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Lower sleep duration is associated with reduced autobiographical memory specificity

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Abstract

Objective/Background. Sleep can have an important influence on memory. However, it is unclear whether there is any relation between sleep quality and the specificity with which autobiographical memories are retrieved, a key factor associated with vulnerability for, and the presence of, depression and other psychiatric diagnoses. The present study provides the first investigation of the association between sleep quality and autobiographical memory specificity.

Participants and Method. Fifty-four unselected community participants completed the Autobiographical Memory Test (AMT) to assess memory specificity, while subjective and objective measures of total sleep time and sleep onset latency were provided through a daily diary and an actigraphy wristwatch worn for a week. Participants also completed questionnaires that measure known correlates of AMT specificity - the Ruminative Response Scale (RRS) and Beck Depression Inventory (BDI-II).

Results. Shorter sleep duration, measured using actigraphy, was associated with reduced autobiographical memory specificity. There was no evidence of an association between total sleep time recorded by self-report diaries, or of sleep onset latency recorded using actigraphy or diaries and memory specificity. The relation between actigraphy-assessed total sleep time and memory specificity was independent of the effects of rumination or depressive symptoms on these variables.

Conclusions. Shorter sleep duration is associated with reduced memory specificity. Future research examining memory specificity and its association with psychopathology should consider the role of sleep quality around the time of memory recall in specificity.

Keywords: Sleep; Memory; Overgeneral; Depression; Actigraphy

Sleep plays a critical role in memory (Diekelmann & Born, 2010; Rasch & Born, 2013; Stickgold, 2005). However, existing research examining the relation between sleep quality and memory has been confined exclusively to the laboratory with studies rarely examining real-life fluctuations in sleep and the association with memory performance. One measure of memory performance of particular interest when considering its association with sleep quality is autobiographical memory specificity. The tendency to recall autobiographical memories with little specificity has been found amongst people with and at risk for depression (Sumner, Griffith, & Mineka, 2010), amongst whom poor sleep quality is common (Jansson-Frojmark & Lindblom, 2008; van Mill, Hoogendijk, Vogelzangs, van Dyck, & Penninx, 2009). Research has yet to clarify whether real-life fluctuations in sleep measured objectively are associated with individual differences in memory performance and particularly memory specificity. Such an investigation would enhance our understanding of the kinds of memory deficits that might be associated with problematic sleep and the presence and emergence of psychopathology. What is memory specificity, how is it measured and why might we expect that it would be influenced by variability in sleep quality?

Memory specificity is typically measured using the Autobiographical Memory Test (AMT; (Williams & Broadbent, 1986). AMT participants are shown positive and negative cue words and are asked to recall an event that they associate with each. Memories involving a personally experienced event that occurred at a specific time and place and which lasted for a day or less (e.g., ‘Jamie’s birthday party last month’) are coded as *specific*. Some studies also code different kinds of *general* or non-specific memories or code memories which follow positive versus negative cues separately. However, psychometric examinations of the AMT suggest it has a single factor for the number of specific memories (Griffith et al., 2009; Griffith et al., 2012; Heron et al., 2012; Takano, Gutenbrunner, Martens, Salmon, & Raes, 2017). Williams et al. (2007) model of autobiographical memory specificity focuses on the

process by which these memories are retrieved. The model suggests that comprised specificity can occur when, during retrieval of a memory, a person is *captured* by self-relevant conceptual information related to a cue word (e.g., how this is related to the kind of person we are) which they then ruminate about. This process truncates one's memory search and prevents one from retrieving specific details of a memory. Although this was not included in Williams et al. (2007) model of reduced autobiographical memory specificity, it is possible that variability in sleep quality might also be related to memory specificity given the association between sleep restriction and other forms of memory deficit. Early studies with rodents found that sleep deprivation can impair the retrieval of previously learnt information (Smith, 1985). In studies with human participants there is evidence that retrieval of long-term memories for semantic information can be negatively influenced by sleep deprivation (Tilley & Warren, 1984). Research has yet to clarify whether normal variability in sleep quality measured near to the time of memory retrieval is associated with memory performance and autobiographical memory specificity in particular.

