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Adna Jaganjac April 7, 2016

Comparing the Construction of Future Events with the Reconstruction of Past Events in Mental Time Travel

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Abstract

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First proposed by Tulving in 1989, mental time travel refers to the movement of the self through time, encompassing the ability to both recreate past experiences and create expectations for future experiences (Suddendorf & Corballis, 1997). Drawing on the concept's relative novelty, the current study sought to further our understanding of how people might differentially represent these past and future events by examining the cognitive processes behind mental time travel using narrative writings and eye-tracking technology with the purpose of investigating the cognitive processes behind mental time travel. There is research that suggests that past and future events differ mainly by topic: future events are more likely to be based on a life script and consequently they are more likely to be positive events as well (Berntsen & Rubin, 2004). However, there is also literature suggesting that the differences between constructing past events and future events (in terms of the neural pathways used in both) are very minimal (Viard et al., 2010). Our findings support the latter statement: the narratives and eye-tracking were not significantly different between times frames, and the only difference occurred in the participants' self-report ratings. People consciously believe that past and future events are thought of in different ways. However, the way we write about them and the amount of effort we place in the construction of these events shows that this is not true. Future research should continue investigating new approaches to determine how the reconstruction of past events is related to the construction of future events.

Keywords: mental time travel, narratives, eye-tracking

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Comparing the Construction of Future Events with the Reconstruction of Past Events in Mental Time Travel

Mental time travel is a comparatively new term. The phenomenon was originally studied by Tulving in 1989, who called it autonoetic consciousness after working with a patient who had damage to his medial temporal lobe and his hippocampus. He noted that this patient, known as Patient KC, could not remember "a single thing that he has ever done or experienced in the past" or describe experiences and events he anticipated doing in the future (p. 362). This concept was elaborated on in 1997 by Suddendorf and Corballis, who coined the term mental time travel and defined it specifically as "the mental reconstruction of personal events from the past (episodic memory) and the mental construction of possible events in the future" (p. 133). This ability is unlike others in that it is the movement of the self through subjective time. It allows us to vividly recall the past and imagine the future and suggests that these two time frames are more linked together than one might intuitively suspect. In fact, understanding mental time travel can help us understand how people differentially think about the past and the future, and as a result, there has been an increase in studies investigating mental time travel in recent years. Similarly, the purpose of this study was to the determine similarities and differences in how people verbally report about past events and future events and in the cognitive processes involved during the reports, to inform the presumed linkages.

Many studies have gathered information about the recall of past events and imaginings of future events by asking participants to mentally imagine the events or to speak them outloud. However, because of the relative novelty of mental time travel as a research question in the scientific community, there are indeed novel ways to explore this question of how the time frames are linked. Specifically, the current study seeks to use the novel applications of narrative

writing and eye-tracking to shed light on this question: how does the reconstruction of past events and construction of future events look similar or different when using narrative writing and eye-tracking data to study the underlying cognitive processes?

The use of narratives (orally spoken or written accounts of events, including both details and evaluations of experiences) is a fairly common and widely-accepted practice in the study of memory and especially with episodic memory, or our memory for specific experiences and events (Tulving, 1972). Studying these narratives can tell us a great deal about what kind of autobiographical memories (concerning the vividness, valence, ability to recall, etc.) people choose to add to their life narrative. Singer and Blagov (2004) for instance noted that self-defining memories (one type of memory which invokes a certain level of vividness and affect) are commonly recounted through narratives. Singer and Blagov's findings indicate that these memories usually include strong visual imagery and receive high ratings in self-reported vividness, which would make them easier to describe in a narrative.

This finding concerning visual imagery and vividness is reflected in other studies as well. Wagenaar (1986) for instance conducted a 6-year study of his own autobiographical memory. He recorded descriptions and key details (*who, what, where, when*) of a number of events that occurred throughout this period of time. Sometime after writing these details out about the events, Wagenaar tested himself for recall: he gave himself one of the cues (*who, what, where, when*) and tested whether he was able to reproduce the rest of the details of the memory. Similar to Singer's findings, Wagenaar noted that valence and emotional involvement played a role in his ability to recall events. Specifically, the events that he rated as "very pleasant" had a statistically significant retention rate as compared to other events that were in contrast given ratings ranging from very unpleasant to neutral: the correlation between pleasantness and

retention came out to be significant (r = .12). Additionally, emotional involvement was shown to be slightly linked to retention rates of the memories (r = .07). Put simply, the narrative information Wagenaar included for his memories predicted longevity of the memories in that the more emotionally involved events were still part of his autobiographical memory years after he first recorded them. These studies suggest that there are noticeable patterns in terms of which autobiographical memories are added to someone's life narrative and that these patterns are observable in the content of narrative accounts of the memories, establishing narratives as an effective method in studying the cognitive process underlying past thinking.

However, the use of narratives is less common with future thinking. Typically, studies ask participants to simply imagine a future event rather than describe it (Viard et al., 2010; Spreng & Grady, 2010; Arzy, Molnar-Szakacs & Blanke, 2008). Berntsen and Rubin (2004) for example asked participants to think from a baby's perspective and simply list possible future events that the baby would experience in its future. As was mentioned above, these are not narrative descriptions of the imagined future events. Regardless, this research was critical for gathering evidence for our expectations for the present research. From the list of events provided to them by the participants, Berntsen and Rubin were able to gather information about the "life script"—or expectations concerning which events will occur during which point in someone's life. These events tend to be shared among a specific culture, and Berntsen and Rubin were able to identify a list of 35 events that were mentioned more than 4 times among the 103 total participants. These include but are not limited to having children (93 records sum, meaning that this event was mentioned by 93 participants), marriage (77), beginning school (68), college (56), falling in love (52), others' deaths (32), etc. Looking at this list here, we can already see some similarities between events. The first five events, mentioned by more than half of the sample, are

all positive. In fact, participants were asked to complete ratings on the valence of the events, and on a scale from -3 (*very negative*) to +3 (*very positive*), those five events were consistently rated as being more positive: mean ratings ranged from 1.24 to 2.58. The first negative event (with a mean valence rating of -2.56) comes up as sixth in the list, and only 32 participants spoke about this event, as compared to the 52 for falling in love. Building from this research, we anticipated that constructing future events could generally involve more optimistic thinking, resulting in more positive narratives. Similarly, as Berntsen and Rubin suggest, imagining future events might simply be more vulnerable to cultural and social influences. The researchers note that the majority of the listed events could be associated with "an educational, work, or family context", reinforcing the conclusion that the life script includes "only events that can be associated with culturally important role contexts" (p. 436). Logically, we can then conclude that this might result in the increased likelihood that our participants use life scripts on which to base their future narratives. These findings concerning the content and valence of life scripts in imagining future events have been replicated in other studies on future thinking (Grysman, Prabhakar, Anglin & Hudson, 2014; Atance & O'Neill, 2005). With these studies, there is not an application of narratives as there is with studies on past events, but we do see that what participants say about their imaginings for the future (through the lists of events and through the self-report ratings especially) can shed light on how people construct these future events.

