autobiographical events is stored at varying levels of specificity, from general knowledge about the self (lifetime periods, e.g. "school") to general event memories (information extracted from multiple common events) to event-specific knowledge (vividly detailed images that are unique to a specific time and place; Conway, 2009; Conway and Loveday, 2015; Conway and Pleydell-Pearce, 2000; Conway et al., 2004). In line with this model and previous reports mentioned above, we hypothesize that individuals with MTL amnesia are less able to access event-specific knowledge associated with selected events and will therefore be more likely to construct events using more general knowledge, which is still accessible to them. Following our hypothesis, mTurk raters are expected to judge the events selected by individuals with MTL amnesia as significantly more frequent in occurrence and less unique than those constructed by healthy control participants. Although we do not have strong predictions for the other dimensions, it seems likely that events rated as more frequent and less unique will also be judged as less personally significant, given that these events are expected to represent the rehearsed, script-like memories that the semantic memory system can access. However, it is also possible that, like ratings of imageability and emotionality, significance ratings may represent the subjective experiencing of the event, which we would not expect to vary with the degree to which the event is accessed using episodic versus semantic memory processes.

To gain a full picture of event construction, we also tested the downstream consequences of the quality of the event selected, as measured by our group of unbiased raters, on the participant's ability to generate the specific details of that event, measured by scoring the episodic specificity of elaborated event narratives. If patients with MTL damage select fundamentally different events compared to healthy controls, this would suggest that MTL processes influence autobiographical memory beyond retrieving specific event details.

2. Materials and methods

2.1. Event definitions

Thirty-four participants (4 patients with MTL damage and 30 age-and education-matched healthy control participants; see Table 1 for patient demographics) completed an adapted version of the Autobiographical Interview (AI; Levine et al., 2002). As outlined by Kwan et al. (2015), the four patients with MTL damage are identified as D.A., L.D., B.L., and S.N. Patient D.A. has bilateral damage to the MTL structures. On the left hemisphere, his lesions were mostly restricted to the MTL region, though he exhibited volume reductions in the right hemisphere in regions

Table 1
Demographic and neuropsychological data for the participants with MTL amnesia.

Patient	Etiology	Age	Ed	FSIQ	WCST	LF	BNT
DA	Encplts	42/62	17	117	6	8	10
LD	TLR	59/61	19	111	6	8	0
DL	Anoxia	25/52	13	92	6	11	–
SN	Stroke	44/46	12	114	3	8	8
Memory performance							
	WMS-R/III/IV		Verb learning				ROCF
Patient	LP/M-I	LP/M-II	AQ	LDFC	R	C	DF
DA	7	1	0	0	0	18	0
LD	10	2	3	3	0	3	8
DL	8	6	8	7	10	2	2
SN	1	2	3	1	1	8	3

Notes: Encplts, encephalitis; TLR, temporal lobe resection; Age, age in years at injury/age in years at testing; Ed, education in years; FSIQ, Full Scale IQ, based on Wechsler Adult Intelligence Scale – Revised for D.A., Wechsler Abbreviated Scale of Intelligence –III for L.D. and S.N., and Wechsler Abbreviated Scale of Intelligence –IV for B.L.; WCST, Wisconsin Cart Sort Test, number of completed categories /6. The following measures are reported in scaled scores: LF, letter fluency; BNT, Boston Naming Test; WMS-R/III/IV, Wechsler Memory Scale Revised/III/IV, LP/M-I, LP/M-II, Logical Passages/Memory I and II; Verb Learning, Verbal learning based on California Verbal Learning Test-II for D.A., and B.L., Hopkins Verbal Learning Test – Revised for L.D., Kaplan Baycrest Neurocognitive Assessment, Word List Learning for S.N., AQ, acquisition, LDFR, long delay free recall, R, recognition; ROCF, Rey Osterrieth Complex Figure, C, copy, DR, delayed recall.

outside the MTL, including regions of the posterior temporal, ventral frontal, occipital, and anterior cingulate cortex, and the posterior thalamus. Patient L.D. has a left hippocampal lesion and a growth in the left parahippocampal region. He underwent a left temporal lobectomoy and amygdalohippocampectomy several years ago, which contributed to his memory impairment. Patient B.L. exhibits bilateral lesions in the hippocampus and hyperintensities indicating hippocampal sclerosis. His lesions are limited to the dentate gyrus. Finally, S.N. displays bilateral damage in the dorsolateral thalamus and left pons as well as smaller lesions in the right pons, right putamen, and left occipital lobe medial to the occipital horn. He exhibits a localized left hippocampal lesion. Kwan et al. (2015) also presented data on a fifth participant, D.G., who has been excluded from our analyses as lack of MRI scan data prevents us from being able to confirm lesions in the MTL region.

