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PAPER

Napping reduces emotional attention bias during early childhood

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Abstract

*Sleep loss alters processing of emotional stimuli in preschool-aged children. However, the mechanism by which sleep modifies emotional processing in early childhood is unknown. We tested the hypothesis that a nap, compared to an equivalent time spent awake, reduces biases in attention allocation to affective information. Children (*n *= 43;* M *= 55.40 months,* SD *= 8.05 months) completed a Dot Probe task, which provides a measure of attention biases to emotional stimuli, following a mid-day nap and an equivalent interval spent awake. No emotional attention biases emerged when children napped. However, when nap-deprived, children exhibited biases towards negative and positive stimuli. This emotional bias after wake was greater in children who napped habitually. Gender differences also emerged such that females were more attentive to positive emotional stimuli whereas males showed heightened attention to negative emotional stimuli, regardless of having napped or not. Moreover, greater slow wave activity (SWA) during the nap was associated with faster responding, which suggests that SWA may promote efficiency of attention allocation. A video abstract of this article can be viewed at: https://www.youtube.com/watch?v=JIoZ8mzxQgg*

Research highlights

- Children exhibit attention biases to emotional stimuli when deprived of a mid-day nap and this is mitigated with a nap.
- The effects of nap deprivation on emotional attention biases are strongest for children who nap habitually.
- Greater slow wave activity during a nap is associated with faster reaction times, suggesting that sleep enhances efficiency of attention allocation.

Introduction

Sleep loss alters the way an individual experiences and manages emotions. It is a common experience for an adult to become ‘grumpy’ following sleep loss. Likewise, when toddlers are deprived of a mid-day nap, they show significantly more negative behaviors and less mature self-regulation skills when faced with an unsolvable puzzle task (Berger, Miller, Seifer, Cares & LeBourgeois, 2012; Miller, Seifer, Crossin & LeBourgeois, 2014) and subjectively rate emotionally salient stimuli more strongly (Berger *et al*., 2012). Although these studies provide evidence of enhanced emotional regulation following a mid-day nap in early childhood, little is known of the underlying mechanisms through which sleep contributes to more efficient emotion processing in early childhood.

One mechanism by which sleep loss may impair emotional processing is through complex interactions of sleep with systems regulating attention. Structurally, both attention regulation and regulation of emotional responses rely on a similar network of cortical and subcortical regions that are susceptible to sleep loss (e.g. the prefrontal cortex, thalamus, and limbic structures; Dahl, 1996). Studies in adults support the behavioral implications of this overlap (see Durmer & Dinges, 2005 and Lim & Dinges, 2008 for review). For example, an

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event-related potential (ERP) study focusing on the late positive potential (LPP) demonstrated that, under typical sleep conditions, neural reactivity differed when attending to emotional (either positive or negative) compared to neutral stimuli (Alfarra, Fins, Chayo & Tartar, 2015). However, following 24 hours of sleep deprivation, the amplitude of the LPP no longer distinguished between the allocation of attention to emotional and neutral stimuli. Although these studies suggest that sleep deprivation alters the activity of anatomical structures underlying attention and emotional processes in adults, the manner in which sleep modifies emotional processing in young children is not well understood. Specifically, it remains unknown whether sleep alters attention mechanisms, such as those underlying attention biases towards emotional stimuli, in early childhood.

Emotional attention biases represent preferential allocation of attention toward or away from emotional stimuli. Such biases are strongly linked to differences in socioemotional well-being. For instance, an attention bias toward threatening stimuli in children has been associated with lower emotional regulation, heightened anxiety (see Cisler & Koster, 2010, for review), and increased social difficulties (Morales, Pérez-Edgar & Buss, 2015; Pérez-Edgar, Reeb-Sutherland, McDermott, White, Henderson *et al*., 2011). In contrast, findings regarding attention biases toward positive stimuli have been more varied. Positive attention biases have been observed in typically developing young children (Broeren & Lester, 2013) and have been associated with higher reward sensitivity (Grafton, Ang & MacLeod, 2012). However, positive attention biases are also found in children who experienced early adversity in caregiving (Troller-Renfree, McDermott, Nelson, Zeanah & Fox, 2015) and correlate with predispositions toward social anxiety (Waters, Lipp & Spence, 2004). As such, here we consider the role of sleep on attention biases to both negative and positive affective stimuli.