We see that, in past research, narratives have been successfully used to make inferences about the mental reconstruction of events from one's memory and construction of events based on one's imaginings into the future. The current research built on this existing research, but in an effort to extend it, we sought to apply the use of written narratives (commonly utilized in studying the reconstruction of past events) to study the construction of future events.

Specifically, we asked participants to type narratives about specific and personally-experienced events (later also answering self-report questions), as opposed to simply imagining the events as in the studies of future thinking that were mentioned briefly in this introduction. This allowed us to directly compare elements of the writing for the past and future events as well. Similarly, the current study sought to approach the narrative work in a novel way. In place of examining content of the narratives as many of the previously mentioned studies did, we instead examined the structure of the narratives. Namely, we were able to examine four key features of the narrative structure: 1) how much detail was given about time and spatial locations as determined by the Narrative Coherence Coding Scheme (Reese et al., 2011), 2) how complete the narratives were as determined by coding for a resolution or a link to other autobiographical memories and knowledge, 3) how long the narratives were (word count), and 4) how much time participants devoted to writing their narratives (length of typing per narrative). This gave us ample opportunity to examine what participants chose to include in their writing of the past versus their writing of the future**.**

Based on the previous literature, there is evidence to suggest that both the narratives and the construction process will be similar for recalling past events and imagining future events. There is one theory by Bluck (2003) that suggests a very clear link between recalling past events and projecting of future events, and it is as follows: “the directive function of memory is seen as a crucial way in which individuals use the past as a resource for present and future behavior” (115). According to Bluck, there is support for the conclusion that people use their knowledge of past events and experiences to create expectations for the future, to predict what might occur in the future, and to prepare themselves for those possibilities.

There is evidence in the literature in favor of this conclusion. In a study by Viard, Chételat, Lebreton, Desgranges, Landeau, de La Sayette, Eustache, and Piolino (2010), the researchers contacted participants' close family members to discuss events and experiences in the participants' past and envisioned future. Participants were then brought into the lab to conduct a study with the functional magnetic resonance imaging (fMRI) device, which measures brain activity. While inside the fMRI, participants were presented cues specific to the information gained from the family members and asked to mentally envision the event it conjured in their minds. Once outside of the fMRI machine, participants verbally described the events they had thought of and were given rating scales to complete. The fMRI results revealed that a number of different brain structures had been active during the recalling of both past and future events. There was activation in the posterior cingulate cortex, precuneus, and medial prefrontal cortex, all of which are related to self-projection. The superior and middle temporal gyri were also activated, and they are involved in controlling semantic information. Lastly, the hippocampus was shown to be activated, and this perhaps does not surprise anyone as it is the hippocampus that is involved with episodic memory in general. This suggests that the same type of information is being used in narratives for both imagining past and future events, which hints at the possibility that the same type of information will then be used in narratives for past and future events.

Likewise, two additional studies (Spreng, Mar & Kim, 2009; Spreng & Grady, 2010) both found links between imagining past and future events in terms of neural pathways activated during recall of the events. In the study by Spreng and Grady (2010), participants were presented with a picture and word cue while in the fMRI and asked to mentally recall an event associated with that they saw. Results indicated that the neural pathways used in past and future thinking

(along with another of their variables of interest, theory of mind) were linked. Comparatively, constructing events for both past and future involved "activation of the midline structures in frontal and parietal lobes; left-lateralized activation of inferior frontal gyrus, temporal pole, middle temporal gyrus, superior temporal sulcus and inferior parietal lobule; and activation of right medial-temporal lobe". Accounting for 81.42% of the covariance in the sample, this shared activation was shown to be consistent over the time it took to complete the task. Experimenters found mean brain scores (representing the sum of activity across the brain) and indicated that the scores increased from 0 to 15 across time and that these scores were consistent for both past and future thinking. When comparing past and future directly (without theory of mind), it accounted for 13.75% of the variance, sharing more similarity together than past and future events shared with theory of mind. There was no information offered concerning differences between past and future events. This could indicate that the brain areas used in thinking about the past are nearly identical to the ones used in thinking about the future, suggesting that there is bound to be more similarity than differences in the cognitive processes for constructing past and future events.

Furthermore, we can anticipate finding similar results in the present research, especially in the eye-tracking component. The results from the neuroimaging studies informed the decision to include eye-tracking technology into the current research. Eye-tracking is another index of neuro-cognitive processes and is already considered an effective method for examining the process of reading and other aspects of cognition (Starr & Rayner, 2001; Poole & Ball, 2005). Based on this, we reasoned that it could reveal the mental effort used as subjects recalled past events and projected themselves into future events.

We focused on pupil dilation in particular. Previous research has found that eye-tracking measures such as pupil dilation especially are "efficient method[s] to investigate cognitive

effort" (Goldinger & Papesh, 2012; Poole & Ball, 2005). A study by Marshall (2002) examined the Index of Cognitive Ability, a measure that tracks changes in pupil diameter to provide "an objective psychophysiological measurement of cognitive workload" (p. 75). Participants were given either a cognitive task or a non-cognitive task to complete, and it was revealed that the Index of Cognitive Ability for both eyes was indeed higher (with scores of 9-10) for cognitive tasks than it was for the non-cognitive tasks (scores roughly around 6). This finding supports our earlier statement that pupil dilation can reflect cognitive load during a task. Similarly, although memory in general has not commonly been studied in relation to eye-related measures, there are studies that examine the relation between eye-movement specifically and emotion. A study by Bradley, Miccoli, Escrig, and Lang (2008) investigated the effect of viewing emotional material on pupil size. Participants were set up in front of an eye-tracker and viewed 96 pictures (some of which were neutral, some pleasant, and some unpleasant) for no longer than 6 seconds. They found that the content of the picture had a large effect on the pupil size ($p < .001$), in that viewing pleasant and unpleasant pictures resulted in larger increases in pupil size as compared to viewing neutral pictures. The difference between pupil size for pleasant and unpleasant pictures was not significant however ($p = .09$). Regardless, after seeing that the valence of the pictures affected pupil size, this suggests that the eyes could then be a strong predictor for the mental experience of a memory.

