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Sleep Quality and the Subjective Experience of Autobiographical Memory: Differential Associations by Memory Valence and Temporality

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Summary: The primary goal of the present research was to examine associations between sleep quality and the subjective experience of autobiographical events. In an online study, 141 university students reported on past events that varied by valence (positive or negative) and temporality (most significant or from the previous 2 weeks); they also completed measures of sleep quality and depression. Relative to participants with good sleep quality, participants with poor sleep quality thought more about their negative experiences, reported negative events that occurred more frequently, and used more negative emotion words when describing recent negative events. In some instances, depressive symptoms mediated the relation between sleep quality and elements of autobiographical reports. Future experimental work should examine the directionality of these effects, with the ultimate goal of improving sleep quality, mental health, and the manner in which individuals discuss and make meaning of their negative life events. Copyright © 2017 John Wiley & Sons, Ltd.

Memory for emotional information is enhanced by sleep. The benefits of sleep are evident in numerous laboratory studies demonstrating that sleep after exposure to emotional and neutral stimuli preferentially facilitates memory for emotional information (narratives: Wagner, Gais, & Born, 2001; Wagner, Hallschmid, Rasch, & Born, 2006; pictures: Hu, Stylos-Allan, & Walker, 2006; scenes: Payne, Chambers, & Kensinger, 2012; Payne, Stickgold, Swanberg, & Kensinger, 2008; Payne & Kensinger, 2011). Relatively few studies, however, have examined associations between sleep quality and the emotional content of autobiographical memories or memories for significant life events that are central to the formation of a personal history and serve to define the self (Williams & Conway, 2009). The documentation of relations between sleep and the subjective experience of autobiographical events may have important implications for psychological well-being. Specifically, sleep quality has been associated with indices of depression (Lund, Reider, Whiting, & Prichard, 2010; Milojevich & Lukowski, 2016; Pilcher, Ginter, & Sadowsky, 1997; Pilcher & Ott, 1998; Stein, Belik, Jacobi, & Sareen, 2008; Tsuno, Besset, & Ritchie, 2005), and depressed participants use more negative emotion words in their narratives relative to non-depressed participants (Rude, Gortner, & Pennebaker, 2004). As such, participant sleep quality, and depression, may be independent or co-contributors to variability in autobiographical memory reports. The present research was conducted to determine (1) whether sleep quality, self-reported by participants using the Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), was associated with the subjective experience of autobiographical events and (b) whether any of the demonstrated associations were mediated by depressive symptoms.

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Understanding the association between sleep quality and the content of autobiographical memories is important in that sleep may be associated with the manner in which individuals make meaning of and integrate past events into their personal histories. Whereas sleep quality is commonly reported subjectively (Buysse et al., 1989; Krystal & Edinger, 2008), previous research has suggested that sleep more generally—and dreaming in particular—promotes the consolidation of autobiographical information. For example, the model proposed by Horton and Malinowski (2015) posits that the episodic content of autobiographical memory becomes fragmented and decontextualized during sleep (refer also to Payne, 2010; Payne & Nadel, 2004). Multiple factors contribute to which specific daytime experiences are replayed in dreams, including emotional intensity (Malinowski & Horton, 2015), stress (including aspects of negative affect and increased physiological arousal), novelty, and personal relevance (Malinowski & Horton, 2014). This fragmented information is then selectively reproduced and paired with other weakly associated semantic content through the process of hyperassociativity, ultimately rendering the reproduced content less context-bound and more easily accessible (Horton & Malinowski, 2015).

Indeed, previous research has indicated that sleep has a lasting impact on the accuracy of autobiographical memory. In one study, Aly and Moscovitch (2010) examined the accuracy of participant report of personal events (a recent phone call or information about recent media consumption) both before and after a 12-h delay that did or did not include a period of sleep. Participants who slept after initially reporting on the events recalled more information about their previous experiences relative to participants who remained awake. More recently, Murre, Kristo, and Janssen (2014) examined associations between participant-reported sleep quality and the accuracy of autobiographical memory over short (2–15 days) or extended (30–46 days) delays. The results revealed a significant interaction between sleep quality and delay length, such that participants with good sleep quality remembered more details about their narratives

over lengthy delays relative to participants with poor sleep quality. Taken together, these findings indicate that sleep is an important factor in the recall of personally salient information.

Overnight sleep has also been associated with recovery from negative emotional information (for a review, refer to Vandekerckhove & Cluydts, 2010). For example, some work suggests that the act of dreaming about negative experiences may contribute to enhanced psychological well-being (Cartwright, 1991; Cartwright, Agargun, Kirkby, & Friedman, 2006). In a study of depressed adults who were experiencing divorce, those who reported dreaming about their ex-spouse after the dissolution of the relationship experienced less depression one year later and demonstrated better adjustment post-divorce relative to individuals who did not dream about their ex-partners (Cartwright, 1991). These findings suggest that depressed individuals may work through their negative emotions by processing negative information while dreaming. More recent research has confirmed the finding that better developed dreams are associated with enhanced psychological well-being in depressed adults undergoing divorces relative to dreams that are less well developed (i.e., those relatively lacking in imagery or plot lines). These data suggest that the replay of certain negative information during sleep may serve to downregulate negative emotion during wake (Cartwright et al., 2006).

Examining associations between sleep quality and autobiographical memory may be complicated by relations among sleep and mental health, on one hand, and relations between mental health and the recall of emotional experiences, on the other. When considering associations between sleep and mental health, previous research has indicated that depressive symptoms and poor sleep quality co-occur in university students. Lund et al. (2010) found that students with poor sleep quality reported higher levels of anger, confusion, depression, fatigue, and tension relative to students with good sleep quality. In another study, poor sleep quality was correlated with increased depression, anger, tension, and negative affect among university students (Pilcher et al., 1997). Even among university students with generally healthy sleep habits, poorer sleep quality has been associated with increased reports of depression (Milojevich & Lukowski, 2016).