While sleep is distributed across two sleep bouts (biphasic; a nap and overnight sleep) at 2 years of age, it is consolidated into a single overnight sleep bout (monophasic) in most children by 5 years of age (Iglowstein, Jenni, Molinari & Largo, 2003). The majority of children between 3 and 5 years of age nap frequently, but not consistently, making both a nap condition and a nap-deprived condition within the range of their normative sleep patterns. For this reason, the nap presents a unique opportunity to compare sleep and wake conditions without introducing the stress of an overnight sleep deprivation protocol. Although naps at this age are composed of little or no REM sleep, which is often implicated in emotional memory processing in adults (e.g. Baran, Pace-Schott, Ericson & Spencer, 2012; Walker, 2009), nearly half of a daytime nap is spent in slow wave sleep (SWS; Kurdziel, Duclos & Spencer 2013). Recent studies in adults have found evidence that SWS is also associated with emotional memory consolidation (Benedict, Scheller, Rose-John, Born & Marshall, 2009; Cairney, Durrant, Power & Lewis, 2015; Groch, Wilhelm, Diekelmann, Sayk, Gais *et al*., 2011). For instance, the amount of SWS and slow wave activity (SWA), the delta frequency power prevalent in SWS, recorded during a nap were positively correlated with emotional memory consolidation in young adults (Payne, Kensinger, Wamsley, Spreng, Alger *et al*., 2015). Reduced emotional attention biases following sleep may come about via consolidation of memories of recent episodic events, a known function of SWS (e.g. Gais & Born, 2004), and stabilization of their affective tone over sleep (Baran *et al*., 2012). Processing of prior memories would, in turn, make available the cognitive resources needed for processing new emotional events upon waking.

Present study

The overarching aim of this study was to understand mechanisms underlying modified emotional processing following sleep in young children. One specific objective was to examine whether napping reduces emotional attention biases (Experiment 1). To this end, we used the Dot Probe task, a task that has been used extensively to index patterns of attention to emotional cues and to understand individual differences in emotional attention bias among both children and adults (Bradley, Mogg, Falla & Hamilton, 1998; Lindstrom, Guyer, Mogg, Bradley, Fox *et al*., 2009; Pérez-Edgar *et al*., 2011). As previous studies suggest that sleep loss impairs both attention and emotional processing, we hypothesized that attention biases to emotional stimuli would be reduced following a nap relative to an equivalent period of time spent awake.

A second objective was to identify specific aspects of sleep that contribute to the reduced emotional attention bias (Experiment 2). For this reason, polysomnography (PSG), a montage of physiological recordings used to characterize sleep, was used to assess nap physiology in relation to emotional attention biases in an additional sample of children. Based on prior studies (Kurdziel *et al*., 2013), we expected little or no REM to be present in the naps and, rather, that attention to emotional stimuli would be modulated by SWS, particularly via SWA (Payne *et al*., 2015).

Experiment 1

Method

Participants

Children were recruited from local preschools in Western Massachusetts. Children were eligible to participate if they had normal or corrected-to-normal vision, and no history of diagnosed sleep disorders, parasomnias, learning or developmental disabilities as reported by caregivers.

Seventy-five children were recruited to the study. Results are based on 43 children (18 females) between 37 and 69 months of age (M = 55.40 months, SD = 8.05). An additional 32 children (15 females, M = 47.68 months, SD = 9.56) were tested but were excluded for missing school on either testing day (n = 16), failing to sleep in the nap condition (n = 1), or failing to reach the 60% accuracy criterion on the Dot Probe task in one or both conditions (n = 15). Although the Dot Probe task has been used to assess emotional attention biases in children as young as 4 years of age (Swartz, Graham-Bermann, Mogg, Bradley & Monk, 2011; Briggs-Gowan, Pollak, Grasso, Voss, Mian *et al.*, 2015), of those excluded for failing to reach the accuracy criterion, younger children were excluded more often than older children for failing to meet accuracy criteria (t (56) = 4.25, p < .001, 95% CI [5.29, 14.70]). Children who were included versus excluded based on accuracy criteria did not differ on gender (x^2 (1, N = 58) = 0.592, p > .250).