Likewise a study by Xu and Bauer (in preparation) examined pupil measurements of participants while they were typing autobiographical memories and found that the pupil dilation was increased in the beginning of the typing. This dilation had decreased by the time the participants were finished writing their narratives, suggesting not only that eye-tracking is a reliable method for observing cognitive changes as reflected in the eyes but also that the very

experience of recounting autobiographical memories is physically evident in the eyes as well. Furthermore, pupil dilation might reflect similarities in past and future thinking, based on the information presented in the above studies on neuro-cognitive processing and the potential neural origins of mental time travel.

However, there is evidence that the narratives themselves will differ between past and future events, and this in turn could affect our eye-tracking data. As was discussed in Berntsen and Rubin (2004), future events are more likely to draw from life scripts. In fact, one life script (having children) was so prevalent in the study that over 90% of the 103 participants included it in their narrative, demonstrating the power of the cultural scripts over future expectations. Future events could feature less variability from participant to participant and would be more likely to involve a positive event. The presence of this positive valence could result in increases in pupil dilation for the future events as compared to past events.

There are indeed other variables that could impact eye-tracking measures such as gender of the participants and the effort required to mentally envision the event. Xu and Bauer (in preparation) observed that, after separating by gender, using cues to prime for emotional narratives (positive, negative, neutral) led to differences in pupil dilation in the beginning of the narrative task. For women, the main difference emerged in negative events (more pupil dilation for negative events than positive and neutral). For men, the main difference emerged between negative/positive and neutral events. To add to this information, because past events are more likely to be about self-defining memories, which in turn are commonly regarded as more vivid than other types of memories (Singer & Blagov, 2004), cognitive effort could be greater for these past events. It makes sense to assume that recalling details of an event for the past narrative will be more difficult than simply relying on a generic script for the future narrative. This could

directly affect our eye-tracking measure as well: if pupil dilation measures cognitive effort and recalling past events requires more cognitive effort, then we could see increases in pupil dilation for past events instead.

Taken all together, the existing literature suggests that there is the potential for a complicated relation to emerge between gender, valence, and cognitive effort. It could indeed show up in both the eye-tracking and the narrative structure of the different events for the current study, resulting in differences due to these variables as opposed to our main variable of interest (time frame).

In summary, in the current study, we investigated the question of how past and future events will look constructed in narratives and represented by eye-tracking data. Our main hypothesis was that characteristics of the narratives (quantified through coding) should correspond with cognitive effort as measured in pupil dilation. There are a number of other variables that could affect this relationship (the valence of the events and gender, for example). However, the main finding should emerge when comparing past and future events, holding constant for other potential confounds.

Findings from this research will further elucidate the premise of future thinking, especially in its relation to past thinking and memory reconstruction. The current experiment also includes a novel way of thinking about the usage of mental time travel and opens up the possibility that even our eyes can shed some clues on this critical ability.

Method

Participants

There were 37 participants tested at Emory University in Atlanta, Georgia. Participants were recruited from the Introductory Psychology courses' (PSYC 110 and 111) study pool.

Students had to meet three requirements to be considered eligible. First, because the study was of adults, participants had to be 18 years of age or older. Second, subjects had to be able to type on a keyboard without having to look at the keyboard, a restriction that was placed to ensure quality eye-tracking data by minimizing the amount of time participants spent looking away from the eye-tracker. Lastly, participants had to be native English speakers. This requirement was imposed to control for quality of writing and keep the level of proficiency with the language consistent across participants. As well, it controlled for the language the memories/events were originally encoded in since this could in turn affect aspects of the writing of the narrative.

A total of 27 participants were included for analyses. Sex was almost evenly split in the sample, with 13 females and 14 males. Age ranged from 18 to 21 years of age, with a mean of 19.34 (*SD* = .90). An additional 10 participants were tested but ultimately excluded from the final analyses for one of the following reasons: failure to meet the eligibility requirements for being a touch typist and a native English speaker (*N* = 3), failure to follow narrative instructions on choosing specific events to write about (*N* = 3), and low sample rates (the percentage of time that eye-tracking data was gathered out of total time) on their eye-tracking data (*N* = 7). Participants needed at least one useable past narrative and one useable future narrative to be included in the analysis.

Informed consent was gathered from each individual participant before beginning their session, and compensation was 1-hour credit granted for participants' psychology course requirement.

Materials and Measures

Event Ratings Surveys. After completion of the eye-tracking and narrative writing, participants were given one event rating survey to complete for each narrative, with the title of

the narrative at the top of the page. This survey was taken from past Bauer Lab studies and edited slightly for the purpose of this study. It consisted of 10 questions total, 2 of which were free response ("how many months in the past/future is this event" or "is your recollection of the event as if you experience it or as if you were watching the event happen?"). The remaining seven questions were ratings on a scale of 1-9, asking participants about the vividness, valence, uniqueness, etc. of their memories/events. See Appendix A for survey.

Narratives. Narratives were coded using a revised version of Narrative Coherence Coding Scheme (Reese et al., 2011), which is available in Appendix B. To be able to examine future narratives as well, this version of the coding scheme only used the theme (examining whether the narrative was resolved) and context (examining the degree and specificity of details for time and spatial location) categories. The chronology component was excluded because it examines whether the actions listed in the narrative have temporal information, i.e. whether these actions can be placed on a time line in terms of which came first and what occurred next. This coding scheme was not applicable to the future narratives in which many participants listed *future* actions: "I will do this" or "I will do that". As a result, we were not able to code for chronology for the future narratives and made the decision to exclude it altogether.

Context was measured in terms of the information given regarding spaces ("I was at the park!") and time ("It was Monday July 29th"). Participants could receive anything from a 0 (neither time nor space included) to 3 (specific information about time and place included).

Theme was likewise scored on a scale from 0 to 3. This component measured how complete and coherent the narrative was. A score of 0 would indicate that the narrative was off-topic and that the progression of the narrative was as a result difficult to follow. A score of 3 would indicate that the narrative was well-developed and that the statements in the narrative

were linked together in a logical way. In addition, narratives would have to include either a resolution statement or a link to other autobiographical information to gain a score of 3.

Other variables relating to the narrative writing process are word count of the narratives and duration of the narrative typing in milliseconds.

Eye-tracking. Eye-tracking was done using the Tobii T120 eye-tracker with a sampling rate of 60 Hz. Calibrations were done before the data collection of each narrative production task. As was mentioned earlier, participants with low samples ratings were eventually excluded from the study. The cut-off was 70%, where any narrative below this number was excluded from analysis.