Similarly, the recall of emotional information has been associated with participant depression. In one study, Rude et al. (2004) found that depressed college students used more negative emotion words in a written essay regarding their thoughts and feelings about starting college relative to students without depression. Depression and depressed mood have also been associated with a negative memory bias for negative information, including past personal events, suggesting that information that is congruent with an individual's emotional state may be more readily accessible (Blaney, 1986; Clark & Teasdale, 1982; Snyder & White, 1982; Teasdale, 1983). In addition, depressed individuals commonly report overgeneral autobiographical memories, or memories that are less specific and event-focused relative to those provided by non-depressed individuals (Gibbs & Rude, 2004; Moore, Watts, & Williams, 1998). Recall of overgeneral information may serve to psychologically protect individuals with depression from re-experiencing painful past events. Because memories are retrieved in a hierarchical manner, with general categories of past experiences being accessed before more specific content (Reiser, Black, & Abelson, 1985), depressed individuals may abort their mental search for specific episodic information at the category level (Williams, 1996). Together, these findings suggest that associations between participant sleep quality and report of autobiographical experiences may be mediated by depressive symptoms, which are often co-morbid in university students (Eisenberg, Gollust, Golberstein, & Hefner, 2007).

Given the relative lack of focus on associations between sleep quality and the subjective experience of autobiographical memory, the primary goal of the present study was to examine associations between participant-reported sleep quality and the manner in which young adults reported on autobiographical events that varied by valence (positive or negative) and temporality (significant or recent, where significant events were the most meaningful experiences in the participant's life and recent events occurred within the 2 weeks prior to participation). Dependent measures obtained from the reported narratives concerned (1) ratings of the frequency with which participants thought and talked about the reported events, the frequency with which they experienced the same or similar events in the past month, affect associated with the event, the vividness or vagueness of the memory, and their confidence that the reported memory was their own and was not due to pictures or conversations with others, and (2) the total number of words included in the narrative as well as the use of internal states language, particularly the percent of words pertaining to negative emotion (such as sad, hate, and cry) and cognitive mechanisms (such as think, resolve, and believe).

Based on previous work demonstrating associations between sleep quality and the accuracy of recall memories (Aly & Moscovitch, 2010; Murre et al., 2014), we predicted that participants with good sleep quality would report events that occurred less frequently, and were therefore more unique, than participants with poor sleep quality. We also expected that participants with good sleep quality would be more confident that their memories were not based on pictures or conversations with others relative to participants with poor sleep quality. Work conducted on the factors associated with the replay of daytime experiences during dreaming (Malinowski & Horton, 2014) led to our prediction that poor sleep quality would be associated with increased focus on the negative aspects of events. In particular, we expected that participants with reduced sleep quality would spend more time thinking about negative events from the past and that they would use a greater percentage of negative emotion words when describing past negative experiences relative to individuals with good sleep quality. We also expected that participants with good sleep quality would use a greater percentage of cognitive mechanism words when describing negative events from the past relative to individuals with poor sleep quality, indicating an increased tendency toward making sense of and integrating these experiences into their autobiography. When these predictions were realized, we anticipated that the demonstrated associations between sleep quality and the content of autobiographical memories would

be more apparent for recent relative to significant memories, given the temporal proximity between the reports of sleep quality and memory for recent autobiographical events. When significant associations were found between sleep quality and dependent measures obtained from the reported narratives, we then examined whether participant depression mediated the obtained relation or whether sleep quality was directly responsible for the effect in question. Because this last study aim was primarily exploratory in nature, we did not make specific predictions as to which outcomes would be explained by the mediating influence of depression.

METHOD

Participants

Three hundred eighty-seven undergraduate students (317 females) were recruited to participate in an online study through the undergraduate participant pool maintained by a large public university on the west coast. The students were enrolled in psychology courses through which they could receive extra course credit for participating in research. The data from 137 participants were excluded due to incomplete data (77 participants did not provide narratives that conformed to the provided prompt, 56 participants did not complete the second session, and 7 participants did not respond to all of the questions necessary for scoring the sleep questionnaire); the data from 75 participants were excluded due to procedural errors (66 participants were sent questionnaires that did not include all of the necessary questions, 4 were sent incorrect questionnaires, and 6 were allowed too much time to complete the surveys), and the data from 27 participants were excluded for multiple reasons. The involvement of three additional students was terminated based on consultation with the Institutional Review Board after the students reported suicidal thoughts on the depression questionnaire.

The final sample includes data from 141 participants (124 females; mean age = 20.53 years, range = 18–52 years). Fifty-four percent of participants indicated that they were of Asian descent, 29% were Caucasian, 4% were of mixed race, and less than 1% of participants identified as Native Hawaiian or Pacific Islander; 13% of participants did not provide race information. Twenty-three per cent of participants identified as Hispanic, including all of the participants who did not provide race information.

Materials

In addition to providing demographic information and reporting on their autobiographical memories, participants completed questionnaires about their sleep quality, and depression; other mental health questionnaires were also included but are not the focus of the present report.

Autobiographical memory

At the first session, participants were randomly assigned to write about either (1) a negative and a positive event that occurred within the past 2 weeks or (2) their most significant positive and negative memories; they reported on the other memory type at the second session (this manipulation was imposed to reduce the amount of time required to complete each set of questionnaires). Participants were asked to report on events that occurred once (or very infrequently) and happened in one place at one time. They were asked to report as many details as they could, including details such as who was there, what they were doing, where they were, why they were doing what they were doing, and how they were feeling as the event occurred. After providing the details of the requested memory in a text box, participants indicated the date on which the memory occurred and rated the event on a number of dimensions. They reported the number of times they experienced the event, how often they thought about the event, and how often they talked about the event with others on a scale ranging from 1 (never) to 5 (many times). They also reported on the valence of the event (−3 as very negative to 3 as very positive), how vivid or vague their memory of the event was (−3 as very vague to 3 as very vivid), and how confident they were that the reported memory was based on their own experience and was not due to pictures or conversations with others (−3 as not very confident to 3 as very confident). Participants always reported on their negative memories before their positive memories.

