Sleep, stress, and emotion interact to influence memory consolidation

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Introduction

- Although sleep was often thought to be a time of quiescence, recent work has demonstrated that active neurobiological processes are at work, consequently affecting emotional processing and memory upon wake (e.g., Diekelmann & Born 2010; van der Helm & Walker, 2011).
- It has separately been demonstrated that emotional processing and memory can be affected by stress, and that stress can affect sleep quality.
  - Stress leads to increases in negative affect and decreases in positive affect (van Eck, Nicolson, & Berkhof, 1998), and also results in enhanced memory for negative stimuli (e.g., Payne et al., 2007).
  - Both acute and chronic stress lead to reductions in sleep efficiency and sleep time (e.g., Astill et al., 2013; Petersen et al., 2013), often perpetuating a negative cycle in which individuals then feel greater stress.
- The present research brings these literatures together, showing that **sleep, stress, and emotion interact to influence one important dimension of cognitive functioning: memory consolidation (Bennion et al., 2013).**

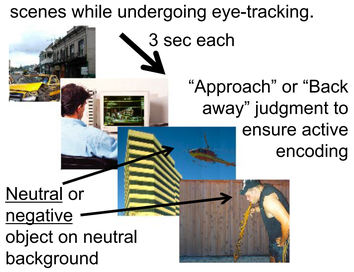
Public Health Relevance

- Approximately one third of American adults get less than 6 hours of sleep per night (CDC, 2012). This deprivation often increases under times of stress, either because individuals cannot sleep or because they sacrifice sleep in attempt to increase productivity in other domains. Understanding how sleep affects cognitive functioning, as in the present study, helps shed light on the possible negative consequences of healthy sleep going awry.
- The present research addresses an important public health question because only by investigating the interactions between sleep, stress, and emotion is it possible to fully understand PTSD, mood, and anxiety disorders, which are characterized by sleep disturbances and elevated stress.

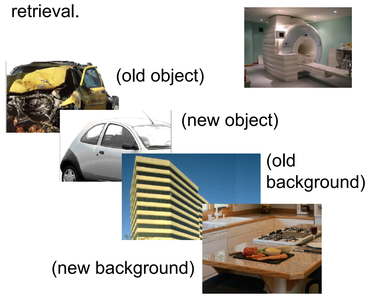
Method

Cortisol procedure: Measured cortisol (a stress hormone) via oral swab prior to encoding

Encoding: 88 subjects (18-30 years old, *M* = 21.0) encoded 124 composite scenes while undergoing eye-tracking.



Retrieval: Shown objects and backgrounds separately and asked whether each was old or new. Sleep and Wake participants underwent fMRI during retrieval.



Study-Test Delay & Time of Encoding/Retrieval by Condition

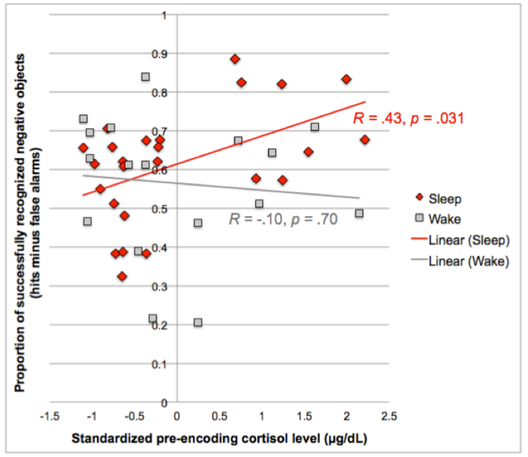
	WAKE (N = 17)	SLEEP (N = 25) Day 1	SLEEP (N = 25) Day 2	CIRCADIAN-AM (N = 23)	CIRCADIAN-PM (N = 23)
AM	Encoding		Retrieval (after sleep)	Encoding → 20-min delay → Retrieval	
	12-hr delay		12-hr delay (overnight)		
PM	Retrieval	Encoding			Encoding → 20-min delay → Retrieval

Results

Cortisol and sleep interact to enhance negative object memory

Significant Group (Sleep vs. Wake) x Cortisol interaction [*t* (41) = 2.23, β = 2.92, *p* = .031]: Cortisol was a stronger predictor of emotional memory performance in the Sleep group than in the Wake group.