All participants were asked to self-select six personal past events from the past five years and six plausible personal future events that could occur in the next five years. When selecting these events, the participants created brief tags, or titles, to identify each event. We note several important features concerning how the participants selected these events. Participants were told they could generate any event they wished, as long as the event was specific in terms of time and place. Participants were allowed to refer to their personal calendars to retrieve future events and were presented with a list of a hundred or so significant life events to use as examples. All events were generated outside of the laboratory, so no time pressure was associated with the task.

About a week after event selection, participants were presented with the event tags and asked to discuss each event in detail. These descriptions were subsequently transcribed and segmented into informational bits that were categorized as *internal* or *external* details. Internal details contain specific information concerning the context of the event and are considered to reflect episodic re-experiencing. External details, or facts and elaborations, are considered to reflect, among other processes, semantic retrieval. We used the ratio of internal details to the total number of details in the event narrative (internal output ratio, IOR) as a means of estimating specificity of autobiographical recall while controlling for verbal output.

To test our specific hypothesis concerning the characteristics of the events chosen by the participants, we created a novel protocol for extracting main event captions using both the brief tags created by the participants and the elaborated narratives (see Fig. 1 for an example from both groups of participants). The first step of the protocol (included in the supplementary materials) involves reading the brief tags to determine the type of event selected. Second, a scorer read through each associated narrative to determine the consistency between the event tag and the main event described. This step was important in that it allowed us to ensure that the results were not confounded by individual differences in participants' ability to title an event. Next, the scorer removed any identifying information from the event caption (e.g., specific names and locations) and replaced it with more generic terms (e.g., replacing "Steven" with "friend"). This step ensured that the unbiased raters appropriately judged event captions. We also ensured that all event captions were framed in the second-person perspective and, when possible, used the active voice, ensuring that raters' judgments were based on the nature of the event and not influenced by differences in grammatical structure. A principle scorer created these main event captions, and a second scorer confirmed the reliability of the extraction protocol.

2.2. Event ratings

2.2.1. Participants.

Eight hundred and sixteen adult participants were recruited using mTurk, an online crowdsourcing platform that enables researchers to access large, anonymous pools of participants who complete tasks in return for an honorarium. Four hundred and fifty responders who passed validity checks (see Methods) were included in our final analysis [average age=35.8 years (SD=11.1); average education=15 years (SD=2.6), 209 females]. Participants gave informed consent by clicking a "submit" button acknowledging that they had read and understood the form and freely consented to participate in the study.

2.2.2. Event selection ratings: materials and procedure

2.2.2.1. Survey construction.. Thirteen separate surveys were constructed online using SurveyMonkey software (https://www.surveymonkey.com/). Unbiased raters randomly selected and completed one of these surveys using the mTurk interface. Each rater was allowed to complete only one survey. Each survey contained between 25 and 32 randomly selected event captions. The raters assessed each event caption along the five dimensions (Table 2). A 5-point Likert scale was provided for each question. Participants rated all event captions one at a time. We also included three extra event captions, created by the researchers, which were intentionally biased toward one end of a rating scale to assess validity. The event "getting up in the morning" required the response "1 – Daily or weekly" on the frequency scale; the event "the birth of your first child" required a high rating on the significance scale; and the event "the death of a parent" required a negative rating on the emotionality scale in order to be deemed valid. Those who did not pass these validity checks, as well as those who completed the survey in less than 5 min, were excluded from our analyses. Excluding these raters allowed us to ensure that the analyzed ratings were not unduly influenced by careless responders.

3. Results

3.1. Event caption ratings

We first investigated how the five rating dimensions of event captions related to one another. We ran a Principal Components Analysis (PCA) with Varimax (orthogonal) rotation on the full set of mTurk ratings for all event captions. The suitability of PCA was demonstrated, prior to analysis, in two ways. First, a correlation matrix showed that all rating dimensions had at least one correlation coefficient greater than 0.24. Second, Bartlett's test of sphericity was highly significant, (χ^2 (10)=5267.99, $p<0.001$), justifying the factoring of our data set. Two Components emerged from the PCA. These Components explained 31.86% and 25.60% of the total variance. Ratings of frequency, significance, and uniqueness loaded strongly onto Component 1, whereas ratings of imageability and emotionality loaded strongly onto Component 2 (Table 3). The same components emerged when past and future event captions were assessed independently.