Measures

Dot Probe task

Stimuli used in the Dot Probe task were 32 happy/neutral face pairs and 32 angry/neutral face pairs. Face stimuli were taken from the NimStim set of facial expressions (Tottenham, Tanaka, Leon, McCarry, Nurse *et al.*, 2009). These stimuli have been used in a number of studies of emotion in young children (Gaffrey, Luby, Belden, Hirshberg, Volsch *et al.*, 2011; LoBue, Matthews, Harvey & Thrasher, 2014; Nozadi, 2014). Displayed images were 6.5 inches in height; each centered on one half of a 14-inch computer screen positioned approximately 15 inches from the child. The presentation of happy/neutral and angry/neutral face pairs was randomized throughout blocks. Face pairs were always of the same actor and equal numbers of male and female face pairs were used.

The probe was a 0.5 inch yellow star, which appeared in the center of one half of the screen, corresponding to the center of one of the previously presented faces in the face pair. Trials were ‘congruent’ if the probe appeared in place of the emotionally salient face (i.e. happy or angry) and ‘incongruent’ if the probe replaced the neutral face (Figure 1).

Each trial began with the presentation of a central fixation mark for 500 ms followed by a 1000 ms presentation of a face pair. The probe appeared for 1100 ms. Children were instructed to press one of two buttons (left versus right) on a mouse to indicate the location of the star on the screen as quickly and accurately as possible.

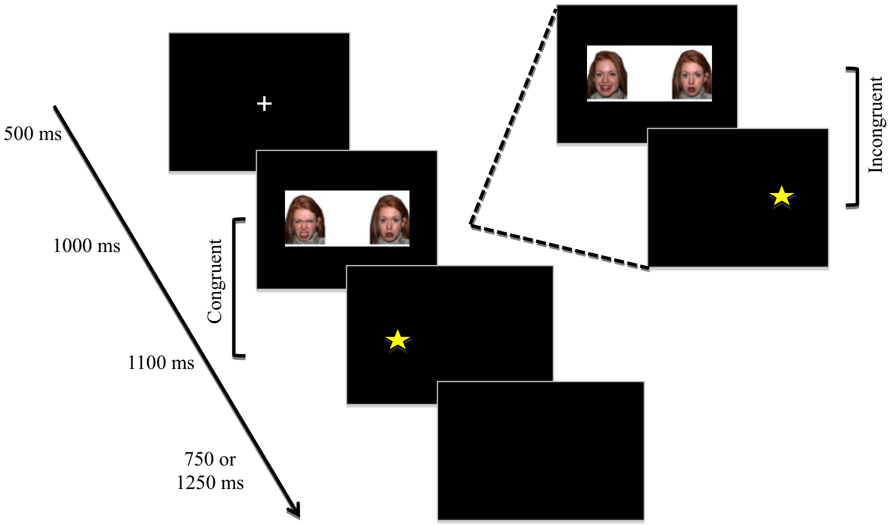

Figure 1 *Order and duration of stimulus presentation during the Dot Probe task. Congruent trials were those in which the probe (star) appeared in place of the emotionally salient face (left). Incongruent trials were those in which the probe appeared in place of the neutral face (right).*

A blank screen was presented for either 750 or 1250 ms between trials (randomized).