There were two measures that were included in the eye-tracking component: pupil dilation across time of the narrative typing and average pupil size per narrative typing. There was no time limit in this study, and subsequently, the duration of each narrative typing varied from participant to participant, narrative to narrative. As a result, we have had to standardize the time stamps for the session. We averaged the dilation of the pupils at each corresponding point in time (a quarter way through the typing of the narrative, halfway through, etc.) to be able to compare pupil dilation as participants progressed through their narrative typing at their own respective pace. Average pupil size on the other hand is an average across the duration of the entire narrative typing.

Procedure

Participants were tested individually. After obtaining informed consent from the participants, the researcher presented them with the initial surveys, the results of which are not relevant to the current research. After completing the surveys, participants were given an instructions sheet to read with information on the eye-tracking component of the study (see

Appendix C). After finishing the reading, the researcher then verbally explained what would be expected of the participants during the eye-tracking. The researcher informed the participants that they would want to have a comfortable position and posture so that they could comfortably type during the eye-tracking. Participants were also asked to try to limit larger movements during eye-tracking and limit the amount of time they spent looking away from the screen of the eye-tracker. Specific instructions for the eye-tracker were emphasized again: choosing events that occurred/would occur in the past/next 3-6 months (and did not exceed this 6 month time frame), choosing unique events, trying to write at least a page but no more than that, and not using the mouse while typing. Then participants went through a practice writing during which they were permitted to ask the experimenter any additional questions about the procedure. After this, participants completed the four (2 past, 2 future) narratives. In order to ensure that the order of the presentation of the time cues did not affect the content or quality of the narratives, the order was counterbalanced so that approximately half of the participants (N = 14) received order 1 (past, future, future, past) and the other half (N = 13) received order 2 (future, past, past, future). Eye-tracking calibration was done before beginning each narrative. After completing each narrative, the researcher asked participants to name the narrative and wrote it down on one of the Event Ratings surveys. Upon completion of all four of the narratives, participants were given the Event Ratings surveys to fill out one for each narrative.

Each participant was tested during a single, one-hour session. There was no time limit placed on the narrative writings so total time of the session varied by participant and was impacted by how quickly each individual participant was able to think of events to write about and how quickly they were able to type the events. However, most sessions lasted for 60 minutes.

Data Analysis

For data analysis, SPSS was used, with the alpha level set at .05. Pearson correlations and paired *t*-tests were used to examine the data.

Results

In the Data Preparation section, we will first discuss preliminary steps taken to format the data to ensure that the correct analyses could be run. In the second section, we will discuss task performance. This includes variables pertaining to how long it took participants to type their narratives and how many words were included in the narratives. The following section will examine narratives, particularly discussing the findings regarding the coding scheme we used. The next section will present findings related to pupil dilation, and the following section will examine the subjective ratings. Lastly, we will discuss how each of these subsets of data (task performance, narrative coding, pupil dilation, and subjective ratings) are related, investigating the analyses linking these variables together. For task performance, narratives, pupil dilation, and subjective ratings, we will first look at the results for the paired *t*-tests, which compare scores for past narratives against scores for future narratives. Then we will look at correlations between scores for past narratives and future narratives. For the last section looking at relations between subsets of data, we will only look at correlations as they relate to the mixing of the subsets (for example, pupil dilation with narrative coding). These correlations are not the focus of this paper in particular. However, they will be included in the following results section and can be found in Table 1.

Data Preparation

Participants completed four narratives, two for past events and two for future events. To compare the narratives based on time frame, all of the measures were averaged across the past

time narratives and across the future time narratives. As a result, each participant had two averages for each variable of interest.

Task Performance

Descriptive statistics are available in Table 2. A paired *t*-test was run to analyze the differences between the averages across past and future writings for the following variables: the number of words typed for the narratives and the duration of narrative typing (in milliseconds). There was a trend for word count at 9.65; $t(26) = 2.03$, $p = .053$. For duration, the difference came out to be 11439.25; $t(25) = 1.65$, $p = .11$. At present, there was no statistically significant difference found between the means for past and future narratives in either word count or duration of session.

Pearson correlation tests were also conducted to examine the relation between the averages for past narratives and averages for future narratives for word count of narratives and duration of typing of narratives. The correlation between future word count and past word count was statistically significant ($r = .94$, $p < .001$), suggesting that participants who wrote more for their past writing were more likely to have written more for their future writing as well. Likewise, the correlation between past duration and future duration ($r = .96$, $p < .001$) suggests that participants who took longer to finish their past writing also took a longer time to finish the future writing. This finding was also reflected in the following correlations: between future duration and past word count ($r = .62$, $p = .001$) and then again between future word count and past duration ($r = .66$, $p < .001$). See Table 1 for these correlations.

Narratives

Descriptive statistics are available in Table 3. To compare scores given to past narratives with scores given to future narratives, we ran further analysis examining the differences in

context and theme. A paired *t*-test examined differences in the scores in each time frame (past and future narratives). There was no statistically significant difference found between past and future narratives when comparing their scores for context (specificity of the narrative, including information about location and time): $t(26) = -1.85$, $p = .076$. Similarly, there was no statistically significant difference found for the theme component (completion of narrative, including development of the topic and possible inclusion of resolutions or autobiographical information) when comparing past narratives against future narratives: $t(26) = -1.27$, $p = .215$. This suggests that there was no observable difference in how participants were writing about the past events versus the future events, as measured in the coherence coding.

Once again, the Pearson correlation gave a number of significant correlations between variables from the past and those from the future, primarily for context and theme (included in Table 1). Measures for context ($r = .59$, $p = .001$) and theme ($r = .53$, $p = .004$) were found to be significantly correlated across time frames, suggesting that participants with high scores in context and theme in one writing were scoring well in the other writing.

Pupil Dilation

The results are depicted in Figure 1. Pupil dilation across time was recorded for each narrative. The data were split by both time frame (past and future) and gender (female and male) of the participants to determine whether either of these factors would potentially influence pupil dilation. Between the four cells of the design (Female Past, Male Past, Female Future, Male Future), there was no difference in pupillary dilation across the time it took the participants to write their narratives. Participants started off with a dilated pupil for the beginning of the narrative for both time frames, and pupil size gradually decreased as the session progressed. This

suggests that there was little difference in the way participants wrote about the past versus the future events, as indexed by pupil dilation.

Descriptive statistics for average pupil size across typing duration are provided in Table 4. In addition to examining changes in pupil size across the duration of the narrative typing, we gathered data regarding the average pupil size per narrative typing. A paired *t*-test was run to examine the difference in average pupil size between past narratives and future narratives. The difference was .005977; $t(25) = .51$, $p = .616$. It was not a statistically significant difference.