3.2. Event title ratings: MTL amnesia Vs. control participants

To determine how the above components differed between the event captions produced by healthy controls versus MTL amnesic participants, we calculated two composite scores for each event caption, one for 'Component 1′, which we labeled the 'Generic Quality Component' (calculated by averaging mTurk ratings of frequency, significance, and uniqueness), and another for 'Component 2′, which we labeled the 'Event Richness Component' (calculated by average mTurk ratings of imageability and emotionality). Generic Quality Component scores were significantly different for the event captions produced by controls (mean=3.60 SD=0.85) than for individuals with MTL amnesia (mean=3.10; SD=0.86, $z=-2.31$, $p=0.02$; Mann-Whitney U test). In contrast, the Event Richness Component scores were not significantly different between the controls (mean=3.60; SD=0.93) and individuals with MTL amnesia (mean=3.50; SD=0.8; $z=-0.42$-, $p=0.68$; Mann-Whitney U test).

Based on the significant group difference for the Generic

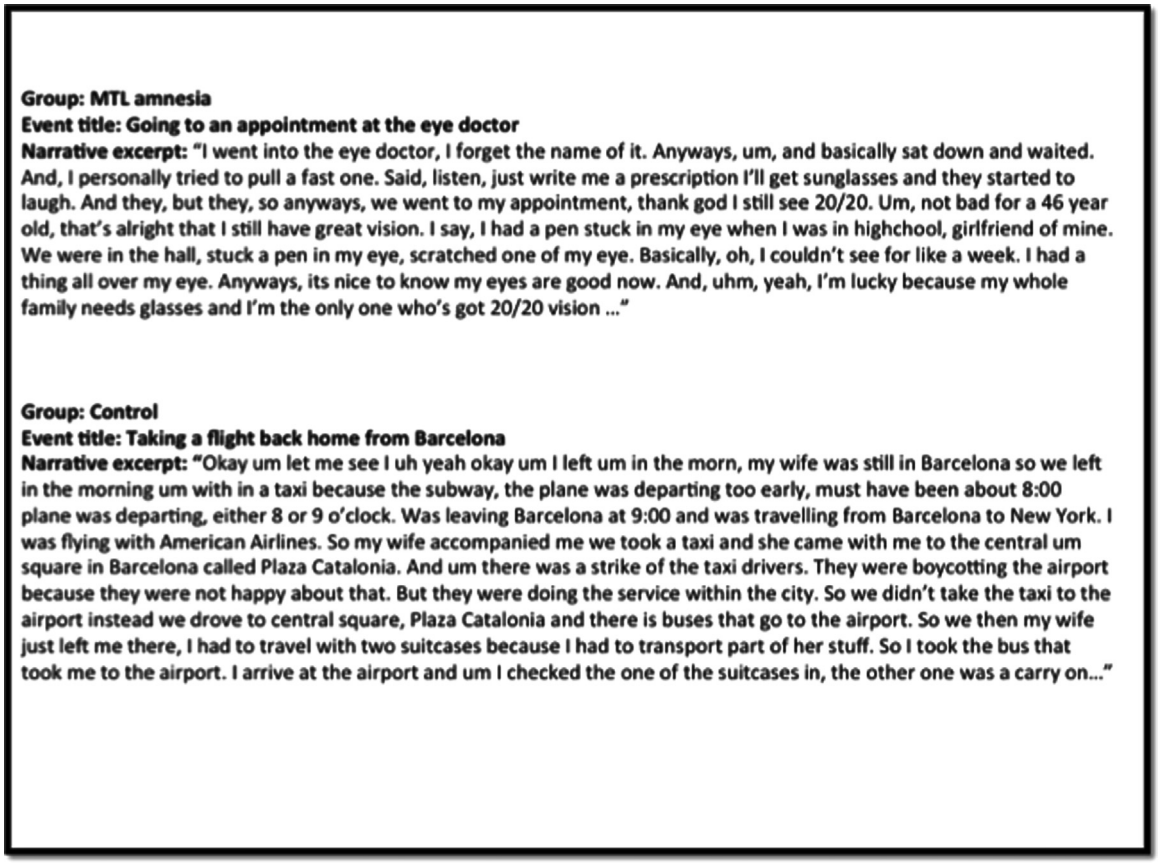

Fig. 1. Examples of an event caption and the associated event narrative for a control and MTL amnesia participant.