Such an investigation is of particular importance given the association between the presence of poor or reduced sleep in psychiatric disorders such as depression and post-traumatic stress disorder (PTSD) (Jansson-Frojmark & Lindblom, 2008; van Mill et al., 2009). Furthermore, poor sleep has also been found to predict later increases in depressive symptoms (Jansson-Frojmark & Lindblom, 2008). However, it remains unclear why poor sleep is associated with such problems, and in particular whether poor sleep is also associated with cognitive factors implicated in the presence of and risk for psychopathology. Autobiographical memory specificity offers one such likely candidate cognitive factor given its association with the presence of and risk for depression and PTSD (Kleim & Ehlers, 2008; Ono, Devilly, & Shum, 2016; Sumner et al., 2010). Therefore, it's important that we examine how memory specificity and sleep quality relate to one another in a first step towards

understanding how they might together be involved in the emergence and course of psychopathology.

It is also important to establish whether any relationship between sleep quality and memory specificity is independent of other known correlates of both factors, such as ruminative disposition. Indeed, self-reports of ruminative disposition have been associated with reduced memory specificity (Raes et al., 2005) and rumination inductions have been found to lower memory specificity relative to control, distraction manipulations (Sutherland & Bryant, 2007). In addition, there is evidence that rumination is associated with poor sleep (Takano, Sakamoto, & Tanno, 2014; Zoccola, Dickerson, & Lam, 2009).

The present study therefore examines whether sleep quality, measured in terms of total time sleeping (TST) and the time taken to fall asleep (sleep onset latency; SOL) correlates with autobiographical memory specificity and whether this relationship is independent of known correlates of memory specificity and sleep quality - depressive symptoms and rumination. Recent advances in wearable technology make it possible to objectively measure sleep quality in natural settings using actigraphy without the necessity for depriving participants of sleep or of requiring participants to remain in the laboratory during the night as would be the case with other techniques such as polysomnography. Actigraphy is similarly accurate and reliable as polysomnography but with greater ecological validity (Cellini, Buman, McDevitt, Ricker, & Mednick, 2013). Actigraphy also affords researchers with the ability to record sleep quality across many nights, allowing us to capture parameters such as TST and SOL across a week, rather than relying on the control of sleep quality for a single night prior to or following participation (Ancoli-Israel et al., 2003). We also measured self-reports of TST and SOL to establish whether objective measures of sleep are associated with memory specificity or whether some component of subjective sleep quality perception corresponds with reduced specificity. We hypothesised that lower TST and

longer SOL would be associated with reduced memory specificity. As memory specificity has also been consistently associated with rumination and depressive symptoms we also examined whether any relationship between sleep quality and memory specificity persists even when the relationships between memory specificity and depressive symptoms and rumination were accounted for.

Method

Participants

Sixty students of the University of Leuven and members of the local community participated for a monetary reward of 25 euros. Two participants did not complete the sleep monitoring procedure; 1 participant did not wear the actigraph for the duration of the study; and 3 participants showed a large discrepancy in their actigraphy and sleep diary measurements of in-bed and out-bed times (>1 h). The final sample consisted of 54 participants (*Mean Age* = 21.8; *SD* = 3.6; *Females* = 87%)[1].

Measures

Sleep assessment

Sleep diary. Participants were asked to record their (a) in-bed and out-of-bed times; (b) sleep onset latency (SOL); and, (c) their total sleep time (TST), each morning for seven consecutive days.

Actigraphy. A wrist-worn actigraph (wGT3X-BT; ActiGraph, Pensacola, FL) was used to estimate TST and SOL objectively. This device detects the three-dimensional limb movements with a sampling rate of 30 Hz, recorded in 1-minute epochs. The GT3X has shown good validity and reliability in measuring sleep-wake cycles when compared with polysomnography and another actigraph (Cellini et al., 2013). Participants were asked to keep the actigraph on their non-dominant wrist for 24 hours across seven consecutive days. Sleep-

[1] Part of this data has been published elsewhere (Takano, Boddez, & Raes, 2016) reporting on pre-sleep arousal and misperception of sleep.

wake intervals were determined using software (Actiware 6.11.8; ActiGraph) with the Cole-Kripke algorithm (Cole, Kripke, Gruen, Mullaney, & Gillin, 1992).

Beck Depression Inventory II (BDI-II)

Current levels of depressive symptoms were assessed using the Dutch version of the Beck Depression Inventory II (Van Der Does, 2002). The BDI-II is a self-report questionnaire including 21 items where participants their experience of typical depressive symptoms on scales ranging from 0 to 3, such that a higher score reflects greater experience of depressive symptoms. The BDI-II had good internal consistency ($\alpha = 0.88$).