Sleep quality

The PSQI (Buysse et al., 1989) is a 19-item measure that assesses indices of subjective sleep quality over the past month, including participant reports of bed time, rise time, nighttime sleep duration, the frequency of sleep disruptions, perceived sleep quality, and enthusiasm for completing daytime activities, among others. The reported values were reduced to yield global sleep quality scores ranging from 0 to 21 (higher scores indicate poorer sleep quality). In previous research, composite scores greater than 5 demonstrated adequate sensitivity and specificity in differentiating the sleep quality of good (healthy controls) and poor (participants with major depressive disorder and those with certain sleep disorders) sleepers (Buysse et al., 1989). We classified participants using the same criteria, such that participants with global sleep quality scores less than or equal to 5 had good sleep quality (n = 75), whereas those with global sleep quality scores greater than 5 had poor sleep quality (n = 66). This measure is the gold standard for assessing subjective sleep quality and has demonstrated adequate internal homogeneity and test–retest reliability ($\propto$ = .63 in the current study).[1]

[1] Global sleep quality on the PSQI was computed excluding responses to the free-recall question associated with nighttime sleep disruptions. We excluded these responses because a subset of the participants (n = 136) was sent inventories that did not include this question. Because all questions on the PSQI must be answered for the inventory to be scored, all inventories were scored omitting the response to this question. For those participants who received the complete questionnaire and provided complete data (n = 175), measures of continuous global sleep quality were highly correlated when global sleep quality was computed including and excluding the item in question (r = .99, p = .0001). Categorical sleep quality was also consistent across inventories, such that all categorical sleep quality assignments were the same when the one optional fill-in item was included or excluded (n = 92 participants with good sleep quality and n = 83 participants with poor sleep quality). Taken together, these data suggest that elimination of the one optional fill-in item on the PSQI did not measurably affect participant ratings of global sleep quality.

Depression

Depressive symptoms were assessed using the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996). Participants were presented with 21 items that assessed feelings associated with depressive symptoms such as sadness, pessimism, and loss of pleasure over the previous 2 weeks. Participants rated the extent to which they identified with the description on 4-point scales that were summed to yield a composite score ranging from 0 to 63 (higher scores indicate more severe depressive symptoms). The BDI-II has high internal consistency and test–retest reliability ($\propto$ = .93 in the current study).

Procedure

The study procedures were approved by the university Institutional Review Board. A waiver of written informed consent was granted such that participants indicated their willingness to participate by clicking forward after reading an electronic study information sheet. Participants were also presented with information about the services offered by the university counseling center as some of the included questions were somewhat sensitive in nature.

Students initially indicated their interest in participating by responding to an electronic advertisement on the website maintained by the Social Sciences Human Subject Pool. A research assistant emailed the student a unique link to the first session questionnaire along with a study-specific identification number. The links included in the emails were active for 2 days from the time the email was sent.

At the first session, participants provided information about either negative and positive memories from the past 2 weeks or their most significant negative and positive memories. They also completed questionnaires inquiring about demographic information, depression, and other aspects of mental health. After a delay of approximately 1 week (mean = 7 days, range = 6–8 days), a research assistant emailed the student a unique link to the second session questionnaire along with his or her study-specific identification number. The links included in the emails were active for 2 days from the time the email was sent. Participants completed the PSQI before providing information about either negative and positive memories from the past 2 weeks or their most significant negative and positive memories (whichever memories were not reported on the first session questionnaire). The PSQI (Buysse et al., 1989) was included at the second session so that participant-reported sleep habits over the previous 30 days were relevant when considering the memories reported at the first and second sessions. Participants reported on these new memories in the same manner as they did on the first session questionnaire.

Data reduction

Narratives were reviewed to ensure that each report referenced one specific event that was of the appropriate valence (positive or negative). Narratives that did not meet the criteria were excluded from analysis. Acceptable narratives were cleaned in preparation for content assessment by the Linguistic Inquiry and Word Count program (LIWC2007; Pennebaker, Booth, & Francis, 2007), text analysis software that provides the percent of words in each narrative that correspond to pre-defined categories (such as negative emotion, cognitive mechanisms, etc.). Narratives were cleaned as indicated in the accompanying manual. In particular, spelling and grammar errors were corrected, and words that would be coded incorrectly based on the context in which they were used were marked for exclusion from analysis (for example, without manual correction, LIWC2007 would incorrectly categorize the word 'like' as a positive emotion word in the sentence, "I felt like my mind would be so preoccupied with housing…"). In addition to these corrections, abbreviations were expanded, and digits were changed from numerical to word format. Cleaned narratives were reviewed by a second research assistant to ensure accuracy and then were reduced by LIWC2007 to determine the total number of words included in the narrative as well as the percent of negative emotion words (e.g., sad, hate, cry) and cognitive process words (e.g., think, resolve, believe). Narratives were reduced separately by valence (positive and negative) and temporality (significant or recent).

RESULTS

Preliminary analyses were conducted to examine whether there was differential attrition based on participant demographics. Chi-squared analyses revealed that included and excluded participants did not differ on race (Asian, Caucasian, or other): χ^2 (2, N = 335) = 5.01, p = .082, ethnicity (Hispanic or non-Hispanic): χ^2 (1, N = 379) = .29, p = .589, or year in school (freshman, sophomore, junior, or senior): χ^2 (3, N = 376) = 2.80, p = .423. Between-subjects ANOVAs revealed that included and excluded participants also did not differ on sleep quality (n = 220): F(1, 218) = .77, p = .383 or depressive symptoms (n = 363): F(1, 361) = .07, p = .790. A significant group difference was found by participant sex: χ^2 (1, N = 376) = 5.53, p = .019. Examination of the data from the chi-squared table indicated that a greater percentage of females (40%) were excluded from the sample relative to males (25%). Given the differential distribution of males and females in the final sample as well as previous research documenting differences in the manner in which males and females report on past events (Bauer, Stennes, & Haight, 2003; Bohanek & Fivush, 2010), participant sex was included as a categorical covariate (0 = males or 1 = females) in the following analyses.