Similarly a Pearson correlation was run to determine if there was any relation between average pupil size for past narratives and average pupil size for future narratives (see Table 1). This correlation echoes what was found in Figure 1: $r = .99$, $p < .001$. Once again, the results highlight the similarities in the production of narratives for both past and future events.

Subjective Ratings

Descriptive statistics are provided in Table 5. The paired *t*-test did find differences in averages for the ratings in the different time frames. When looking at the means, there was a statistically significant difference for the self-reported uniqueness of the narratives; $t(26) = 2.798$, $p = .01$. Past narratives were frequently rated as more unique (mean = 7.94, $SD = 1.30$) than future narratives (mean = 6.91, $SD = 1.73$), meaning that participants often evaluated their past memories as more unique than their future imaginings. Vividness was also significantly different; $t(26) = 4.612$; $p < .001$. Understandably, past narratives were also rated as more vivid (mean = 7.80, $SD = 1.40$). Confidence of details of the narratives was found to be statistically significant with past narratives being rated higher than future narratives; $t(26) = 5.278$, $p < .001$. And lastly, completeness of the narrative was statistically significant with past narratives being rated higher again; $t(26) = 3.748$, $p = .001$. These findings suggest that participants rated their

narratives as significantly different. However, contrary to the participants' perceptions, production and coding showed no differences between two time frames, suggesting that the true difference was in the participants' beliefs, not in how they constructed narratives for both the times.

A Pearson correlations test did find some statistically significant correlations between past and future ratings (available in Table 1). The self-reported rating for uniqueness of future narratives was correlated with the following measures for past narratives: vividness (r = .41, p = .033) and completeness (r = .40, p = .039). This indicates that participants who rated their future narratives as more unique also rated their past narratives as feeling more vivid and more complete. The self-reported rating of valence for future narratives was correlated with the rating for uniqueness of past narratives (r = .47, p = .014). This suggests that there is a relation between how emotional the future narratives were and how unique the past narratives were: the more positive the future narratives were rated, the more unique the past narratives were rated. Future valence also correlated with self-reported ratings of arousal (r = .50, p = .008) and completeness (r = .40, p = .038) for past narratives. Similar to the previous finding, this indicates that more positive future narratives correlated with more arousal in and more complete past narratives. Ratings for the valence of past narratives were correlated with the ratings for significance of future narratives. The correlation held both for significance of the future events then at the time of occurrence (r = -.55, p = .003) and significance of the future events now at the time of the narrative writing (r = -.43, p = .026). There was an interestingly negative relation between valence of past events and significance of future events. Lastly, significance of the past narratives (significance now at the time of the narrative writing) was found to be correlated with ratings for confidence of details (r = .43, p = .024) and completeness of future narratives (r = .41,

p = .032). Although the current study did not focus extensively on these correlations, these analyses offer revealing information about how participants relate their past narratives with their future narratives.

Relations between Subsets

Pearson correlations were also conducted between the subsets, and all of these correlations can be found in Table 1. Future theme was found to be correlated with the following variables for past: word count (r = .41, p = .032), duration (r = .41, p = .035), and average pupil size (r = -.44, p = .024). Past theme was also found to correlate with future duration (r = .46, p = .019). These results hint at a relation between the task and eye-tracking measures and the coherence coding in that important factors from the narratives were consistently showing up in the production as well.

There were also correlations found when we included the self-report ratings. Past arousal was for example correlated with duration of future narratives (r = -.51, p = .008). We find that this correlation revealed that participants that gave higher ratings of arousal for their past narratives also ended up writing for a much shorter time for their future narratives. Past completeness was also correlated with future duration (r = -.42, p = .035). Similarly, ratings for past valence were correlated with measures of average pupil size for future narratives (r = .40, p =.043), suggesting a relation between valence and cognitive effort across time frames. Lastly, scores for theme on past narratives were correlated with ratings for significance of future events, specifically for “significance then” or the significance of the event at the time of its occurrence (r = .48, p = .012). These correlations indicate that a relation also existed between a select number of the objective variables (task production, eye-tracking, and narrative coding) and a select number of the self-report measures.

Gender

The data was split according to gender to check for possible differences in any variables according to gender. However, even when split and evaluated separated, similar patterns as the ones mentioned above were found for both females and males.

Discussion

The present research was created with the following hypothesis in mind: that narrative organization could potentially unveil how we understand construction of past and future events for mental time travel, and based on this, that the cognitive effort participants were experiencing as they thought and made decisions on what to include in their narratives would display itself in their pupil size. Accordingly, the purpose of this study was to examine whether there was any observable difference between past and future as demonstrated by differences between narratives of past and future events in the narrative structure and eye-tracking measures throughout the session.

Work done in similar fields gave evidence that the data could go in either direction in regards to our question. There was the suggestion that narratives of future events would look different from those of past events in terms of valence, topic, and consequently pupil size. For example, Berntsen and Rubin (2004) noted that people typically use life scripts for constructing expectations for the future. Because these events were found to be rated consistently as positive experiences, we hypothesized that eye-tracking measures could differ between past and future narratives due to this difference in valence. Xu and Bauer (in preparation) also touched on the possibility of a gender difference emerging in pupil size in particular. Their study found an interaction between gender and valence when looking at participants' pupil size. Subsequently, this could have also affected eye-tracking data in the present research.

However, it would appear that the current findings turn in the same direction as the findings of the neuroimaging studies that show that the underlying neural and cognitive mechanisms for recalling past events and projecting oneself into future events are to a large degree very similar (Viard et al., 2010; Spreng & Grady, 2010; Arzy, Molnar-Szakacs & Blanke, 2008). And indeed the main result showed no difference between constructing past and future events in terms of the more objective (as compared to self-report ratings) measures, i.e. those relating to eye-tracking and narrative coding. This suggests that the cognitive effort used in mentally creating, experiencing, and writing the narratives is comparable between the past and future conditions for the following variables: pupil dilation (across session time and averaged per narrative), word count, and duration of session. Both conditions produced similar levels of cognitive effort: participants worked just as hard to mentally recreate the past as they did to mentally imagine the future. There was a trend with word count, in the direction that past narratives featured more words on average than future ones, but as the study is now, the result did not come out statistically significant. Perhaps with more participants, this could potentially be the one variable for production of narratives that comes out as being significant.

