The Effects of Recent Sleep Duration, Sleep Quality, and Current Sleepiness on Eyewitness Memory

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Summary: This study examined whether three sleep-related variables (current sleepiness, the duration of the previous night's sleep and the quality of that sleep) were predictors of an eyewitness's ability to remember central and peripheral details from a crime. Participants first completed a self-report questionnaire assessing their current sleepiness, then watched a video of a bank robbery, next completed a self-report questionnaire about their previous night's sleep, and then had their memory of the crime tested. It was found that as the eyewitnesses' sleep quality decreased and their sleepiness increased, their ability to accurately recollect peripheral details from the crime was compromised. This is the first demonstration that variations in sleep prior to witnessing a crime, and sleepiness at the time of a crime, can predict eyewitness memory. Copyright © 2013 John Wiley & Sons, Ltd.

Eyewitnesses play a vital role in establishing the facts of a crime during police investigations and subsequent legal trials. It is estimated that eyewitnesses feature in 77 000 criminal cases per year in the USA (Wells et al., 1998). Eyewitness memory, however, can be tainted by a number of factors (see Loftus, 2005, for a review) and of the first 250 individuals in the USA to have their convictions overturned as a result of DNA evidence, 76% were convicted, at least in part, as a result of eyewitness error (Innocence Project, 2010). It is therefore important to establish the conditions under which eyewitness memory can be compromised. As only 49% of American adults report having a good night's sleep every night, and 29% report experiencing daytime sleepiness at least 3 days a week (National Sleep Foundation, 2005), eyewitnesses can vary in the amount of sleep they have had prior to witnessing a crime, the quality of that sleep, and their sleepiness at the time of the crime. The present study aims to examine whether or not these three sleep-related variables can predict an eyewitness's ability to remember a crime.

Eyewitness memory is a form of episodic memory. Episodic memories are memories of past events that are situated in a specific time and place (Tulving, 2002). In the laboratory, episodic memory can be assessed by having participants study and recollect stimuli such as word lists, stories, and mock crimes. To date, researchers examining the impact of sleep and sleepiness on memory have favoured materials such as word lists (and not crimes), so the findings from this more general episodic memory literature will be considered.

Prior to discussing the effects of sleep on episodic memory, it is important to distinguish between studies examining the impact of sleep prior to encoding on subsequent recollection and those investigating the impact of sleep after encoding on subsequent recollection (see Walker & Stickgold, 2006, for further details on this distinction). The relationship between sleep and episodic memory has typically been studied by having participants encode new information and then subsequently recollect this information after a period of sleep or a period of wakefulness. Newly learned information is better remembered following a period of sleep, as one of the functions of sleep is the consolidation of newly encountered information in memory (see Diekelmann & Born, 2010, for a review). Far fewer studies have been conducted examining the impact of sleep prior to encoding on recollection, and it is this literature that is of interest here.

Researchers have primarily examined the impact of pre-encoding sleep duration on episodic memory by depriving participants of sleep for up to two nights before testing. It has been found that sleep deprivation prior to encoding disrupts participants' picture recognition (Yoo, Hu, Gujar, Jolesz, & Walker, 2007), word recall (Drummond et al., 2000) and temporal memory (Harrison & Horne, 2000). This has led to the suggestion that sleep is not only essential for consolidating previously learned information, but is also important in preparing the brain for future memory formation (Yoo et al., 2007). To the author's best knowledge, only Nebes, Buysse, Halligan, Houck and Monk (2009) have examined whether natural variations in sleep duration (i.e. with no induced deprivation) prior to encoding can predict episodic memory test performance. In their study, Nebes et al. found no correlation between elderly adults sleep duration over the previous month and their story recall, but poor sleep quality was associated with reduced story recall.

Sleep quality is a subjective measure of how sleep is experienced, including the feeling of being rested when waking up and satisfaction with sleep (Pilcher, Ginter, & Sadowsky, 1997). Correlations between sleep duration and sleep quality are often low or non-significant as people can vary in how deeply they sleep (e.g. Liu & Zhou, 2002; Meijer, Habekothe, & Van Den Wittenboer, 2000). The impact of pre-encoding sleep quality on episodic memory is not fully understood, with some studies reporting that reduced sleep quality harms episodic memory and some studies reporting no effect (see Fulda & Schulz, 2001, for a review).