Partial correlations controlling for participant sex were conducted to examine whether the order in which participants reported on their memories (0 = recent memories first or 1 = significant memories first) was associated with participant ratings and the content of the reported events (55% of the participants reported on their recent memories first). None of the examined associations were significant. As such, the following analyses are presented across order.

We also conducted a preliminary 2 (temporality: significant and recent) × 2 (valence: positive and negative) repeated measures ANCOVA controlling for participant sex to determine whether significant positive and negative events occurred in the more distant past relative to recent positive and negative events. The results revealed significant main

effects of temporality: $F(1, 133) = 21.59$, $p = .0001$, $r = .37$, and valence: $F(1, 133) = 9.37$, $p = .003$, $r = .26$, that were further qualified by an interaction with one another: $F(1, 133) = 9.34$, $p = .003$, $r = .26$. Follow-up pairwise comparisons indicated that for both positive and negative events, significant events occurred in the more distant past relative to recent events (ps = .0001). Follow-up pairwise comparisons conducted by temporality revealed that significant negative events occurred in the more distant past (1807.20 ± 189.44 days) relative to significant positive events (1025.48 ± 123.66 days) ($p = .0001$); differences were not found for recent events (negative: 7.63 ± .48 days; positive: 6.42 ± .68 days). These effects were not qualified by sleep quality.

In the primary analyses reported in the succeeding texts, significant effects are presented when $p < .05$. Given that the primary focus of the conducted research was on associations between sleep quality and autobiographical memory, only results including sleep quality as a factor are presented (other findings independent of sleep quality may be obtained from the first author). Significant main effects and interactions are presented in the succeeding texts, although the results are only interpreted within the context of the highest order interaction.

Sleep quality

Descriptive statistics and group differences concerning participant sleep quality are presented in Table 1. Between-subjects ANOVAs and chi-squared analyses were conducted to determine whether participants with good or poor global sleep quality differed on individual contributors to the scale score. The results revealed that participants with good sleep quality reported significantly earlier bed times, shorter sleep latencies, better sleep efficiency, greater nighttime sleep duration, and less frequent nighttime sleep disruptions relative to participants with poor sleep quality. Participants with good sleep quality also reported experiencing better sleep quality on one self-report item (not a composite), less difficulty staying awake during the day, and more enthusiasm for daytime activities relative to those with poor sleep quality.

Associations between sleep quality and autobiographical memory

Narrative ratings

We first considered whether participant sleep quality (good or poor) was associated with participant ratings of reported narratives in combination with factors pertaining to memory valence (positive and negative) and temporality (significant and recent) controlling for participant sex. We conducted six mixed ANCOVAs on dependent variables pertaining to the frequency with which participants thought about the reported events, the frequency with which participants talked about the reported events, the frequency with which they experienced the same or similar events in the past month, affect associated with the event, the vividness or vagueness of the memory, and confidence that the reported memory was not based on pictures or conversations with others.

A significant sleep quality by valence interaction was found when considering the frequency with which participants thought about past events: $F(1, 136) = 4.47$, $p = .036$, $r = .18$. These data are shown in Figure 1. Pairwise comparisons conducted by sleep quality revealed that participants with poor sleep quality thought more about their negative memories relative to their positive memories ($p = .001$); differences were not found by valence when considering participants with good sleep quality ($p = .91$).

Table 1. Descriptive information and group differences on the Pittsburgh Sleep Quality Index

	Sleep quality			Between-group differences		
	Overall ($n = 144$)	Good ($n = 75$)	Poor ($n = 66$)	Statistic	p value	r effect size
Rise time	8:34 (:08)	8:38 (:11)	8:29 (:11)	$F = .34$	.563	.05
Bed time*	12:56 (:08)	12:37 (:10)	1:20 (:11)	$F = 8.12$	.005	.24
Sleep latency (minutes)*	24.44 (3.46)	14.14 (4.59)	36.13 (4.89)	$F = 10.74$	.001	.27
Sleep efficiency*	90.88 (.84)	93.71 (1.10)	87.66 (1.17)	$F = 14.29$	.0001	.31
Sleep duration*	6.92 (.10)	7.50 (.11)	6.27 (.12)	$F = 55.76$	.0001	.54
Sleep disruptions*	6.72 (.39)	4.80 (.47)	8.91 (.50)	$F = 35.51$	.0001	.45
Reported sleep quality percent reporting fairly good or very good sleep quality over the past month)*	77%	97%	55%	$FET = .0001$	—	—
Sleep medication (percent reporting no use during the past month)	96%	99%	92%	$FET = .098$	—	—
Staying awake (percent reporting no problems during the past month)*	72%	85%	56%	$\chi^2 = 14.80$	.0001	.32
Enthusiasm (percent reporting no problems during the past month)*	26%	41%	9%	$\chi^2 = 18.86$	.0001	.37
Global sleep quality*	5.47 (.22)	3.53 (.20)	7.67 (.21)	$F = 210.43$	.0001	.78

Note: Means and standard deviations are reported for continuous variables; percents are reported for categorical variables. The sleep efficiency data for 12 participants were truncated to 100% given discrepancies with reporting wake and bed times. Fisher's exact tests (FETs) were conducted as indicated due to small cell sizes. Significant group differences are indicated (*) when $p < .05$.