Table 2
The five rating dimensions that were used to assess the quality of the event captions. Listed are the associated questions and Likert-scale anchors for each dimension.

Rating Dimension	Survey Question	1	5
Frequency[a]	How frequently would an event like this occur?	Daily or weekly	Once in a lifetime
Significance	How significant is an event like this to someone's life?	Not significant / very routine	Very significant / life changing
Imageability	How well can you picture an event like this in your mind?	Not at all	A very detailed picture or image
Emotionality	How emotional is this event?	Extremely negative	Extremely positive
Uniqueness	What is the likelihood that this event would occur similarly from person to person?	Completely the same for everyone	It's completely different for everyone

[a] Note that this scale is coded in the reverse of the other scales: a high rating for an event means that it is less frequent.

Table 3
The two discrete components underlying event caption ratings that emerged from the principal components analysis. Bolded dimensions indicate inclusion in the associated component.

Rating dimension	Generic quality component	Event richness component
Frequency	**0.69**	−0.42
Significance	**0.82**	0.15
Imageability	−0.16	**0.78**
Emotionality	0.35	**0.68**
Uniqueness	**0.55**	0.06

Extraction method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Quality Component, we compared each rating dimension from this component independently between groups. We performed this analysis using the average mTurk ratings for each event caption. We also included time (past versus future event captions) as a variable to determine if constructing events from different time periods contributed to rating differences. We ran separate linear mixed effect models for each rating with group (control versus MTL amnesia) and time (past versus future) as independent predictors. Frequency rating scores were the only dimension to show a main effect of group [$F(1,405)=10.68$, $p=0.001$; time was not significant; $F(1,405)=0.87$, $p=0.77$]. When we examined this difference further, we found that patients with MTL amnesia generated events that were significantly more frequent (mean=3.6, SD=0.1) than events generated by their control counterparts (mean=4.1 SD=0.04). No significant effect of group was found for ratings of significance [$F(1, 405)=2.19$, $p=0.14$] or uniqueness [$F(1,405)=0.19$, $p=0.67$]. These findings suggest that differences in frequency ratings are likely driving the difference in General Quality Component scores between individuals with MTL amnesia and healthy control participants (Fig. 2). We are confident that this pattern is due to MTL processing. When we contrasted the event caption frequency ratings associated with the patients with damage that extended outside the MTL (D.A. and S.N.; mean=3.71, SD=0.76) to those in which damage was relatively restricted to the MTL (L.D. and B.L.; mean=3.70; SD=0.83), there was no difference ($t(46)=0.09$, $p=0.93$).

This result is interesting because, as is evident in Table 3, the

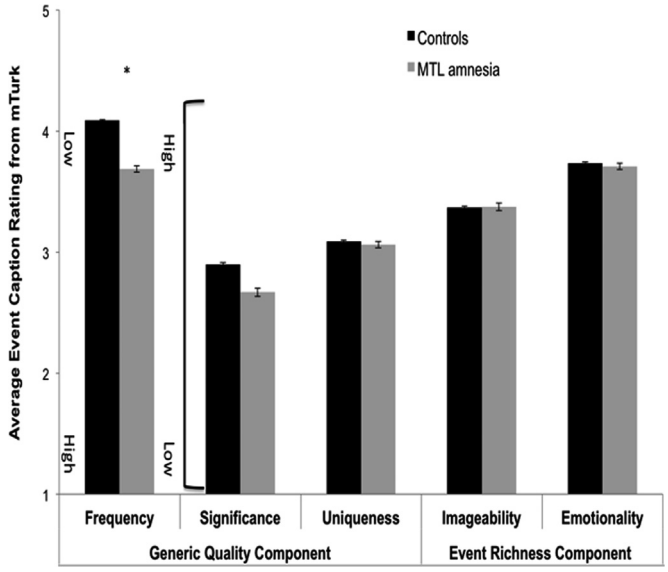

Fig. 2. The average mTurk ratings on the five tested dimensions for the event captions that were associated with the control and MTL amnesia participants. Error bars indicate standard error.

contribution of significance ratings to the General Quality Component was numerically larger than that of frequency. Thus, to ensure that the group differences in frequency are not confounded by the contribution of personal significance ratings, we compared frequency ratings between the groups while covarying out the effect of personal significance. The group difference of frequency remained when we performed this analysis ($F(1, 405)=9.32$, $p=.002$).