The impact of sleepiness on episodic memory has also been examined. Sleepiness can be defined as a physiological state or 'urge' to sleep, which can be satiated (although not always) by sleeping (Guilleminault & Brooks, 2001). Daytime sleepiness can result from either reduced sleep duration, poor sleep quality or a combination of the two

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(Roehrs, Carskadon, Dement, & Roth, 2005). Sleepiness has been shown to influence episodic memory although research on this topic has, to the author's best knowledge, been limited to two studies. Hoddes, Zarcone, Smythe, Phillips and Dement (1973) found that as sleepiness increased, participants performance on a word recall task decreased. Similarly, Wallace, Vodanovich and Restino (2003) found that participants who scored the highest on a sleepiness scale also scored the highest on the Cognitive Failures Questionnaire (Broadbent, Cooper, Fitzgerald, & Parkes, 1982), which includes questions assessing episodic memory.

The aforementioned research demonstrates that episodic memory can sometimes be impaired by reduced sleep duration and poor sleep quality prior to encoding, as well as sleepiness levels at the time of testing. There is also indirect evidence to suggest that these sleep-related factors could impact upon eyewitness memory. Geiselman (2010) reported unpublished data from three of his own studies where over 600 participants answered the question 'How well rested are you right now?' when recollecting crimes. The participants self-reported levels of rest were positively correlated with their memory performance in each study. Although the term 'rested' is fairly ambiguous and is not a direct measure of recent sleep duration, sleep quality, or current sleepiness levels, this unpublished data does raise the possibility that these sleep-related factors could also impact upon eyewitness memory. The aim of the present study was to investigate this possibility by examining whether or not an eyewitness's ability to recollect a crime can be predicted by the duration and quality of sleep they have had in the evening prior to observing it and their sleepiness levels at the time of its occurrence.

METHOD

Participants

There were 75 participants in total (*M* age = 19.33 years; *SD* age = 2.95 years; 55 women, 20 men), all of whom were undergraduate students that completed the study for course credit. All provided written consent prior to taking part. Only native English speakers with normal or corrected-to-normal vision participated. None reported having clinically diagnosed psychiatric disorders or sleep disorders, and none reported taking any medication that could affect their sleep.

Stimuli and design

There were three sleep-related predictor variables. The first was participants' sleep duration on the evening prior to the study, whereas the second was the quality of that sleep. These were assessed using the St Mary's Hospital Sleep Questionnaire (SMHSQ) (Ellis et al., 1981). Sleep duration is measured on this questionnaire by asking participants how many hours and minutes they slept the previous evening. Several studies (e.g. Freeman et al., 2004) have previously used Question 9 of the SMHSQ (*How well did you sleep last night?*) as a measure of sleep quality, and this was also used here. For this question, participants

rate the overall quality of their sleep on a scale of 1 (*very badly*) to 6 (*very well*).

The third sleep-related predictor variable was current sleepiness levels, and this was assessed using the Stanford Sleepiness Scale (Hoddes et al., 1973). In this questionnaire, participants indicate on a scale of 1 (*feeling active, vital, alert or wide awake*) to 7 (*no longer fighting sleep, sleep onset soon or having dreamlike thoughts*) how sleepy they are currently feeling.

The crime that eyewitnesses were exposed to was a 2-minute video of a bank robbery taken from the film 'The Stick-Up'. In the video, two security guards unload sacks of money from an armoured vehicle, enter the bank, place the sacks in the safe, exit the bank, and then drive away. Shortly afterwards, a shotgun-wielding man in a clown's mask enters the bank, threatens the people inside, passes the bank manager a holdall to fill with money from the safe, and then exits the bank with the holdall. This video has previously been used in several studies (e.g. Luna & Migueles, 2009).

There were four memory-related dependent measures in this study, and these were derived from participants' answers on a 16-item questionnaire assessing their recollection of the bank robbery. Specifically, the dependent measures were the quantity and accuracy of central and peripheral crime details recollected. The distinction between the central and peripheral details will be considered prior to discussing the measures of quantity and accuracy. In the present study, Christianson and Loftus (1991) definition of central and peripheral details was adhered to, whereby central details are those that are spatially central or in the foreground of an event, whereas peripheral details are background details. Luna and Migueles (2009) previously identified eight central details and eight peripheral details in relation to the bank robbery video used here. Half of these details related to true information (e.g. a true central detail is that the robber wore beige overalls), whereas half related to false information (e.g. a false central detail is that the robber had a gun holstered to his belt). Using these details, the author created eight questions relating to central details and eight questions relating to peripheral details. For each question, the response options were either *yes*, *no*, or *don't know*. For half of each question type, the correct answer was *yes* (e.g. central detail question: *Did the robber wear beige overalls?*), and for the remainder, the correct answer was *no* (e.g. central detail question: *Did the robber have a gun holstered to his belt?*).