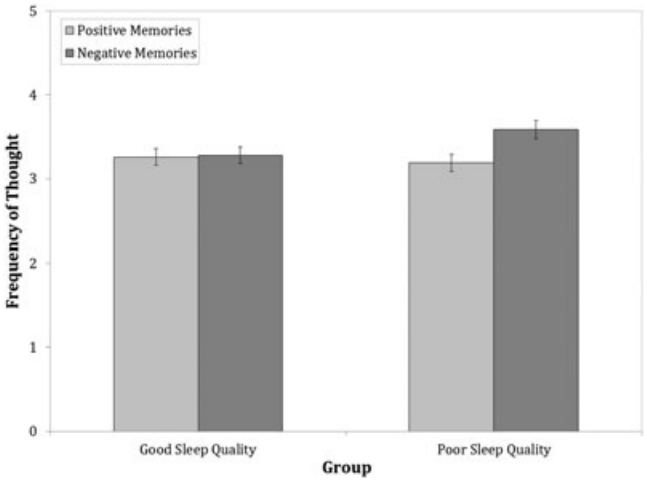

Figure 1. Sleep quality × valence interaction for participant ratings pertaining to the frequency with which they thought about the reported events. Participants with poor sleep quality thought more about negative events relative to positive events; they also thought more about their negative events relative to participants with good sleep quality

Pairwise comparisons conducted by valence revealed that participants with poor sleep quality also thought more about their negative memories relative to participants with good sleep quality (p = .041); group differences were not found when considering positive memories (p = .614).

When considering the frequency with which participants experienced the reported events, a main effect of sleep quality, $F(1, 136) = 6.95$, $p = .008$, $r = .22$, was qualified by an interaction with valence: $F(1, 136) = 4.34$, $p = .039$, $r = 18$. These data are shown in Figure 2. Pairwise comparisons conducted by sleep quality revealed that participants with good sleep quality experienced their positive events more frequently than their negative events (p = .018); differences by valence were not found for participants with poor sleep quality. Pairwise comparisons conducted by valence revealed that participants with poor sleep quality experienced their negative events more frequently than participants with good sleep quality (p = .0001); group differences were not found when considering positive events.

When considering participant-reported confidence about whether their memories were influenced by pictures or conversations with others, the main effect of sleep quality, $F(1, 135) = 7.71$, $p = .017$, $r = .23$, was qualified by an interaction with valence: $F(1, 135) = 4.28$, $p = .040$, $r = .18$. These data are shown in Figure 3. Pairwise comparisons conducted by sleep quality revealed no difference in confidence ratings by group for positive or negative events. Pairwise comparisons conducted by valence revealed that participants with good sleep quality were more confident that their positive memories were their own relative to participants with poor sleep quality (p = .001); group differences were not observed for negative events.

Significant effects involving sleep quality were not found on variables pertaining to the frequency with which participants talked about the reported events with others, the affect associated with the reported events, or the vividness or vagueness of their memory for the reported events.

Internal states language

We then considered whether participant sleep quality (good or poor) was associated with the use of internal states language in combination with factors pertaining to memory valence (positive and negative) and temporality (significant and recent). We conducted four mixed ANOVAs on dependent variables obtained from LIWC2007 (Pennebaker et al., 2007) concerning the number of words used in the narrative and the percent of words pertaining to positive emotion, negative emotion, and cognitive mechanisms.

When considering negative emotion, the three-way interaction among valence, temporality, and sleep quality was statistically reliable: $F(1, 138) = 4.54$, $p = .035$, $r = .18$. Follow-up simple effect analyses were conducted by each of the included independent variables but are only presented by

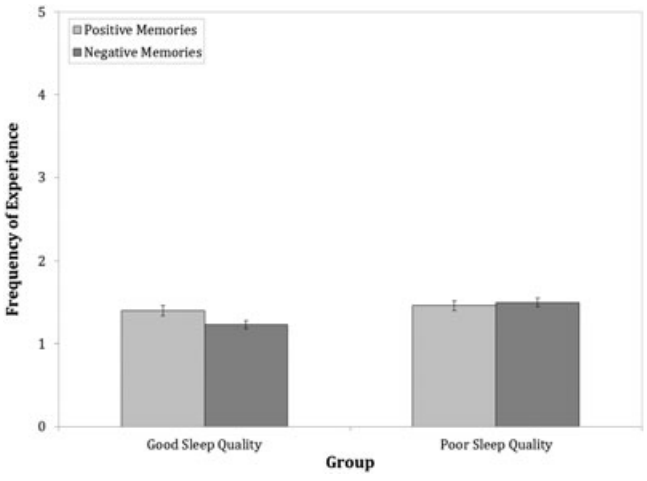

Figure 2. Sleep quality × valence interaction for participant ratings pertaining to the frequency with which they experienced the reported events. Participants with good sleep quality experienced the reported positive events more frequently than the reported negative events; in addition, participants with poor sleep quality experienced their reported negative events more frequently than participants with good sleep quality

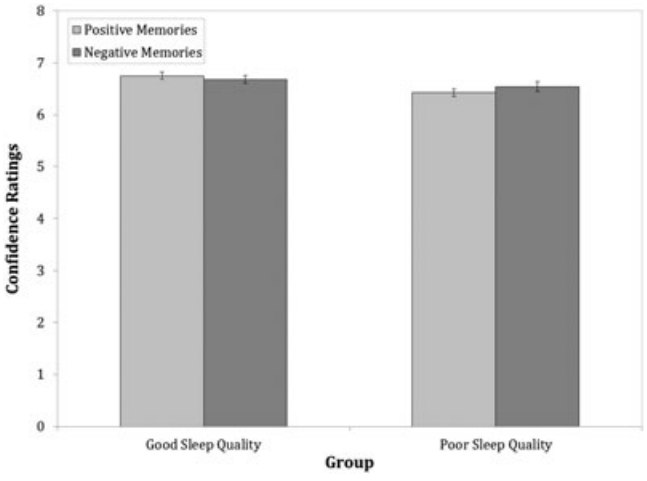

Figure 3. Sleep quality × valence interaction for participant ratings pertaining to participants' confidence that the reported memories were their own and did not result from pictures or conversations with others. Participants with good sleep quality were more confident that their positive memories were their own relative to participants with poor sleep quality; differences were not found by valence for participants in either group

temporality given our prediction that sleep quality would be preferentially associated with memories from the recent relative to the distant past (information on the other analyses is available from the last author). These data are shown in Figure 4. Significant findings were not obtained when considering significant events (panel A). When considering recent events (panel B), main effects of valence, $F(1, 138) = 20.99$, $p = .0001$, $r = .36$, and sleep quality, $F(1, 138) = 5.24$, $p = .024$, $r = .19$, were further qualified by an interaction with one another: $F(1, 138) = 3.93$, $p = .049$, $r = .17$. Follow-up pairwise comparisons conducted by sleep quality revealed that participants in both groups used a greater percentage of negative emotion words in narratives of recent negative relative to recent positive events (ps = .0001). Follow-up pairwise comparisons conducted by valence indicated that participants with poor sleep quality used a greater percentage of negative emotion words in narratives of recent negative events relative to participants with good sleep quality ($p = .021$); group differences were not found when considering narratives of recent positive events ($p = .580$).