We did not have any strong reason to examine group differences for the ratings that comprised the Event Richness Component because we did not find group differences at the factor level. However, one issue arises with the emotionality rating that was included in this factor. The scale that we employed for rating the emotionality of event captions was anchored by "extremely negative" and "extremely positive." Consequently, the ratings captured the emotional valence of the event captions rather than emotional intensity. To test group differences in emotional intensity ratings, we re-coded the ratings by converting ratings of 1 ("extremely negative") and 5 ("extremely positive") as highly intense emotional events (new rating of 1) and the ratings of 2, 3, and 4 as moderately intense emotional events (new rating of 2). A chi-square analysis revealed that the counts of these two levels of emotional intensity were significantly different between the groups (χ^2 (1)=26.65, $p<0.001$). When we examined the average emotional intensity of these two groups, patients with MTL amnesia generated events that were, on average, less emotionally intense (1.72, SE=0.01) than controls (1.66, SE=0.004), with the effect of group approaching significance when we entered these scores into a regression equation ($F(1, 394)=1.91$, $p=0.06$). However, the valence of the highly emotionally intense events was not significantly different between groups (χ^2 (1)=2.17, $p=0.14$). This re-coding suggests that while controls generated events that were ranked as more emotionally intense, they were no more likely to generate highly positive or negative events compared to participants with MTL amnesia.

3.3. Event caption ratings and event details.

Our final analysis established the link between event captions and event narratives by comparing the event caption ratings with the amount of specific episodic detail found in the elaborated event narrative. The measure we used to assess the amount of episodic detail in the narratives was the ratio of episodic (internal) details to the total number of details provided in the event narrative descriptions (IOR scores; Kwan et al., 2015). Across all participants, we found a small positive correlation between Generic Quality Component scores and IOR scores ($r=0.10$; p=0.05) but no significant correlation between the Event Richness Component and IOR scores.

Based on our prediction that different processes guide event construction in our tested groups, we then examined the relationship between event caption ratings and IOR scores by performing stepwise linear regressions for the MTL amnesia patients and controls separately. For controls, neither the Generic Quality nor the Event Richness Component scores significantly predicted IOR (this model was not significant: $F(2, 356)=0.39$, $p>0.25$). For individuals with MTL amnesia, the extent to which Generic Quality Component scores predicted IOR scores was significant (p=0.04) whereas Event Richness Component scores did not predict IOR scores (p=0.41) when both scores were entered into a model ($F(2, 45)=2.82$, $p=0.07$).

When we probed the relation between the event caption ratings and IOR scores separately for the MTL amnesia and control participants with correlational analyses (Table 4), we found no significant correlations between ratings and IOR for control participants. For the MTL amnesia group, both frequency and significance significantly correlated with IOR scores such that less frequent and more personally significant events were associated with memory narratives containing more episodic details. These findings suggest a link between selecting frequent events and the ability to narrate event details in the MTL amnesia group.

We followed this finding with two further analyses. First, we investigated whether the tendency of MTL amnesic patients to select more frequent events could be accounted for by their reduced episodically specific recall during event elaboration. To do so, we examined the effect of group on the frequency ratings of the event captions while covarying out IOR scores of the associated narratives (i.e., episodic specificity). When we did this, the effect of group was still significant ($F(1, 404)=8.83$, $p=0.003$). Second, prior work has indicated that future event generation is more constructive and is consequently more taxing to hippocampal processing (Addis et al., 2007; Gaesser et al., 2013). We tested if the relation between highly frequent and significant events to the episodic specificity of the narratives for the MTL amnesia participants was different for past versus future events. If the relation is stronger for future events, this would support the hypothesis that selecting scripted or frequent events is a form of compensation that is particularly helpful for construction under ambiguous circumstances. Fig. 3 plots the relation between IOR scores and frequency ratings, illustrating that the details generated for future

Table 4
Pearson correlations (*r*) between the amount of internal details generated on the events narratives after controlling for overall detail output (internal detail ratio, IOR) by the control and MTL amnesia participants and the average ratings on the associated event captions by mTurk participants.