The Ruminative Response Scale questionnaire (RRS)

The Dutch version of the RRS was used to assess ruminative disposition (Schoofs, Hermans, & Raes, 2010). The RRS is a 22-item self-report questionnaire, which asks participants to indicate the degree to which they engage in ruminative responses when in a negative mood, on a 4-point Likert scale. A higher score in the RRS reflects greater tendency to ruminate. The RRS had good internal consistency ($\alpha = .87$).

Autobiographical Memory Test (AMT)

A written, self-report version of the AMT (Henderson, Hargreaves, Gregory, & Williams, 2002; Raes, Williams, & Hermans, 2009) was used to assess autobiographical memory specificity. Participants were shown 5 positive and 5 negative cue words: *zelfverzekerd* (confident), *alleen* (alone), *bekwaam* (capable), *wanhopig* (desperate), *geslaagd* (succeeded), *jaloers* (jealous), *verrast* (surprised), *beschaamd* (ashamed), *tevreden* (satisfied), and *gefaald* (failed). Participants were asked to recall and write down an event that they personally experienced in the past that related to each cue word. Memories were coded as specific or not before statistical analysis, by using the computer coding algorithm described elsewhere (Takano et al., 2017) A specific memory was one which referred to an event that occurred on a particular day (e.g., Last Sunday, I went hiking in my local area). Although

other studies have also coded forms of general memory, we chose to only code specific memories, in line with psychometric evaluations of the AMT (Griffith et al., 2009; Griffith et al., 2012; Heron et al., 2012; Takano et al., 2017).

Procedure

The study protocol was approved by the Social and Societal Ethics Committee and by the Medical Ethics Committee of the University of Leuven.

Participants were invited to a briefing where they were informed about the study protocols. Participants also provided written informed consent and completed the questionnaire measures and the AMT. Participants were then given the actigraph and were then asked to wear it for the following seven days whilst also maintaining a sleep diary. Participants were asked to complete the diary each morning after waking. Participants maintained the diary for an average of 6.7 nights (*SD* = .8).

Statistical procedure

As an initial test of the relationship between each of the sleep variables (SOL self-report, SOL actigraphy, TST self-report, and TST actigraphy) and memory specificity, correlations between these variables were calculated. We also correlated the sleep variables with scores on the RRS and BDI to examine to what extent rumination and depressive symptoms were associated with variability in sleep quality. Where there was evidence of a significant relationship between any of the sleep variables and specificity, we followed this with linear regression analyses. In these analyses, the number of specific memories recalled was the outcome. In the first step of the analysis RRS and BDI scores are added and then the sleep variables are each added in the second step depending on whether there was evidence of a relationship with specificity. Throughout the analyses alpha level was .05.

Results

Sample characteristics

Mean and standard deviations for participants' self-reported and actigraph-assessed total sleep time and sleep onset latency are presented in Table 1 along with mean and standard deviations for the RRS, BDI and the number of specific memories recalled by participants in the AMT. There was agreement between the self-report and actigraphy measures of total sleep time (*Mean Difference* = .17; *SE* = .12; $t(52) = 1.37$, $p = .18$) but participants reported that it took significantly longer to fall asleep than was recorded using actigraphy (*Mean Difference* = 16.62; *SE* = .12; $t(53) = 5.95$, $p < .001$).

Correlation analysis

Actigraph-assessed TST showed a trend-level relationship with memory specificity, $r = .25$, $p = .07$, whereas self-reported TST showed no evidence of a relationship with specificity, $r = .10$, $p = .46$. Also, neither self-reported SOL, $r = -.20$, $p = .14$, nor actigraph-assessed SOL, $r = -.15$, $p = .27$, showed any evidence of a relationship with specificity. A similar pattern of results was evident when correlating each of the sleep variables with RRS and BDI scores. Actigraph-assessed TST correlated significantly with RRS scores, $r = .32$, $p = .02$, and BDI scores, $r = .31$, $p = .02$. There was no evidence of a relationship between self-reported TST and RRS scores, $r = .00$, $p = .99$, or BDI scores, $r = -.02$, $p = .90$. There was also no evidence of a relationship between actigraph-assessed SOL and RRS scores, $r = .11$, $p = .43$, or BDI scores, $r = .15$, $p = .28$. However, self-reported SOL showed a trend-level correlation with RRS scores, $r = .24$, $p = .09$, and a significant correlation with BDI scores, $r = .30$, $p = .03$. Neither RRS or BDI scores correlated significantly with memory specificity, $r = .05$, $p = .73$, and $r = -.15$, $p = .28$, respectively. In summary, greater memory specificity was associated with objectively greater total time spent sleeping, but not perceptions of total time spent sleeping and not the time spent trying to fall asleep. Greater ruminative disposition and higher depressive symptoms were also associated with

objectively greater total time spent sleeping and there was evidence that these variables were also associated with self-reports of it taking longer to fall asleep.