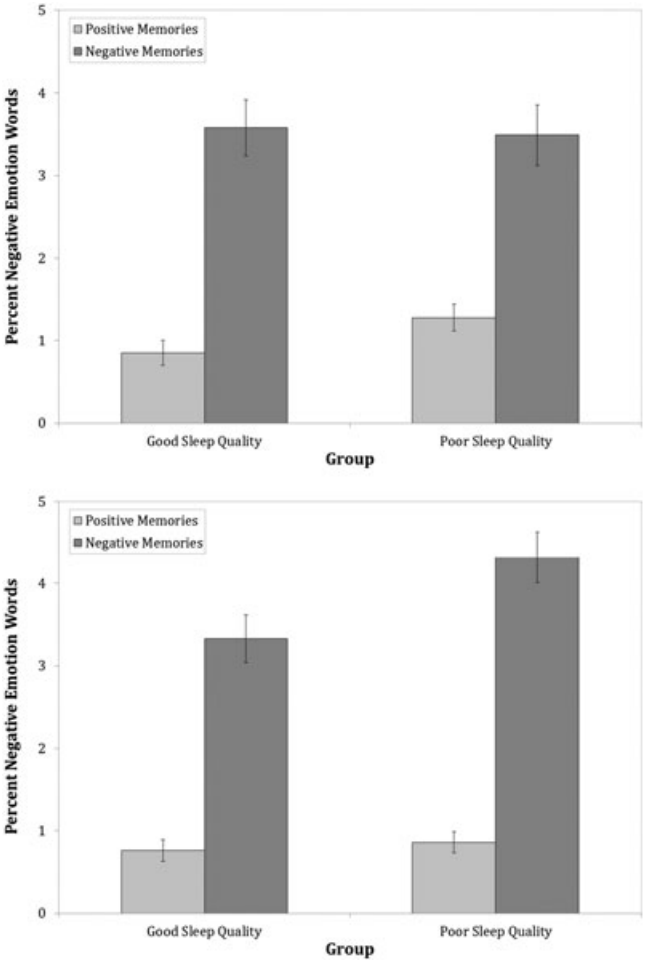

Figure 4. Sleep quality × valence interaction for the use of negative emotion words in significant (panel A) and recent (panel B) events. Differences were not found by group or valence when considering significant events. For recent events, participants in both groups used a greater percentage of negative emotion words when describing negative events relative to positive events; participants with poor sleep quality also used a greater percentage of negative emotion words when describing negative events relative to participants with good sleep quality

Significant effects involving sleep quality were not found when examining the number of words used in the reported narratives or the use of positive emotion and cognitive process words.

The mediating role of depression

Given the documented associations between reduced sleep quality and depression (Lund et al., 2010; Milojevich & Lukowski, 2016; Pilcher et al., 1997; Pilcher & Ott, 1998; Stein et al., 2008; Tsuno et al., 2005), we conducted a one-way between-subjects ANCOVA controlling for participant sex by sleep quality (good or poor) to determine whether participants differed on self-reported depressive symptoms on the BDI-II (Beck et al., 1996). The results indicated that participants with poor sleep quality (14.12 ± 1.13) had higher depression scores relative to those with good sleep quality (7.64 ± 1.08): $F(1, 133) = 17.22$, $p = .0001$, $r = .34$. Based on the classification criteria reported in Beck et al. (1996), 68% of participants were minimally depressed (total scores ranging from 0 to 13), 16% were mildly depressed (total scores from 14 to 19), 10% were moderately depressed (total scores from 20 to 28), and 5% were severely depressed (total scores from 29 to 63).

We conducted mediation analyses to examine whether variability in depression mediated the relation between participant sleep quality and aspects of autobiographical memory after controlling for participant sex (0 = males or 1 = females) (Figure 5). Mediation analyses were conducted on the variables that were significantly associated with sleep quality as reported in the ANCOVAs described previously for those participants who had complete BDI-II questionnaires ($n = 136$). Analyses were only conducted on variables that differed by sleep quality given (1) our interest in understanding whether depression explained the association between sleep quality and autobiographical memory and (2) in order to reduce the likelihood of type I errors obtained by conducting too many statistical tests. Mediation analyses were conducted using the regression-based approach described in Hayes (2013), such that mediation occurred when bias-corrected bootstrap confidence intervals ($k = 10{,}000$ resamples) did not include zero.

Two of the tested mediation models were significant: one concerning frequency of thought and another concerning the percent of negative emotion words used when describing significant positive events. In the former, global sleep quality was positively associated with depressive symptoms ($a = 1.73$, $p = .0001$), and depressive symptoms ($b = .03$,

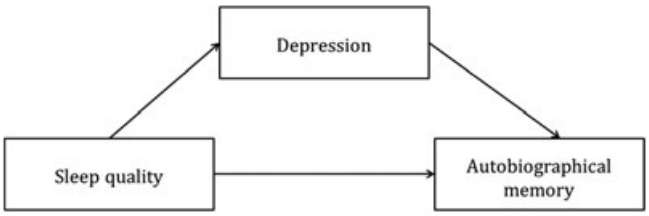

Figure 5. Mediation analyses were conducted to examine whether depression mediated the association between continuous sleep quality and autobiographical memory for those variables that were significantly associated with sleep quality as reported in ANOVAs

$p = .0009$) were positively associated with the frequency of thought about negative events. Depressive symptoms ($ab = .05$, confidence interval from .0226 to .0863) mediated the association between global sleep quality and frequency of thought about negative events. In addition, global sleep quality was not associated with frequency of thought about negative events when controlling for depressive symptoms ($c' = .00$, $p = .969$). Mediation was not found when considering frequency of thought about positive events.