Group	Frequency	Significance	Imageability	Emotionality	Uniqueness
Control	0.03 ^{ns}	0.06 ^{ns}	0.06 ^{ns}	−0.02 ^{ns}	−0.01 ^{ns}
MTL amnesia	0.37 *	0.30 *	−0.13 ^{ns}	0.08 ^{ns}	0.08

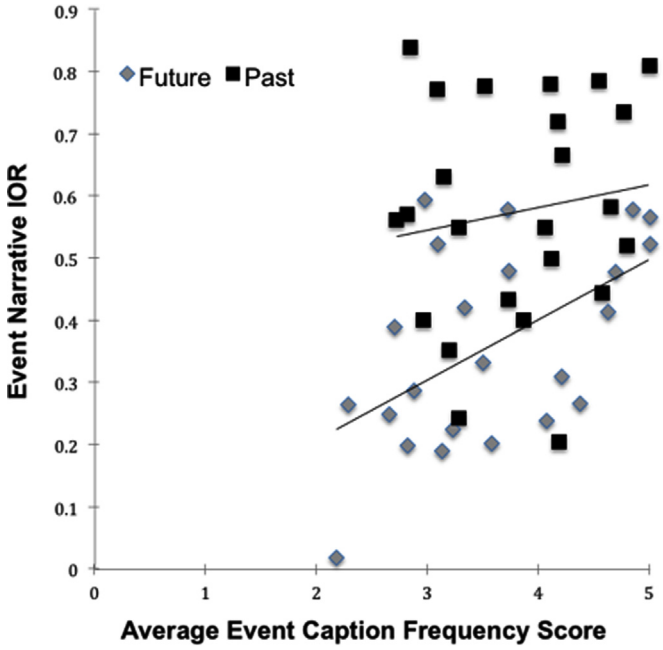

Fig. 3. A scatterplot of the relation between event caption frequency ratings from the mTurk raters and the internal detail ratio (IOR) score from the associated event narratives for the past (squares) and future (diamonds) events generated by individuals with MTL amnesia.

and past events related differently to these ratings for the patients with MTL amnesia. For the patient group, future event frequency and significance ratings were strongly related to IOR scores ($r=0.54$, $p=0.005$; $r=0.52$, $p=0.009$, respectively). This pattern was not apparent for past events ($r=0.14$, $p=0.51$; $r=0.15$, $p=0.48$ for frequency and significance, respectively). The significant relationship established between these future events ratings and IOR scores remained when the potential outlier visible in Fig. 3 was removed ($r=0.45$, $p=0.03$; $r=0.53$, $p=0.01$, for frequency and significance, respectively).

4. Discussion

Many studies have examined how MTL damage or deterioration affects the ability to recover specific episodic details from autobiographical events (e.g., Addis et al., 2009; Murphy et al., 2008; Rosenbaum et al., 2011; Rosenbaum et al., 2008; Sheldon et al., 2011; St-Laurent et al., 2009). However, little research has been conducted on how such damage influences autobiographical memory and future imagining before these details are brought to mind. Here, we provide new evidence that MTL damage significantly affects the type of events selected when participants are prompted to remember past events or imagine future ones (i.e., construct an event). These results promote the view that the integrity of the MTL is required for both selection and elaboration processes of autobiographical event construction.

In this study, we used a novel method that involved extracting event captions from detailed event narratives generated by patients with confirmed damage to the MTL and associated amnesic symptoms as well as matched healthy control participants. These event captions represented the type of event that was chosen for an event recall task, but did not reference any specific event details that were subsequently generated, ensuring we were measuring the process of event selection. A large sample of unbiased raters recruited via mTurk assessed these event captions on five characteristics known to vary with event construction: frequency of event occurrence, personal significance, the ability to form a mental image of an event, the emotionality of the event and its uniqueness.

Our main finding was that past and future events selected for construction by individuals with MTL amnesia were significantly different from the events selected by control participants. Specifically, individuals with MTL amnesia selected events that were associated with a higher rating of lifetime frequency than the control participants. This finding provides evidence for our proposed hypothesis that deficits in the use of MTL-mediated episodic memory processes when generating autobiographical events will lead to an increased reliance on semantic memory processes. By virtue of their intact episodic memory processes, control participants were able to select events for this task by constructing a unique occurrence from a single time and place, the very definition of an episodic event (Tulving, 2002). The key symptom of MTL amnesia is a difficulty in recalling episodic events, thus individuals with MTL amnesia must rely on other processes to select events for this task. The finding that individuals with MTL amnesia selected more frequent events is consistent with the notion that they relied more heavily on semantic memory representations. These semantic memory representations, such as lifetime scripts and schemas, are thought to be relatively intact in cases of MTL amnesia (St-Laurent et al., 2009). Thus, the patients in this study could retrieve broader scripts and schemas, which operate independently of the MTL, and use them to guide event construction. Other investigators have used this account to explain why patients with extensive memory impairment are more impaired at recalling recent compared to remote events (Scoville and Milner, 1957; Stefanacci et al., 2000; Steinvorth et al., 2005). Whereas more recent memories can only be recalled as a unique occurrence, by virtue of limited event rehearsal, remote events can be also be recalled via a gist-like route because they have been rehearsed multiple times, leading to the creation of a semantic representation of the event (see views associated with the Multiple Trace theory of memory; Nadel and Moscovitch, 1997).