Assessing recollection of central and peripheral details from the crime allowed the researcher to examine whether sleep duration, sleep quality, and sleepiness impact upon the type of information eyewitnesses remember. Previous eyewitness memory research has demonstrated that central details are more frequently and more accurately remembered than peripheral details (e.g. Luna & Migueles, 2009) as our attention focuses on information central to incidents (Christianson, 1992; Easterbrook, 1959; Heuer & Reisberg, 1992). Given that central details are better remembered than peripheral details, recollection of central details may be better protected from any recent sleep deficiencies or current sleepiness.

The *don't know* response option was included as eyewitnesses can use variants of this when withholding

answers to questions during interviews if they are unsure of an answer (Roebers & Fernandez, 2002) and this option has been demonstrated to increase their overall accuracy (Koriat & Goldsmith, 1996). This option also allows the researcher to distinguish between the quantity of information eyewitnesses correctly remember, as well as the accuracy of this information (Koriat & Goldsmith). Quantity refers to proportion of information correctly remembered about an event. In the present study, this would be the proportion of questions answered correctly out of 16. For example, if a participant answered eight questions correctly, the proportion of correct information remembered would be 50%. On the other hand, accuracy is the proportion of questions answered that are correct. For instance, in the present study, participants could opt to only answer 10 questions and get eight correct, meaning their accuracy would be 80%.

Procedure

Participants were tested within single-person, partitioned computer booths with headphones attached to the computers. Onscreen instructions informed participants that they would be required to answer a questionnaire about their current sleepiness levels, watch a video, complete a questionnaire assessing their recent sleep history, and then answer 16 questions about events in the video. The participants were informed that the sleep-related questionnaires and the response sheet for the 16 video-related questions were inside a booklet placed next to the computer. The final onscreen instructions asked participants to place their headphones on so that they could hear the audio in the video.

The study began with the onscreen instructions asking participants to open the booklet next to the computer and complete the Stanford Sleepiness Scale. They were then asked to press any key on the computer to start the video. Immediately following the video, new instructions appeared asking the participants to open the booklet again and complete the SMHSQ. The onscreen instructions informed participants that once they had completed the questionnaire they should press any key to reveal the first of the 16 questions about the video.

The 16 questions relating to the video appeared onscreen one at a time, and participants could navigate their way through the questions at their own pace using the downward arrow key on the keyboard. The questions always alternated between a central detail question and a peripheral detail question, with the former appearing first. Participants were asked to record their answers on the response sheet inside the booklet. The response sheet contained each question number and the three response options (*yes*, *no* or *don't know*). To answer each question, participants circled the appropriate response option. After answering the final question, the participants were debriefed and thanked for their time.

RESULTS

The first set of analyses focussed exclusively on the participants' responses to the 16 questions assessing their memory of central and peripheral details in the crime video.

There were three response options for each question, which were *yes*, *no* and *don't know*. The quantity of correct answers was calculated by dividing the total number of correct answers by the total number of questions: *don't know* responses are treated as errors. The accuracy of the correct answers provided was calculated by dividing the total number of correct answers by the number of questions answered: *don't know* responses are ignored. Table 1 contains the descriptive statistics for these quantity and accuracy measures.

Preliminary analysis revealed that the number of *don't know* responses for peripheral and central detail questions were significantly different from normal, as assessed by the Kolmogorov–Smirnov test (both p's $< .01$). The Wilcoxon-Signed Rank Test was therefore used to compare the number of *don't know* responses given to each question type. It was found that 39% of all questions were answered with a *don't know* response, with a greater proportion provided in relation to peripheral detail questions ($M = 0.26$, $SD = 0.17$) than the central detail questions ($M = 0.13$, $SD = 0.11$), $T = 254.50$, $p < .01$, $r = .38$.

The quantity and accuracy scores for the peripheral and central detail questions were also significantly different from normal (all p's $< .01$). With regard to recollection quantity, there were more questions answered correctly in relation to central details than peripheral details $T = 88.50$, $p < .01$, $r = .55$. When questions were answered, accuracy was greater for central detail questions than peripheral detail questions $T = 32.50$, $p < .01$, $r = .56$.