The second main finding was that there was no significant difference between past and future narratives in the scores they received for their narrative coding. Our modified coding scheme simply investigated context (specificity of time and place) and theme (resolution and linking to self). However, it failed to find a difference when comparing past and future in both of the measures. This suggests that certain features of the narratives were very similar. Participants included the same amount of detail about time and place regardless of the time frame of the narrative, and participants reached an end or established an autobiographical link to the same degree regardless again of time frame. In this respect, the writing was very similar in that

participants formulated their narratives with very similar structures and portrayed these events similarly. By using the Coherence Coding Scheme (Reese et al., 2011), we determined that our participants made the same decisions about which details to include (regarding time and place) and how to end the story (or link it to other aspects of their autobiographical memory), which is indeed interesting in and of itself. A number of the studies mentioned earlier such as the Viard et al. (2010) only asked participants to mentally or verbally recall the event so perhaps we could have expected some contradictory finding to emerge from having to recount the events in a different medium (writing, where there is more time and the ability to self-edit). Regardless, however, the resulting narratives had much in common.

Based on previous research on prospection especially, these findings were not too surprising. We stated earlier in the introduction that people could potentially be using their experiences to prepare for the future (Bluck, 2003). If this is indeed true, it would make sense for the narratives to look similar. Prospection (thinking and projecting into the future) does require a degree of imagination, but people who draw from their past experiences might anticipate similar experiences in the future. And so, if our participants were unknowingly basing their expectations for their future events on their past experiences, their stories would look the same and would require the same amount of effort to write as narratives. In this context, the findings seem logical, especially when combined with the conclusions from the Spreng and Grady (2010) study on neuroimaging. It found that there was a substantial degree (over 80%) of overlap in the brain areas activated during thinking of past events as compared to thinking of future events, suggesting that the brain's bias is to think of these two time frames as the same thing. If this were true, then the pattern of brain activation could affect the way we represent these events and how we portray them in writing as well.

What *is* surprising is the last main finding. When comparing past versus future, there was no statistical difference in eye-tracking measurements or narrative coding. The difference emerged in the self-report ratings that the participants filled out after completing their narratives, at the very end of the session. Participants consistently rated past events as being more unique, more vivid, and more complete. They also reported feeling more confident in the details of the past events than the future events. These findings are consistent with Singer and Blagov's findings (2004) where they indicated that the memories saved in the autobiographical memory system can have two important characteristics: the presence of visual imagery and high ratings of vividness. We consistently found that participants felt that their past events differed in this characteristic (primarily vividness) from future events and that participants chose events that felt different to them in this way.

Uniqueness is perhaps a more complicated idea. The finding for uniqueness might have in part been affected by the role autobiographical memory plays in our lives. Autobiographical memories contribute to every person's unique, life-long narrative, and subsequently it is logical to assume that participants have had more time to evaluate the experiences in their lives and determine which experiences are meaningful in their eyes and as a result, should be included in their autobiographical memory. This could lead participants to feel that these past events are more unique and irreplaceable compared to the future events, which they had likely spent less time thinking about. On the other hand, it could simply be that this sample chose more unique past events to write about and that this in turn affected their ratings of vividness and their confidence in the details. However, it is the former conclusion that is supported by the literature. Singer and Blagov's work (2004) on self-defining memories suggested that the memories that are added to the autobiographical narrative are considered important in some way. Consistent

with Wagenaar's findings (1986) as well, these memories are considered vivid and emotionally relevant, and they are more memorable than other memories.

The findings regarding completeness of narratives are complex. Theme came out to be nonsignificant, but on the other hand, self-reported completeness came out to be significant. To make matters even more complicated, there is a trend with word count (another variable that could evaluate narrative completeness). With a p value of $p = .053$, past narratives had a marginally higher word count than future narratives, suggesting that past narratives are as a whole more lengthy than future narratives. Indeed, if participants chose unique and vivid memories for their past narratives, then it would be safe to say that they have had other opportunities to think over these memories, to recall them and even discuss them. As a result, their recounting of the memories here in this study could feel more complete and participants might have more to say on the topic. It hints at a possible difference in comprehensiveness for past versus future that unfortunately might simply not be showing up in the measures included here.

Overall, there were no definite differences found between past and future narratives in the objective measures: pupil size, word count, duration, context coding, and theme coding. The statistically significant differences only emerged in subjective ratings that the participants completed themselves. This finding might have its basis in the research on life scripts. Perhaps as a society, people are more inclined to construct future events that are more positive, more significant, more generic than past events. As a result, we could expect participants to convey some differences between future and past events in the self-reported ratings of their narratives. However, despite this, no differences arise in the structures of their narratives. Indeed, the way we consciously delineate time into definite periods such as *past* and *future* is not reflected in the

way we use narratives to describe events in those different time frames, and it certainly is not reflected in the cognitive effort we employ as we differentially imagine events occurring in the past versus the future.

This study is indeed novel in a number of ways and reveals new, interesting information about the way we construct events for the past and future and the amount of effort we use to create these representations. However, as with any novel approach, the study also has a fair number of limitations. First and foremost, mental time travel is indeed a mental process. Just as Spreng and Grady (2010) could not control what the participants were truly imagining during the fMRI scanning, we could not completely control for what the participants thought during the eye-tracking component. We are unable to completely confirm, for example, that the participants' minds did not wander as they were writing or that they were consistently picturing the event in their minds while typing. Having narratives the participants wrote themselves does give us the chance to guarantee that participants *wrote* what we asked them to (past versus future) so the current research does take these precautions. However, this is simply an unavoidable struggle that is characteristic of studying mental time travel in general.

Another noteworthy line of inquiry for future studies is to assess both verbally spoken narratives and written narratives. Using the paradigm set up in the present research would facilitate a more direct comparison of the different mediums. The spoken narratives could serve as a control condition with which we could compare and contrast the written narrative. This would offer a way to check and control for the amount of cognitive effort that goes simply into completing the task (typing, reading, etc.) on the eye-tracker and would allow us a way to further isolate the effects of the narrative writing (remembering, imagining, etc.) on cognitive effort.

Because mental time travel has not been studied as extensively using written narratives and eye-tracking, methodology in future studies could be tightened to ensure that the narratives written are about specific events. For example, the current research asked participants to write 4 narratives (2 for past, 2 for future). To create a more robust average score for each variable for each participant, future research could involve asking participants to write at least 3 narratives per time frame. On the other hand, future research could also use cued recall prompts. Viard et al. (2010) for example spoke with their participants' family members to gather information about major events in their lives. Once they had done this, the researchers created key words from the event descriptions to present to the participants. This ensured that participants were primed to discuss a very specific event (their recent birthday, for example). In contrast, the instructions to our study were very open. It allowed participants the opportunity to interpret the task as they wanted. This could potentially have resulted in more variability in the narratives. It is not clear yet how this variability could have influenced the findings. However, because the cued recall requires participants to write about similar events for their narratives, using the cued recall might allow for a more direct comparison of the narratives. For example, researchers would be able to examine the narratives for someone's last birthday and their upcoming birthday. Because the subject matter is the same, it might be easier to make inferences on the structure of the narratives, according to their time frame.