It was somewhat surprising that ratings of emotion and imageability did not emerge as significantly different between the groups, since these qualities are known to correlate positively with how vividly individuals can recall autobiographical memories (Holland and Kensinger, 2010; Rubin et al., 2003). One explanation for the lack of emotionality differences is that the emotionality rating scale we used asked raters not to indicate how emotionally intense an event was, but to indicate whether the event was associated with positive or negative emotion. When we re-coded the emotionality rating scale to measure intensity and valence separately, we found that participants with MTL amnesia generated events that were judged as less emotionally intense than control participants but which were not different in terms of valence. This result hints at how events are 'pre-retrieved' differently when the MTL is damaged. The amygdala, in concert with the hippocampus and prefrontal cortical regions, is important for processing emotional events (Buchanan, 2007). It is likely difficult to use such online emotional processes to guide event construction if this circuit is damaged. This could explain the difference in emotional intensity rating between the groups. Another explanation ties the emotional intensity ratings to event frequency ratings, which found an increased generation of frequent or generic events by the participants with MTL amnesia. It could be that detail-rich or more specific autobiographical events are more emotionally arousing than scripted or generic events, but not necessarily more emotionally positive or negative (for a review of emotion and memory, see Holland and Kensinger, 2010).

Finally, we note the observed group differences when we examined the relationship between the event caption ratings and the amount of episodic detail contained in the associated event

narratives. For individuals with MTL amnesia, the events that were rated as less frequent and more personally significant were associated with more episodically detailed descriptions, a pattern that was driven by the more hippocampally-demanding future imagined events. Overall, these patterns suggest that participants with MTL amnesia and healthy control participants rely on fundamentally different processes when accessing events.

4.1. Event selection as a form of compensation

We speculate that the individuals with amnesia in the current study compensate for their memory loss by selecting higher-order hierarchical events that are more semantic in nature. Indeed, in one study, older adults with episodic memory loss were shown to recruit brains areas outside of the MTLs thought to support semantic processing, such as the middle temporal gyrus, during autobiographical memory retrieval (Maguire and Frith, 2003). Findings of this sort have been interpreted as evidence for the engagement of neural compensatory processes that recruit general semantic details compared to specific event details when remembering episodic events. This interpretation is also supported by a case study that reported increased activity in the middle temporal gyrus in concert with decreased activity in MTL regions during recall of specific autobiographical events in the amnesic case ML (Levine et al., 2009). At the risk of reverse inference, it is possible that the individuals with MTL amnesia described in the current study preferentially engage semantic processes mediated by intact middle temporal gyri.

Whether the tendency to recall more frequently occurring memories in cases of MTL amnesia reflects a form of conscious compensation or strategy on behalf of an impaired MTL system or reflects a non-conscious dependency of event selection on the integrity of the MTL, remains unclear. The interpretation that the individuals with MTL amnesia in this study were consciously adopting a particular strategy or retrieval orientation to compensate for their episodic memory impairments by recalling scripted occurrences is related to recent findings that retrieval orientations or modes have a strong influence on the nature of recalled events (Madore et al., 2014; Madore and Schacter, 2014). For example, one study found that in healthy participants, inducing a gist-based form of retrieval limited the ability to generate episodically specific autobiographical events (Rudoy et al., 2009). One hurdle in applying these views to our current findings is confirming the assumption that the patients with MTL amnesia had acute awareness of the specificity of their memory problems, which is still unclear. Future research would benefit from probing participants to determine whether they have insight into the steps or strategies they use to construct an event.

4.2. Methodological implications

Beyond the theoretical implications for conceptualizing MTL contributions to autobiographical memory, our findings have important implications for methods used for assessing memory (for other recent findings on this topic, Aizpurua and Koutstaal, 2015). Many tools characterize autobiographical event generation by assessing the detail with which autobiographical events can be described. We suggest that simultaneously examining the type of event and the quantity of details used to describe that event will provide powerful insight into the ways that particular neural processes support these two aspects of autobiographical retrieval. In doing so, the field can better clarify how damage to the MTL, and other neural structures that contribute to memory, affect the experiences of remembering the past and imagining the future.