The second set of analyses examined whether any of the three sleep-related predictor variables (current sleepiness, the duration of the previous night's sleep, and the quality of that sleep) were associated with the quantity of correct answers and accuracy of these answers to the peripheral and central detail questions. Table 1 contains the descriptive statistics for each predictor variable. For comparison purposes, the mean sleep duration on the evening prior to the study was 7.03 hours ($SD = 2.31$), which is slightly higher than the 6.90 hours of sleep a night obtained by US adults (National Sleep Foundation, 2005). The reported sleep durations ranged from 1.5 to 15 hours. There was, therefore, no evidence of total sleep deprivation amongst participants, and there was a wide range of sleep durations evident in the sample. As there was no *a priori* expectation that any

Table 1. The quantity and accuracy of central and peripheral details remembered from a crime video, participants' sleepiness levels at the time of the crime, and their sleep duration and sleep quality in the evening prior to viewing the crime

Memory measures	Mean proportion	SD
Central details accuracy	0.77	0.16
Peripheral details accuracy	0.53	0.20
Central details quantity	0.67	0.16
Peripheral details quantity	0.40	0.18
Sleep measures	Mean	SD
Sleepiness	2.70	0.84
Sleep duration	7.03	2.31
Sleep quality	4.19	1.15

individual sleep related variable would be a better predictor of recollection quantity or accuracy than another, they were entered into four separate simultaneous multiple regressions, with the first focussing on peripheral detail recollection quantity, the second examining central detail recollection quantity, the third focussing on peripheral detail recollection accuracy, and the fourth examining central detail recollection accuracy. These analyses exceed Steven's (2009) recommendation of 15 participants per predictor to achieve statistical power.

Preliminary analyses revealed that responses to each of the three predictor variables were significantly different from normal (all p's $< .01$). The data were therefore ranked prior to running the analyses, as ranking is recommended for overcoming the problems associated with non-normal data when conducting regression (Iman & Conover, 1979). Preliminary analyses also revealed no multicollinearity between the three predictor variables when data were ranked, with all intercorrelations being less than .24, which is below Tabachnick and Fidell's (2006) recommended cut-off point of .70.

When the three sleep-related predictor variables were entered into a simultaneous multiple regression with peripheral detail recollection quantity as the dependent variable, no significant regression model emerged, $F(3, 71) = .51$, $p = .68$, with only 2% of the variance in peripheral detail recollection quantity explained ($R^2 = .02$). None of the individual sleep-related measures were predictors of peripheral detail recollection quantity (all p's $> .05$). Similarly, when central detail recollection quantity was entered as the dependent variable, a non-significant regression model emerged, $F(3, 71) = 1.37$, $p = .26$, with only 6% of the variance ($R^2 = .06$) explained. None of the individual sleep-related measures were significant predictors of central detail recollection quantity (all p's $> .05$).

When the three sleep-related predictor variables were entered into the simultaneous multiple regression with peripheral detail recollection accuracy as the dependent variable, a significant statistical model emerged, $F(3, 71) = 12.87$, $p < .001$. The model explains 35% of the variance in peripheral detail recollection accuracy ($R^2 = .35$). Table 2 gives information about the regression coefficients for each of these predictor variables. To summarise, only current sleepiness levels and the previous night's sleep quality were significant predictors of peripheral detail recollection accuracy. More specifically, as sleep quality decreased and sleepiness increased, peripheral detail recollection accuracy decreased. When central detail recollection accuracy was

Table 2. Coefficients for the simultaneous multiple regression analysis containing three sleep-related predictor variables (sleepiness, duration and quality of the previous night's sleep) and peripheral detail recollection accuracy as the dependent variable

Predictor variables	B	$SE\ B$	$Beta$	p
	Peripheral detail recollection accuracy			
Sleepiness	−.46	.11	−.42	.00*
Sleep duration	−.10	.10	−.10	.32
Sleep quality	.41	.10	.39	.00*

*Significant at the .001 alpha level.

entered as the dependent variable there was no significant regression model, $F(3, 71) = 1.06$, $p = .37$, with only 4% of the variance in the central detail recollection accuracy explained ($R^2 = .04$). None of the individual sleep-related measures were predictors of central detail recollection accuracy (all p's $> .05$).

DISCUSSION

This study examined whether or not an eyewitness's ability to recollect central and peripheral details from a crime can be predicted by the duration and quality of sleep they have had in the evening prior to observing it and their sleepiness levels at the time of its occurrence. Memory of the crime was assessed using forced choice questions which participants could refrain from answering by using a *don't know* response, making it possible to distinguish between the quantity of questions answered correctly and the accuracy of those questions that were answered. The main finding was that as sleep quality decreased and sleepiness increased, peripheral detail recollection accuracy was compromised.

Participants responded *don't know* to just over one-third of questions in the present study, with more central detail questions answered than peripheral detail questions. Moreover, participants provided more correct answers overall to central detail questions and their accuracy was greater for the central detail questions. These findings are consistent with those of past research demonstrating that central details are remembered more frequently and more accurately than peripheral details (e.g. Luna & Migueles, 2009).