Questionnaires

Visual Sleepiness Scale (VSS). The VSS is a 5-point picture scale used to assess a child's self-report of sleepiness at a given time point. The VSS picture scale significantly correlates with other self-reported assessments of sleepiness such as the Karolinska Sleepiness Scale and the Stanford Sleepiness Scale in both clinical (KSS: $r = 0.73$, $p = .046$; SSS: $r = 0.95$, $p = .001$) and non-clinical (KSS: $r = 0.48$, $p = .01$; SSS: $r = 0.41$, $p = .04$) populations (Maldonado, Bentley & Mitchell, 2004). The VSS has been validated for use in children over 6 years of age (Kollins, López, Vince, Turnbow, Farrand *et al*., 2011). Both the child and the experimenter rated the child's sleepiness using this scale.

Visual Analogue Mood Scale (VAMS). The VAMS is a 6-point picture scale used to asses a child's report of his or her mood at a given time point. This is a valid and reliable ($r > 0.60$) assessment of mood that has been used in a variety of clinical and non-clinical populations (Folstein & Luria, 1973; Cella & Perry, 1986). The VAMS has been shown to be reliable in 5–6-year-old children ($\alpha = 0.75$; Cremeens, Eiser & Blades, 2007). Both the child and the experimenter rated the child's mood using this scale.

Nap diary. Classroom teachers were given nap diaries to indicate the number of naps children took in the classroom over a 16-day period that included the two experimental conditions. Teachers noted whether the child napped and the start/end times of the classroom nap opportunity.

Procedure

All procedures were approved by the Institutional Review Board at the University of Massachusetts, Amherst. Caregivers consented to their child's participation and child assent was sought before commencing with the procedures.

Children completed two conditions, a nap and a wake condition, which were separated by approximately one week with the order counterbalanced across participants. In the nap condition, during the typical afternoon nap opportunity (~1–3 pm), children were encouraged to sleep. Experimenters noted the duration of time each child spent asleep during the nap opportunity (nap length). In the wake condition, children were given minimal quiet activities (i.e. reading books or coloring) to maintain wake for the same interval of time. Children were on cots, lights were dimmed, and the room was kept quiet in both conditions.

Following the nap/wake interval, children completed the Dot Probe task consisting of eight practice trials and 64 experimental trials, presented in two blocks of 32 trials each. There were two pseudo-random trial orders used for all participants. The trial order was counterbalanced across participants. The task took approximately 10–15 minutes to complete. Children were tested in a quiet location within the preschool. Following completion of the task, the VSS and VAMS were completed by children (regarding themselves) and experimenters (regarding the child).

Data analyses

Attention bias scores were calculated by subtracting the reaction time (RT) for all correct congruent trials (probe behind emotional face) from the RT for all correct incongruent trials (probe behind neutral face; MacLeod, Mathews & Tata, 1986). As such, a bias score greater than zero represents vigilance to the emotional stimuli whereas a bias score less than zero represents avoidance of emotional stimuli. For each child, happy and angry attention bias scores were calculated separately for both the nap and wake conditions.

Paired-samples *t*-tests were used to compare accuracy, RTs, and attention biases between the nap and wake conditions. A repeated-measures ANOVA was used to explore within-subject differences in attention biases between conditions. Specifically, condition (nap and wake) and emotion (happy and angry) were entered as within-subjects factors and gender as a between-subjects factor. Results of this ANOVA motivated follow-up one-sample *t*-tests to validate the emergence of attention biases. Paired-samples *t*-tests were used to assess differences in attention biases for females and males independently.

A separate repeated measures ANOVA was performed to address behavioral differences among children who had data regarding nap habituality status. Attention bias (averaged across happy and angry) served as the within-subjects factors and nap habitually (habitually napping versus non-habitually napping) was the between-subjects factor. Results of this ANOVA motivated follow-up independent samples *t*-tests to compare the presence of attention biases among habitually and non-habitually napping children. Using the data collected in the nap diaries, nap percentage was calculated for each child by dividing the number of naps taken by the number of recorded nap opportunities during the 16-day testing period, with experimental days (when children were nap or wake promoted) excluded (i.e. typically eight days total). Due to our small sample size, we were unable to follow the previously established convention for classifying habitual versus non-habitual nappers (see Kurdziel *et al.*, 2013). Rather, a median split was used to disassociate 'habitually napping' children from 'non-habitually napping' children. Children who had napped on 100% of recorded days were considered 'habitually napping' whereas those who napped less than that (range: 0–93%; mean 59%) were considered 'non-habitually napping' children.