In the significant mediation model concerning the percent of negative emotion words used when describing past events, depressive symptoms ($b = .03$, $p = .033$) were positively associated with the percent of negative emotion words used when describing significant positive events. Depressive symptoms ($ab = .05$, confidence interval from .0097 to .1079) mediated the association between global sleep quality and the percent of negative emotion words used to describe significant past events. In addition, global sleep quality was not associated with the percent of negative emotion words used when controlling for depressive symptoms ($c' = -.03$, $p = .521$). Mediation was not found when considering the percent of negative emotion words used when describing significant negative events, recent positive events, or recent negative events. Evidence of mediation was also not apparent when considering the other variables that were related to sleep quality through ANOVAs (the number of times the event was experienced and confidence that the reported event was not based on pictures or conversations with others).

DISCUSSION

The present study was conducted to examine relations between sleep quality and the manner in which young adults reported on autobiographical memories that varied on temporality (significant and recent) and valence (positive and negative). Previous research has examined associations between sleep and memory for emotional stimuli that are not personally relevant as well as relations between sleep and the accuracy of memory for past episodes. The present research is the first to our knowledge to indicate that sleep quality is related to the subjective experience of personally significant emotional events. We addressed this question by examining narrative ratings, which revealed how participants subjectively experienced the reported events, as well as the language participants used when reporting their memories, which reflects the manner in which individuals are evaluating and interpreting their past experiences (Bohanek, Fivush, & Walker, 2005; Fivush, Sales, & Bohanek, 2008; Pennebaker, 1997).

When considering the ratings of past events, participants with poor sleep quality thought about their negative memories more frequently than their positive memories and relative to participants with good sleep quality. Increased focus on the negative elements of events was also found when considering the use of negative emotion words to describe past events, such that participants with poor sleep quality used a greater percentage of negative emotion words in narratives of recent negative events relative to participants with good sleep quality; group differences were not found when considering narratives of recent positive events. Taken together, these findings indicate that participants with poor sleep quality spent more time thinking about negative events relative to participants with good sleep quality regardless of temporality, whereas group differences in the percent of negative words used to describe the past were only found when considering narratives of recent negative events. Participants with good sleep quality also reported that they were more confident that their positive memories were their own and were not influenced by pictures or conversations with others more so than were participants with poor sleep quality. This finding may be due to the consolidating effect of sleep on episodic memory (Diekelmann, Wilhelm, & Born, 2009; Ellenbogen, Hulbert, Stickgold, Dinges, & Thompson-Schill, 2006; Stickgold, 2005), as good sleep quality has been associated with more accurate recall of the details of events in previous research (Aly & Moscovitch, 2010; Murre et al., 2014).

An additional goal of this research was to identify one potential pathway by which poor sleep quality may impact reported autobiographical memories. To this end, we examined whether depressive symptoms accounted for the relations between sleep quality and the report of autobiographical events. As in previous research (Lund et al., 2010; Milojevich & Lukowski, 2016; Pilcher et al., 1997; Pilcher & Ott, 1998; Stein et al., 2008; Tsuno et al., 2005), our participants with poor sleep quality had higher depression scores relative to those with good sleep quality. Depressive symptoms accounted for the relation between global sleep quality and the frequency of thought about negative events as well as the association between global sleep quality and the percent of negative emotion words used to describe significant positive events. Future research should examine other potential pathways that might explain additional variability in autobiographical memory reports. For example, future studies should focus on interrelations among rumination, depression, and sleep quality, as rumination has been associated with heightened negative affect and reduced sleep quality (Thomsen, Yung Mehlsen, Christensen, & Zachariae, 2003) as well as with elements of autobiographical memory (Teasdale & Green, 2004). Participant rumination may negatively impact participant sleep quality, resulting in more negative mood and alterations in the processing and content of autobiographical memory reports. Future research should examine these possibilities using relevant statistical techniques (path models or multiple mediation models) and research designs (longitudinal studies and experimental studies, perhaps in which rumination about negative experiences is experimentally manipulated before a period of overnight sleep).

Understanding the multi-directional associations among sleep, dreaming, mental health, and autobiographical memory has significant implications for participant well-being. Whereas group differences were found when considering the frequency with which individuals thought about past negative events as well as the percent of negative emotion words used when reporting on the recent past, individuals with good and poor sleep quality did not differ in their use of cognitive process words. This lack of a group difference is meaningful and suggests that participants with poor sleep quality are not evaluating or attempting to make meaning of their past negative experiences. For example,

previous work suggests that individuals make sense of previous experiences through their combined use of emotion and cognitive process words (Bohanek et al., 2005; Fivush et al., 2008; Pennebaker, 1997). Our finding that participants with poor sleep quality are not using a greater number of cognitive process words relative to participants with good sleep quality—despite differential focus on the negative elements of past experiences—may have important implications for mental and physical health (Francis & Pennebaker, 1992; Pennebaker, 1993, 1997; Pennebaker & Beall, 1986; Pennebaker & Francis, 1996).

Given the potential implications of this work, future research should be conducted to further explore associations between sleep quality, depression, and autobiographical memory in young adults so as to address the limitations of the present study as well as to replicate and extend our findings. The primary limitation of the conducted research is that participants reported on past events using a temporal dimension that was not orthogonal. That is, participants reported on their most significant positive and negative memories as well as positive and negative events that occurred within the past 2 weeks. As such, significant events could have been reported both as a most significant memory as well as a recent memory, if the same event occurred within the past 2 weeks. Based on the comment provided by an anonymous reviewer, we examined how frequently this phenomenon occurred in the collected data. Participants reported the same narrative in the significant-recent positive or negative categories only eight times (an incidence rate of approximately 3%).