Past research with young adults has demonstrated that sleep deprivation prior to encoding can harm episodic memory (e.g. Drummond et al., 2000; Harrison & Horne, 2000; Yoo et al., 2007). Research with elderly adults, however, has found no relationship between natural variations in sleep duration and episodic memory (Nebes et al., 2009). The present study also found that natural sleep duration variations in the evening prior to encoding did not predict either the quantity or accuracy of the central and peripheral details recollected. As there was no sleep deprivation evident in the present study, with sleep duration ranging from 1.5 to 15 hours, it remains to be determined whether a complete absence of sleep prior to encoding can compromise eyewitness memory.

Past research on sleep quality prior to encoding has yielded mixed results with some studies reporting that poor sleep quality harms episodic memory and some studies finding no effect (see Fulda & Schulz, 2001, for a review). The present study found that participants' sleep quality on the evening prior to witnessing a crime predicted how accurately they remembered peripheral details. Sleep quality did not predict the quantity of peripheral details correctly remembered or the quantity or accuracy of the central details remembered.

Peripheral detail recollection accuracy was also predicted by levels of sleepiness in the present study. This is consistent with past research, which also found sleepiness harms episodic memory (Hoddes et al., 1973; Wallace et al., 2003). As with

the sleep quality measures, sleepiness did not predict the quantity of peripheral details correctly remembered or the quantity or accuracy of the central details remembered.

The present study may help clarify the findings of Geiselman (2010), who reported that participants who felt least 'rested' when witnessing a crime were subsequently the poorest at recollecting it. The term 'rested' in his research was fairly ambiguous as it is not a direct measure of prior sleep duration, sleep quality, or sleepiness. The current study suggests that 'rested' could correspond with sleep quality, sleepiness, or both. Unfortunately, Geiselman failed to distinguish between central and peripheral detail recollection in his studies, so it is difficult to draw further parallels between his research and the current one.

The findings from the present study raise the question as to why only peripheral detail recollection accuracy was affected by sleep quality and sleepiness. As discussed, central details were generally better remembered than peripheral details. This is in line with the suggestion that participants' attention is drawn to central details during a crime, thus making them more memorable (Christianson, 1992; Easterbrook, 1959; Heuer & Reisberg, 1992). Given that accuracy, but not quantity, was predicted by these measures, it suggests that participants were inclined to answer peripheral detail questions regardless of their recent sleep quality or sleepiness, but their ability to accurately remember these details was compromised when they had experienced poor quality sleep and were sleepy. It is important to emphasise that encoding and retrieval were only separated by a few minutes in this study. Any effects observed here could have been a result of compromised encoding, retrieval, or both. Although this study has provided an important first step in understanding how recent sleep history and sleepiness can impact upon eyewitness memory, future research should be directed towards examining the cause of these effects.

If a holistic understanding of how sleep influences eyewitness memory is to be obtained, it is also important to consider how the findings from the present study relate to those from studies where the effects of sleep on memory consolidation after encoding have been examined. As in the pre-encoding sleep literature, researchers have typically utilised more general episodic memory materials as stimuli (e.g. word lists) and reported that sleep benefits memory (see Diekelmann & Born, 2010, for a review). In research more closely aligned with the current one, Payne, Stickgold, Swanberg and Kensinger (2008) examined the impact of post-encoding sleep on recollection of central and peripheral details from negatively arousing scenes. When participants were tested 30 (sleepless) minutes after encoding, they remembered central details better than peripheral details. After 12 hours awake, their memory for both types of detail decayed. In contrast, when participants had a full night's sleep, central details continued to be better remembered than peripheral details. The findings from the 30-minute delay condition mirror those of the present study, but it remains to be determined exactly how the harmful effects of poor sleep quality and sleepiness will impact upon subsequent recollection when participants are tested after longer periods of wakefulness or periods of sleep.

The findings from the present study have important psycho-legal implications. In the courtroom, a common strategy to discredit an eyewitness during cross-examination is to demonstrate that they have made errors in their statements (Salhany, 1991). Errors and inconsistencies in a statement can reduce an eyewitness' credibility regardless of whether they relate to central or peripheral details (Borckardt, Sprohge, & Nash, 2003). If an eyewitnesses' ability to accurately recall peripheral details when describing a crime was compromised by poor quality sleep or sleepiness then their testimony could be undermined, irrespective of how accurate or important the central details are. It is therefore important to consider whether an eyewitness has had poor quality sleep prior to witnessing a crime or is sleepy at the time of a crime as these factors could lead to peripheral detail recollection errors.

ACKNOWLEDGEMENTS

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