Future directions for this study would include using additional narrative coding schemes. Currently, the narratives in this study were only coded for coherence. As we also asked participants to complete the self-report ratings for each narrative, we did not seek to code the narratives for questions that were covered in those ratings (such as valence, intensity). However, future research could consider adding additional coding schemes as well. Coding schemes such

as mental states, evaluative states, emotional words, and WH could be used and could potentially yield interesting results. In particular, coding for the valence and quantity of emotional words used in the narrative could add valuable information to the question of whether the narratives truly differ by valence. In addition, the narrative sample can even be categorized in a number of different ways. Because participants were allowed to choose which events from their lives they wanted to write about, additional studies could take the opportunity to investigate whether the content, topic, and title of the narratives differed from past to future to determine whether the narratives varied in any other way across past and future.

In conclusion, mental time travel encompasses both past and future thinking together in one movement. That being said, it is still a relatively new concept, and this has many advantages for researchers who are interested in pursuing the topic. For one, the body of research for mental time travel is still growing, and new information is constantly being added. There are plenty of opportunities to conduct novel and exciting studies and paradigms, to ask fascinating questions and learn more about this ability. The present study sought to add to the growing body of research and elucidate how people differentially constructed events for the past and the future. It is critical to see how past and future are interconnected in human minds and how thinking about one could affect the other because it adds to our knowledge of how humans understand time. It was especially interesting to see how our perception and representation of the line between past and future actually runs counter to what might have expected based on the distinctions and subtleties made between past and future time frames. Uncovering more about the process of mental time travel helps shed light on how we as humans think about and organize world around us.

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Table 1.

*Correlations between past narratives (first column) and future narratives (top row). Comparing averages for measures of future narratives with averages for measures of past narratives, * indicating correlations that are significant. Not all correlations were included in discussion for the present paper.*

Measure	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1. Distance	.72*	.03	-.03	.31	-.01	-.19	-.14	-.33	-.23	-.09	-.23	-.06	.02	-.12
2. Uniqueness	.34	.21	-.05	.47*	.28	.14	.21	-.09	-.07	.28	-.26	-.02	-.28	-.21
3. Vividness	.31	.41*	.01	.37	.14	.21	.22	-.01	-.06	-.17	-.08	-.01	-.17	-.10
4. Valence	.04	.27	-.08	.16	-.19	-.55*	-.43*	-.04	.04	.14	-.38	.16	-.21	.40*
5. Arousal	.21	.19	.28	.50*	.28	-.07	.08	.17	.21	.28	-.35	-.29	-.51*	.03
6. Sig Then	-.07	.06	.24	.06	.20	.12	.14	.13	.31	.19	-.20	.13	-.18	-.08
7. Sig Now	.08	.21	.20	.20	.30	.11	.31	.43*	.41*	-.05	-.23	-.07	-.25	-.06
8. Confidence	.21	.27	.10	.29	.11	.21	.20	.02	.02	-.17	.06	-.06	-.12	-.11
9. Completeness	.14	.40*	.04	.40*	.23	.08	.11	-.17	-.02	-.37	.01	-.13	-.42*	.00
10. Context	.12	-.12	-.11	.27	.00	-.35	-.19	.00	-.16	.59*	-.15	-.09	-.13	.06
11. Theme	.02	-.20	-.10	-.02	.12	.48*	.35	-.09	-.08	-.09	.53*	.22	.46*	-.33
12. Word Count	-.10	-.15	-.01	-.14	-.16	-.15	.02	.14	.16	.06	.41*	.94*	.62*	-.12
13. Duration	.11	-.22	.00	-.21	-.12	.06	.07	.10	.13	-.01	.41*	.66*	.96*	-.27
14. Average Pupil Size	.06	.28	-.14	.11	.00	-.23	-.21	.14	.05	-.10	-.44*	-.25	-.29	.99*

Table 2.

Means and Standard Deviations for Task Performance

	Past		**Future**	
Measure	**Mean**	**(*SD*)**	**Mean**	**(*SD*)**
Word Count	298.52	69.27	288.87	69.76
Duration	398988.42	110935.91	387549.17	118845.72

Table 3.

Means and Standard Deviations for Narratives

	Past		**Future**	
Measure	**Mean**	**(*SD*)**	**Mean**	**(*SD*)**
Context	2.39	.59	2.57	.55
Theme	2.39	.58	2.52	.51

Table 4.

Means and Standard Deviations for Pupil Dilation

	Past		**Future**	
Measure	**Mean**	**(*SD*)**	**Mean**	**(*SD*)**
Average Pupil Size	3.14	.38	3.13	.37

Table 5.

*Means and Standard Deviations for Subjective Ratings, * for significant correlations*

	Past		**Future**	
Measure	**Mean**	**(*SD*)**	**Mean**	**(*SD*)**
Distance	2.79	1.44	2.55	1.60
*Uniqueness	7.94	1.30	6.91	1.73
*Vividness	7.80	1.40	6.19	1.18
Valence	6.06	2.39	6.83	1.39
Arousal	7.04	1.41	7.00	1.31
Significance of the event as it occurred	7.11	1.93	6.94	1.48
Significance of the event now	6.04	1.76	6.74	1.69
*Confidence	7.93	1.05	6.07	1.50
*Completeness	7.20	1.26	5.74	1.57

Figure 1.