An additional limitation of this research is that we did not ask participants to rate the personal significance or meaningfulness of the reported events. To ensure that the events reported as significant were indeed more personally meaningful or relevant relative to those reported as recent, two undergraduate research assistants coded the significance or personal relevance of the significant-recent positive and significant-recent negative narratives using a forced choice procedure. The primary coders coded all 280 comparisons, whereas the reliability coder independently evaluated 25% of the same narratives ($n = 69$). Coders were unaware of the temporality of the narratives, and they were not told why they were asked to engage in this coding procedure. The results indicated that the primary coder found the narratives reported as most significant to be more significant or personally meaningful than the narratives reported as recent in 92% of the cases, when scored across valence (percent agreement across the two coders was 93%). Taken together, these two metrics (the percent overlap in reporting the same memory as a significant and recent event, as well as the ratings of the significance or personal meaningfulness of the events by blind coders) indicate that the most significant memories reported by participants were largely distinct from—and were certainly more meaningful than—the most recent memories they reported. Nevertheless, this methodological limitation should be remedied in future research by asking participants to report on (1) the most significant positive and negative event that occurred more than 2 weeks ago as well as (2) the most significant positive and negative event that occurred within the past 2 weeks so as to isolate the effects of temporality when examining associations with sleep quality.

Readers may also be concerned with the amount of data lost in this study, despite analyses that revealed that the included and excluded participants did not differ on a variety of demographic characteristics other than participant sex. Although a literature search did not reveal any empirical papers on the topic, we expect that the data loss reported in this manuscript is likely representative of what is obtained in online studies conducted on our campus and on university campuses more broadly (and that more data are lost in online studies relative to studies conducted in on-campus research facilities). To be clear, significant results were not obtained in this study by searching through the data to identify a subset of participants whose inclusion could be explained through the application of post-hoc exclusion criteria. Participants were excluded from the sample before data analysis was initiated; as such, there was no attempt to manipulate the results through the inclusion or exclusion of various groups of individuals.

Future research should also extend the findings reported herein. For example, additional studies should be conducted to determine whether associations between sleep and autobiographical memory can be traced to variability in the dreams students record about their recent negative experiences. Previous research indicates that dreaming—and the occurrence of nightmares in particular—has been associated with self-reported sleep quality (Levin, 1994) and altered sleep architecture (Simor, Horvath, Gombos, Takacs, & Bodizs, 2012). Additional work is needed to identify whether and how dreaming about negative experiences more generally is associated with variability in participant sleep quality and daytime reports of autobiographical memories. In this way, dreaming may not only contribute to the process of consolidating negative event-related information—the act of processing information during sleep may impact how individuals reflect on their past experiences during the day. This possibility builds on the continuity hypothesis proposed by Horton and Malinowski (2015), which suggests that autobiographical memories exist across periods of sleep and wake.

Subsequent studies should also address some of the limitations of the present research. Future work conducted on this topic should include a balanced sample of male and female participants, as sex differences could not be analyzed in the present study due to the small number of males. Because sex differences have been previously documented on some of the measures used in the present study (e.g., autobiographical memory reports: Bauer et al., 2003; depression: Kessler, 2003), participant sex should be considered as a potential moderator in future research. Additional research should also include objective measures of sleep, such as those obtained from actigraphy or polysomnography, to examine and account for the recall biases that may impact self-report data. Indeed, previous research indicates that measures from the PSQI correlate with self-reported sleep diaries but do not correlate well with objective data obtained from actigraphy (Buysse et al., 2008; Grandner, Kripke, Yoon, & Youngstedt, 2006) and/or polysomnography (Buysse et al., 2008). Moreover, PSQI scores correlate positively with depression (Grandner et al., 2006) and other indicators of psychological distress (Buysse et al., 2008), suggesting that the PSQI may tap general dissatisfaction more so than

specific issues with sleep disturbances (Grandner et al., 2006). For these reasons, the inclusion of objective measures of sleep quality is theoretically as well as methodologically significant, informing the question of whether the mere perception of poor sleep quality or general dissatisfaction more broadly is associated with the effects reported herein more so than objective indicators of good sleep. We suspect that this may be the case: Previous experimental work has indicated that participants who were made to believe they had poor quality sleep the previous night performed less well on various cognitive assessments relative to those told they experienced good quality sleep (Draganich & Erdal, 2014). As such, the association between sleep and autobiographical memory may well be in the eye of the beholder, resulting either from perceptions of poor sleep quality specifically or from general dissatisfaction more broadly.

Finally, additional work should be conducted to examine the accuracy of reported autobiographical memories (Aly & Moscovitch, 2010; Murre et al., 2014). Although the focus of the present study was on the manner in which individuals rated and reported on past events that differed by temporality and valence, additional research examining the accuracy of the memory reports would further inform the question of whether sleep quality is differentially associated with the retention of the details of past events and the subjective experience of their emotional content. To this end, future research should be conducted using a daily diary approach in which participants report on their sleep quality as well as their most positive and negative personal events on a daily basis. Night-to-night variability in sleep quality may be associated with the accuracy with which events are reported over time as well as participant perceptions of their reported experiences.

Although additional research is needed to identify the manner in which sleep quality impacts the subjective experience and accurate reporting of autobiographical memories, the present study contributes significantly to the literature on emotion-cognition associations by indicating that global sleep quality is associated with the subjective experience of autobiographical events. The finding that participants with poor sleep quality engaged in more frequent thought about past negative events and used more negative emotion words when discussing negative events but did not include greater use of cognitive process words may have implications for their mental health. As such, future experimental work should be conducted to examine whether improvements in sleep quality reduce indices of depression, ultimately affecting the way in which individuals discuss and making meaning of their negative life events.

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