Regression analysis

Only one regression was performed as only one sleep variable – actigraph-assessed TST – showed evidence of a relation with memory specificity in our correlation analysis (cf. Table 2). In the first step of the regression, neither RRS or BDI scores explained a significant amount of variance in memory specificity, and this first model did not explain a significant amount of variance in specificity, $R^2 = .05$, $F(2, 51) = 1.27$, $p = .29$.

In the second step of the regression, actigraph-assessed TST explained a significant amount of variance in memory specificity and BDI scores now explained a trend-level amount of variance in memory specificity. RRS continued to explain a non-significant amount of variance in memory specificity. The step 2 model explained a trend-level amount of variance in memory specificity, $R^2 = .13$, $F(3, 50) = 2.46$, $p = .07$, whilst explaining significantly more variance than the step 1 model, $\Delta R^2 = .09$, $F(1, 50) = 4.64$, $p = .04$.

Individual differences in total sleep time explained a significant amount of variance in memory specificity, over and above any relationship between these variables and depressive symptoms or ruminative disposition.

Discussion

The present study sought to examine the association between sleep quality, measured objectively and in an ecologically valid manner, and memory performance. In line with our hypotheses we found that lower total sleep time, measured using actigraphy, was associated with reduced autobiographical memory specificity. Given that both reduced autobiographical memory specificity and problematic sleep have elsewhere been associated with the presence and severity of a range of psychiatric disorders (Jansson-Frojmark & Lindblom, 2008; Kleim & Ehlers, 2008; Ono et al., 2016), and that we have shown that memory specificity and sleep

problems are also associated with one another, it is possible that these problems compound one another and contribute towards psychopathological risk. Our correlational analysis revealed that higher total sleep time, measured using actigraphy, was also associated with higher levels of rumination and depressive symptom severity. However, as hypothesised, our regression analysis showed that the relationship between total sleep time and memory specificity was independent of these effects. It is of note that individual differences in rumination and depressive symptoms were not significantly associated with memory specificity. This is to be expected to some extent as while some studies have found an association between higher levels of rumination and reduced memory specificity, such an association is not always evident (Smets et al., 2013). The same is true for depressive symptoms and memory specificity when measured in non-clinical populations, as was the case here (Raes, Hermans, Williams & Eelen, 2007).

Contrary to our other hypotheses, there was no evidence of an association between total sleep time recorded using participants' self-report diaries, or of sleep onset latency recorded using actigraphy or diaries and memory specificity. It is also of note that actigraph and self-report sleep onset latency measures differed significantly from one another with actigraphy showing substantially shorter SOL compared with diary reports. Girschik, Fritschi, Heyworth, and Waters (2012) suggest that disagreement between objective and subjective sleep parameters is perhaps to be expected and that this might be explained by biases in the way that people measure and report their sleep, such as anchoring their estimates around their expectations of a typical night rather than their actual experiences of sleep. Disagreement between measures may also be due to actigraphic misidentification of quiet wakefulness as sleep (Kushida et al., 2001). It may be that neither self-reports nor actigraphy provide sufficiently accurate measures of the time taken to fall asleep. However, there was no difference between self-reports of total sleep time and actigraph measurements of the same

sleep parameter. If the actigraphs had erroneously recorded wakefulness as sleep throughout the night, we would expect self-reports of total sleep time to differ significantly from actigraphy-assessed total sleep time. Given that there was no difference between these measurement forms in their estimation of total sleep times, it is therefore surprising that only actigraph-assessed total sleep time was associated with memory specificity and not self-reports of total sleep time.