To examine differences in sleepiness and mood following the nap compared to the wake interval, paired-samples *t*-tests were used to compare VSS and VAMS ratings reported by the child and experimenter. Pearson's correlations were also used to determine whether child and experimenter ratings of sleepiness and mood were related to one another.

Results

Accuracy

Results of paired samples *t*-tests indicated that overall accuracy (averaged across happy and angry trials) did not differ between the nap and wake conditions ($t(42) = 0.89$, $p > .250$; Table 1). Accuracy for happy and angry trials also did not differ across conditions (*p*s > .250).

Reaction time

Reaction times for angry and happy trials following both the nap and wake conditions did not violate tests of normality (Shapiro-Wilk *p*s > .120). RTs (averaged across happy and angry trials) did not differ between conditions (paired samples *t*-test; $t(41) = -0.67$, $p > .250$; Table 1). Similarly, RTs for happy and angry trials did not differ between the nap and wake conditions (*p*s > .250).

Table 1 *Average accuracy, RT, and attention bias assessed by the Dot Probe task (n = 43)*

	Nap Condition		Wake Condition		
	Mean	*SD*	Mean	*SD*	*p*-value
Happy Accuracy (%)	74.88	15.71	74.80	18.55	0.977
Angry Accuracy (%)	73.40	17.38	72.51	19.61	0.755
Overall Accuracy (%)	90.16	7.33	88.80	10.54	0.377
Happy RT (ms)	693.21	101.26	695.69	85.59	0.858
Angry RT (ms)	689.05	97.86	702.83	81.24	0.336
Overall RT (ms)	691.00	96.08	699.70	12.34	0.504
Happy Bias	−9.53	71.27	14.31	76.39	0.131
Angry Bias	−2.53	72.08	13.21	54.77	0.254
Overall Attention Bias	−6.03	47.60	13.76	37.83	0.040

Attention bias

Attention bias to emotional stimuli (averaged across happy and angry trials) was significantly greater following the wake than the nap condition (paired samples *t*-test; $t(42) = -2.12$, $p = .040$; Table 1). Attention bias scores for happy and angry trials were not significantly different between the nap and wake conditions (*p*s > .131).

A repeated measures ANOVA, with condition and emotion entered as within-subjects factors and gender as a between-subjects factor, revealed a significant main effect of condition with greater attention bias in the wake compared to the nap condition ($F(1, 41) = 6.10$, $p = .018$, $\eta_p^2 = 0.129$; Figure 2). One sample *t*-tests also validated the emergence of an attention bias following wake ($t(42) = 2.39$, $p = .022$, 95% CI [2.11, 25.40]) that was not present after the nap ($t(42) = -0.83$, $p > .250$). The main effect of emotion was not significant ($F(1, 41) = 0.03$, $p > .250$). However, the two-way interaction between emotion and gender was significant ($F(1, 41) = 6.40$, $p = .015$, $\eta_p^2 = 0.135$). The two-way interaction between condition and gender was marginally significant ($F(1, 41) = 3.70$, $p = .062$); the difference in attention bias scores across conditions was slightly greater in females than males. The two-way interaction between condition and emotion was not significant ($F(1, 41) = 0.32$, $p > .250$) nor was the three-way interaction ($F(1, 41) = 1.58$, $p = .216$).