Strong relation between cortisol levels and memory for negative objects in the Sleep group but not the Wake group.

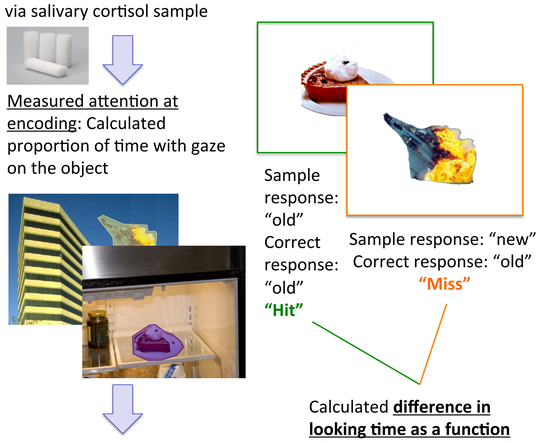


Eliminating potential confounds associated with time of day

- To ensure these differences were due to sleep, rather than time of day, similar multiple regression analyses were run for the Circadian-AM and PM groups.
- No Group (AM vs. PM) by Cortisol interaction [*t*(37) = 1.42, β = .33, *p* = .17]: Time of day did not influence the effects of cortisol on emotional memory.

Cortisol enhances the relation between looking time at encoding and subsequent emotional memory following sleep greater than wake

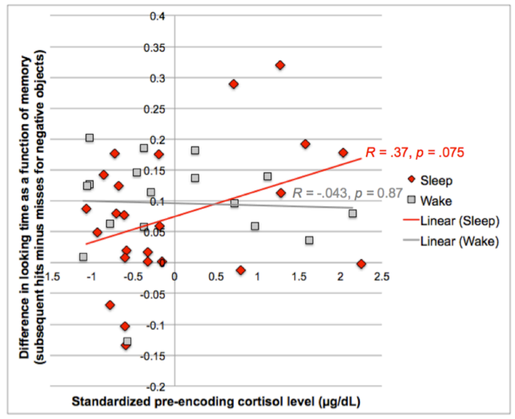
See right for calculation of the Dependent Variable: Proportion of time spent looking at negative objects during encoding as a function of subsequent memory (hits minus misses)



Effect of cortisol on the relation between attention at encoding and subsequent emotional memory (cont.)

Significant Group x Cortisol interaction [*t* (40) = 2.04, β = 2.99, *p* = .049]: Cortisol was a stronger predictor of the link between looking time and subsequent memory for negative objects if sleep rather than wake followed encoding.

Marginally significant relation between standardized levels of cortisol and the link between looking time and negative object memory in the Sleep group but not the Wake group.



Conclusions

- These results show that optimal memory is achieved when cortisol is mildly elevated during an emotional event, and when sleep occurs during consolidation. This also suggests that the beneficial effect of cortisol on emotional memory shown in prior studies, nearly all of which spanned at least a 24-hour delay, may be dependent on sleep occurring during the consolidation interval.
- This consolidation benefit may arise because cortisol intensifies the link between time spent looking at images during encoding and subsequent memory for those images, as long as sleep occurs during the delay. In other words, elevated cortisol may 'tag' attended information as important to remember during encoding, enabling sleep-based processes to optimally consolidate salient information in a selective manner.
- Given that many disorders (e.g., mood and anxiety disorders, PTSD) are characterized by problems with sleep, stress, and emotional processing, the evidence that these factors interact highlights a need for a more nuanced understanding of their effects, and points toward sleep deprivation as an often-overlooked contributor to mental disorders.

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