Although the present study measured sleep quality proximal to AMT participation, that is not to say that this is the only time when sleep could impact memory specificity. We examined sleep proximal to AMT participation, however, sleep near to events that are later recalled might also influence the later retrieval of these events from memory. To this end, sleep has been found to improve consolidation of these events and this may be particularly so for the kinds of emotional events recalled within the AMT (Wagner, Hallschmid, Rasch, & Born, 2006). Also, poor sleep immediately after an event can negatively impact memory consolidation because of the effects of deprivation on neuronal plasticity in key areas of the brain involved in memory formation, such as the hippocampus (Kreutzmann, Havekes, Abel, & Meerlo, 2015). It is possible that poor sleep quality during our test period was associated with poor sleep quality at the time when the events recalled in the AMT occurred. Irrespective of the timing of sleep quality measurement and its effects on consolidation of the events after they happened or retrieval of the memory for these events within the AMT, the present investigation shows a clear association between objectively measured sleep quality and memory specificity. Future research could explore the longitudinal association between sleep quality during the year and the specificity with which memory of events from this year are later recalled. Also, while the timing of actigraph measurements in the present investigation provides us with a picture of general sleep quality in the time proximal to AMT performance, it is less clear whether sleep quality immediately prior to the AMT predicted

the specificity of subsequent memory recall or if the quality of one's sleep more generally is what influences memory specificity. Future research could examine day-to-day variability in sleep prior to AMT participation and the relationship with memory specificity, and in particular whether sleep during the night prior to AMT testing is associated with memory specificity. There are several limitations present in the current investigation that should also be considered. The correlational nature of the current study precludes us from drawing definitive conclusions regarding the direction of the observed effects. It is possible that the retrieval of less specific memories drives sleeping problems, perhaps because a person might stay awake whilst they try to elaborate on these memories and retrieve more detail associated with them. To further examine our hypotheses regarding the effects of impaired sleep on reducing autobiographical memory specificity, future research might deprive a group of participants of sleep whilst allowing a second group to sleep normally and then to test differences in memory specificity; or, they might test AMT performance at different times of day. Also, our sample included disproportionately more women than men. Although there is little evidence suggesting that males and females differ in autobiographical memory specificity, there is some evidence of gender differences in total sleep time (Burgard & Ailshire, 2013) and the extent to which impaired sleep can impact cognitive functioning (Santhi et al., 2016). Future research in this area should seek to replicate our findings in a more representative, community sample of males and females and in doing so examine whether gender moderates the impact of sleep time on memory specificity. It is also of note that no relationship was found in our regression analysis between memory specificity and self-reported rumination or depressive symptoms. This finding may be due to the nature of our sample and the limited variability in their memory specificity. However, research using larger, community samples also suggests that the relationship between these variables may not be as strong as previously thought (Smets, Griffith, Wessel, Walschaerts, & Raes, 2013).

Indeed, such findings highlight the importance of examining mediators and moderators of the relationship between specificity and pathology such as individual differences in sleep quality.

Despite these limitations, the present study provides the first investigation of whether sleep quality in the time proximal to AMT participation is associated with variability in memory specificity. Our data suggest that reduced total sleep time, but not variability in sleep onset latency, is associated with reductions in memory specificity even when accounting for the effects of individual differences in depression and rumination in this relationship. Future research examining the relationship between autobiographical memory specificity and emotional disorders should consider the potential influence of sleep quality in this relationship.

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Table 1. Sample characteristics.

	Mean	SD
Diary reports		
Total Sleep Time (hours)	7.62	1.14
Sleep Onset Latency (minutes)	28.02	24.53
Actigraphy		
Total Sleep Time (hours)	7.46	.93
Sleep Onset Latency (minutes)	11.39	8.04
RRS	46.52	3.06
BDI	10.03	10.78
Number of Specific Memories	8.77	1.57

Note. Mean and standard deviations for diary reports and actigraphy measurements of total time spent sleeping and time taken to fall asleep, as well as scores on the Ruminative Response Scale (RRS) and Beck Depression Inventory (BDI-II). The mean number of specific memories recalled by the sample is also given.

Table 2. Regression analysis.

Dependent variable: Memory Specificity	*B*	*SE*	*P*
Step 1			
RRS	.19	.02	.25
BDI-II	-.26	.03	.13
Step 2			
RRS	.13	.02	.43
BDI-II	-.32	.03	.06
TST	.31	.24	.04

Note. Regression analysis predicting variability in Autobiographical Memory Specificity, measured using the Autobiographical Memory Test, with individual differences in rumination (Ruminative Response Scale; RRS) depression symptoms (Beck Depression Inventory second version; BDI-II) and actigraphy measured Total Sleep Time (TST).

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