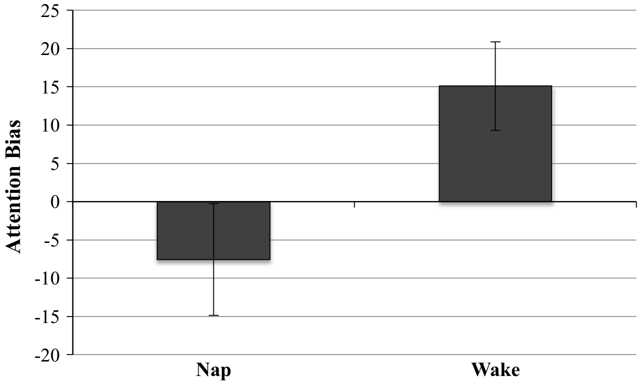

Figure 2 *Attention biases following the nap and wake intervals (n = 43). Note: Means represent estimated marginal means from repeated measures ANOVA; Error bars represent standard error.*

To further explore the significant two-way interaction between emotion and gender, paired-samples *t*-tests were used. For females ($N = 18$, $M = 52.89$ months, $SD = 8.46$), the bias towards happy stimuli ($M = 18.75$, $SD = 55.56$) tended to be greater than for angry stimuli ($M = -12.39$, $SD = 45.38$; $t(17) = 1.89$, $p = .076$); whereas for males ($N = 25$, $M = 57.20$ months, $SD = 7.38$), the bias towards angry stimuli ($M = 18.11$, $SD = 42.73$) tended to be greater than the bias towards happy stimuli ($M = -9.39$, $SD = 50.20$; $t(24) = -1.76$, $p = .092$; Figure 3), regardless of condition.

Sleepiness and mood

To assess whether differences in performance across conditions were due to greater child sleepiness and emotionality following the wake interval, we used paired samples *t*-tests to compare VSS and VAMS scores across conditions. There were no differences in child or experimenter reported sleepiness as measured by the VSS following the nap and wake intervals ($ps > .110$). Similarly, there were no differences in child or experimenter reported mood as measured by the VAMS following the nap and wake intervals ($ps > .250$). Child and experimenter reported sleepiness and emotionality were significantly correlated following both the nap and wake intervals ($rs > 0.427$, $ps \geq .007$).

Nap habituality

We next considered whether the presence of attention bias, averaged across emotion, depended on whether the child napped habitually. Of the 43 children with complete data, information regarding nap habituality was available for 32 children (23 females; $M = 54.94$ months, $SD = 8.60$ months), as not all teachers elected to complete the nap diaries. Fifteen children (7 females; $M = 55.47$ months; $SD = 8.53$ months) were classified as habitually napping and 17 (6 females; $M = 54.47$ months, $SD = 8.90$ months) as non-habitually napping. An independent samples *t*-test indicated that the average number of naps for habitual nappers ($M = 7.40$, $SD = 1.59$) was significantly greater than that of non-habitual nappers ($M = 4.76$, $SD = 2.61$; $t(30) = 3.39$, $p = .002$, 95% CI [1.05, 4.23]).

A repeated measures ANOVA, with condition entered as a within-subject factor and nap habituality as a between-subjects factor, revealed a main effect of condition such that attention biases were greater following the wake interval ($M = 15.96$, $SD = 34.17$) relative to the nap interval ($M = -10.69$, $SD = 47.57$; $F(1, 30) = 7.62$, $p = .010$, $\eta_p^2 = 0.203$), replicating the result in the full sample. Of interest, the condition by nap habituality interaction was significant ($F(1, 30) = 10.69$, $p = .003$, $\eta_p^2 = 0.263$). Post-hoc independent samples *t*-tests revealed that, following the wake interval, habitually napping children had a significantly greater attention bias to emotional faces ($M = 32.68$, $SD = 37.00$) than non-habitually napping children ($M = -0.76$, $SD = 31.32$; $t(30) = 2.77$, $p = .01$, 95% CI [8.78, 58.11]; Figure 4). Attention biases following the nap did not significantly differ between habitually and non-habitually napping children ($t(30) = -1.76$, $p = .088$, 95% CI [−64.01, 4.65]), although habitually napping children

Figure 3 *Attention biases to happy and angry stimuli for males and females averaged across the nap and wake intervals* (n = *43). Note: Means represent those from paired-samples* t*-tests; Error bars represent standard error.*