4.3. Limitations and future directions

The present study has some limitations. First, there are some concerns over the validity and generalizability of mTurk data. However, mTurk participants have been shown to be at least as representative of the U.S. population as traditional subject pools in social science experiments (Paolacci et al., 2010). Moreover, our study was designed to reduce any issues concerning the validity of responses. We only used mTurk workers with at least a 98% prior approval rate and we removed data from participants who completed a survey in under five minutes and/or responded inappropriately to our validity check items.

In our study, we could not directly test the nature of the relationship between the episodic details provided in the elaborated event narratives and the specificity of the event captions. For example, if a participant provided the brief tag “going to the store,” but then discussed a specific detail relating to this event (e.g., “knocking over a stack of boxes”), it is possible that the event caption would be influenced by this detail and therefore changed to incorporate that specificity (e.g., “knocking over boxes at the store”). However, we believe that this is unlikely for several reasons. First, the event captions were generally quite similar to the brief tags provided by the participants themselves. The changes made to brief tags were small and reflected changes to grammar or the removal of pronouns to improve accessibility and understanding for the mTurk raters. Second, if episodic details from the narratives influenced event selection, one would expect that the event captions judged as less frequent would also have higher IOR scores, indicating more specific episodic details. While this relationship was indeed found for the MTL amnesia participants, IOR ratings did not correlate with ratings of frequency for control participants, suggesting that there is not a consistent relationship between narrative specificity and the dimensions of frequency. Finally, when we included IOR scores as a regressor, the effect of group on ratings of event frequency remained significant, suggesting that the presence of specific details in the narrative did not account for ratings of frequency or significance.

This study collapsed across time (past and future events) based on the strong line of work that has found similar processes engaged during past and future event construction, particularly within the MTL (Addis et al., 2010; Schacter and Addis, 2007; Schacter et al., 2007, 2008; Spreng et al., 2009; Suddendorf et al., 2009). Nevertheless, we did probe differences between these time periods as a means to guide future research. Specifically, the correlation between frequency and significance ratings and event narrative specificity was only significant for future events for the patients with MTL amnesia. We speculate that this finding may be due to the demands of constructing future events. Unlike recalling events from our past that may benefit from selecting well-rehearsed events, imagining events that have yet to happen cannot rely on such rehearsal or existing schematic representations of events to the same degree, thus this task is a more open-ended and construction dependent task, a hypothesis that fits with our recent proposal that open-ended scenarios engage the MTL more than closed-ended tasks (Sheldon et al., 2011, 2013, 2015).

A methodological limitation worth noting relates to the generalizability of our findings to other methods of probing autobiographical events. In our study, participants were invited to self-select events from either the past 5 years or generate plausible events from the next 5 years. We do not know whether the same pattern would emerge, that is the importance of pre-retrieval selection processes to event generation, if we probed for events using different methods (e.g., cued-recall) or if participants were given a wider time period from which they could generate the events (e.g., 10 years). In addition, the autobiographical task used in our study (Kwan et al., 2015) involved voluntary event

construction and not involuntary autobiographical remembering, the process by which personal experiences come to mind spontaneously without a conscious attempt at retrieval (Rubin and Berntsen, 2009). Although voluntary and involuntary memory may share the same encoding and maintenance factors, they differ with regards to event retrieval in terms of the amount of conscious effort involved, which is evident in the neural processes that are recruited (Berntsen, 1998; Berntsen and Hall, 2004; Hall et al., 2014). Whether involuntary memory selection is similarly affected by MTL damage is not clear. The presence of an effect of pre-selection processes on involuntary memory retrieval depends on whether patients with MTL amnesia consciously use semantic-based retrieval modes to access memories or whether this happens automatically.

4.4. Conclusions

By implementing a novel method for characterizing events, we provide new evidence that the effect of MTL damage is evident at the initial stage of event selection, before specific episodic details are accessed. Individuals with MTL amnesia are more likely to access events that are more frequent and more schematic than those selected by control participants. There are two ways to interpret these findings. First, it is possible that MTL lesions lead participants to select more generic events and produce fewer episodic details when they elaborate on these events. These two effects may operate independently of one another as they influence different aspects of the autobiographical memory system. Alternatively, it is possible that deficits in episodic memory, resulting from MTL damage, lead participants to select more generic events for autobiographical recall. That is, a lack of access to episodic details may drive the selection of more generic events. Our study calls for a more comprehensive approach to assessing autobiographical event generation: one that considers both event selection and detailed elaboration.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.neuropsychologia.2016.02.023.

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