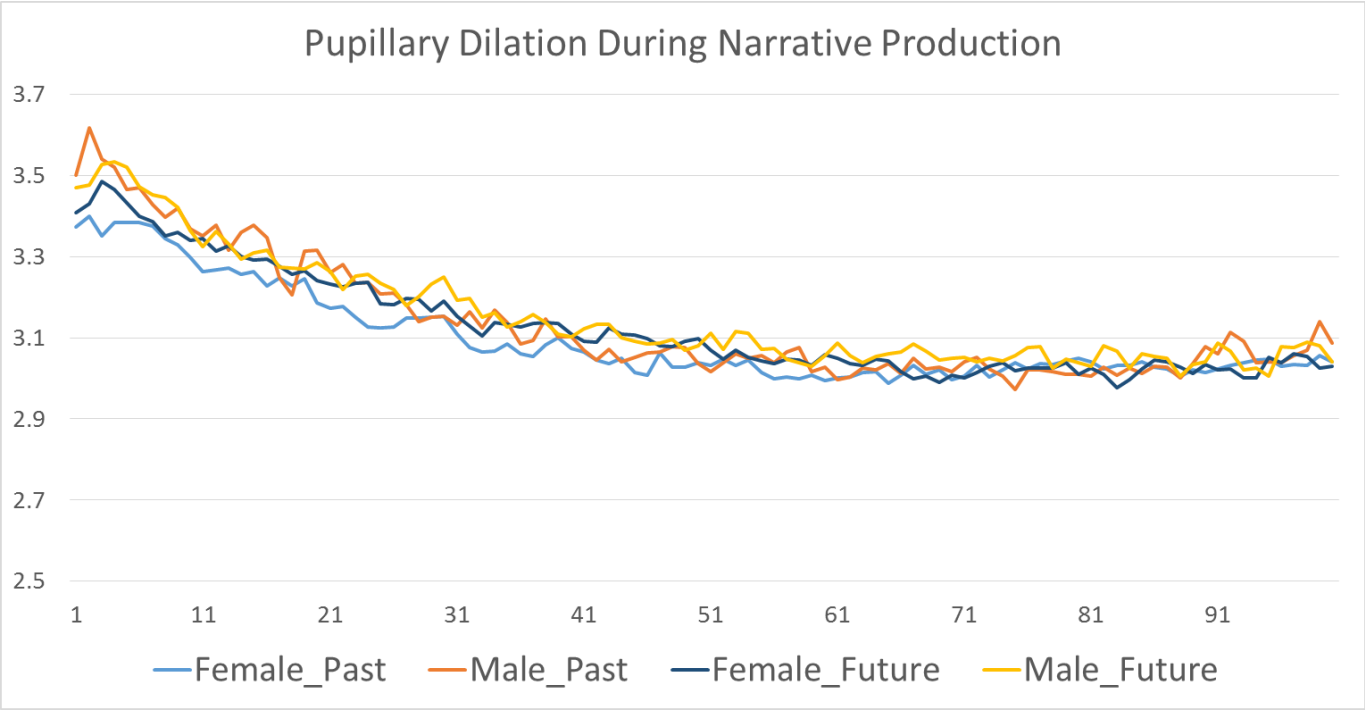
Pupillary Dilation During Narrative Production
3.7
3.5
3.3
3.1
2.9
2.7
2.5
1
11
21
31
41
51
61
71
81
91
Female_Past
Male_Past
Female_Future
Male_Future

Figure 1.

Pupil Dilation across Duration of Narrative Typing. The bottom axis reflects the duration of the narrative typing, reflected as a percentage out of 100%. The y-axis covers the pupil dilation, its diameter by millimeter. The blue lines represent female narratives, and the orange and yellow lines represent male narratives. There is no difference in dilation when broken down both by time frame and by gender.

Appendix A.

Self-report ratings.

Ratings from 1 (lowest) to 9 (highest)

Distance. How many months in the past/future is this event? _____

Uniqueness. How rarely does this event occur?

1 (often)	2	3 (somewhat often)	4	5 (occasionally)	6	7 (rarely)	8	9 (very rarely)

Vividness. How vividly do you recall the details of the memory?

1 (very unclear)	2	3 (unclear)	4	5 (neither unclear or clear)	6	7 (clear)	8	9 (very clear)

Valence. How positive or negative was this event?

1 (very negative)	2	3 (negative)	4	5 (neutral)	6	7 (positive)	8	9 (very positive)

Arousal. How excited/nervous or bored/calm did you feel at the time of the event?

1 (very bored/calm)	2	3 (bored/calm)	4	5 (not bored/calm)	6	7 (excited or nervous)	8	9 (very excited or nervous)

Significance

How significant was this event at the time of its occurrence?

1 (not at all important)	2	3 (slightly important)	4	5 (fairly important)	6	7 (quite important)	8	9 (very important)

How significant is this event to you now?

1 (not at all important)	2	3 (slightly important)	4	5 (fairly important)	6	7 (quite important)	8	9 (very important)

Confidence of details. How confident are you about the details of the event?

1 (very unsure)	2	3 (unsure)	4	5 (neither sure or unsure)	6	7 (sure)	8	9 (very sure)

Completeness. How complete or incomplete is your memory?

1 (very few details)	2	3 (few details)	4	5 (some details)	6	7 (may details)	8	9 (all details)

Point of view. Is your recollection of the event as if you experience it (1st person) or as if you were watching the event happen (3rd person)? _____

Appendix B.

Modified coding scheme; an example of criteria and coding (Reese et al., 2011).

Criteria	Context: Orienting the narrative in time and space	Theme: Maintaining and elaborating on topic
Level 0	No information about time or location is provided.	The narrative is substantially off topic and/or characterized by multiple digressions that make the topic difficult to identify. No attempt to repair digressions.
Level 1	Partial information is provided; there is mention of time or location at any level of specificity.	A topic is identifiable and most of the statements relate to it. The narrative may include minimal development of the topic through causal linkages, or personal evaluations and reactions, or elaborations of actions.
Level 2	Both time and place are mentioned but no more than one dimension is specific.	The narrative substantially develops the topic. Several instances of causal linkages, and/or interpretations, and/or elaborations of previously reported actions are included.
Level 3	Both time and place are mentioned and both are specific.	Narrative includes all the above and a resolution to the story, or links to other autobiographical experiences including future occurrences, or self-concept or identity. Resolution brings closure and provides new information.

Appendix C.

Instructions for narrative typing for eye-tracker.

For this study, we would like you to write about personally-experienced events that happened to you in the **past 3-6 months** or that you anticipate happening to you in the **next 3-6 months**. You will be writing about 4 events total. For each event, you will see one of the two prompts – "past" or "future" for a limited amount of time before ach writing activity, specifying which time frame you should be writing for. The even you choose to write about must be specific and unique, happening at one place at one time and lasting no more than one day. It should not be an everyday event such as brushing your teeth in the morning (unless something unique happened).

All information you provide will be kept confidential and only the researchers will have access to the data. If you feel uncomfortable sharing some personal memories with us, please feel free to choose different events to write about. But please be as detailed possible in your writing. You should write enough to fill roughly the entire page of the word document that appears after the prompt but please limited it to ONLY one page. Do not worry about spelling, sentence structure, or grammar as these factors will not be evaluated. On the keyboard, you can use any letter, number, symbol, and arrow keys as well as the spare bar and the enter key. However, the mouse and function keys (Home, End, and Page Up/Page Down) should not be used. If you need to make corrections, please use the arrow keys and backspace in place of the mouse. Please press the Esc key when you have finished you writing.

We will have a practice session first. You'll be able to ask me any questions you have about the instructions during this practice writing.