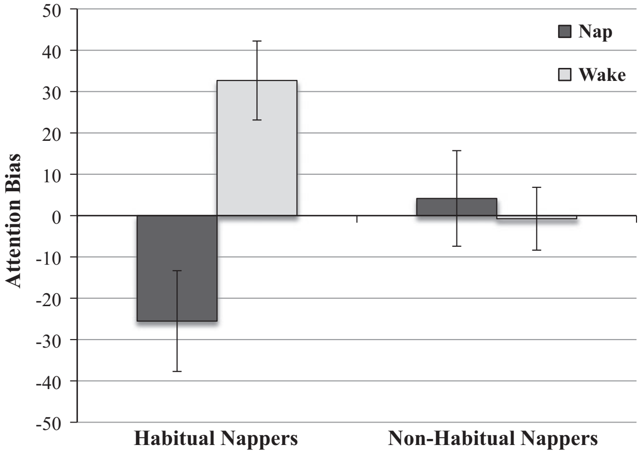

Figure 4 *Attention biases for habitually napping and non-habitually napping children following the nap and wake intervals* (n = *32). Note: Means represent those from independent samples* t*-tests; Error bars represent standard error.*

tended to avoid emotional faces ($M = -25.52$, $SD = 47.23$) more than the non-habitually napping children ($M = 4.15$, $SD = 47.65$).

Experiment 2

To determine whether a specific physiological property of sleep supports differences in emotional attention bias following a nap compared to wake, we replicated Experiment 1 in an additional sample of children who were tested in the laboratory with PSG. If differences in emotional attention biases are the result of a specific mechanism, we expected a correlation between a specific aspect of sleep (stage and/or spectral power) and post-nap attention bias scores.

Method

Participants

Eleven children (6 females; $M = 51.74$ months, $SD = 9.39$ months) were tested in the sleep laboratory with PSG. An additional two children were tested but were excluded from analyses due to equipment malfunction ($n = 1$) and failure to meet the 60% accuracy criterion ($n = 1$).

Measures

The Dot Probe task and the sleepiness (VSS) and mood (VAMS) scales were the same as described in Experiment 1.

Polysomnography (PSG)

Polysomnography (PSG) was recorded during the nap opportunity using an EEG/PSG 32-electrode cap (Easy-Cap). Electroencephalogram (EEG) electrodes were assigned to ground (FPz), reference (Cz), O_1, O_2, C_3, C_4, CP1, CP2, CP5, CP6, F_3, F_4, F_z, FCz, FC1, FC2, FC5, FC6, F7, F8, P3, P4, P7, P8, P_z, and POz. This montage also included two electrooculogram (EOG) leads, two electromyogram (EMG) leads (affixed to the chin), and reference electrodes placed on the mastoids (A1 and A2).

Procedure

Procedures were identical to Experiment 1 with children completing both a nap and wake condition with the exception that procedures took place in the laboratory setting. Children and caregivers were asked to arrive at the sleep laboratory approximately one hour before the child's typical naptime. Upon arrival, children were given time to acclimate to the sleep lab (~10 minutes). Children were then fitted with a PSG montage. To confirm wake, children also wore PSG in the wake condition (all stayed awake). Following the nap and wake intervals, children completed the Dot Probe task. After completing the Dot Probe task, both children and experimenters completed the VSS and VAMS.

Data analyses

Behavioral data were analyzed as described in Experiment 1. Polysomnography data were scored for sleep stages according to the revised American Academy of Sleep Medicine manual (AASM, 2007). Spectral analysis of the PSG data was based on a central electrode (C3) and generated using BrainVision Analyzer 2 software (Version 2.4; Brain Products). Spectral power is reported in power density ($\mu V^2/Hz$). C3 was chosen based on previous literature calculating spectral power from this site (e.g. Jenni & Carskadon, 2004). Pearson's correlations were used to explore relationships between sleep measures, attention bias scores as well as RTs to emotional stimuli. Specifically, these measures were correlated with the percentage of time spent in nREM2 and SWS (sleep stages that account for the majority of nap physiology during the preschool years; Kurdziel *et al*., 2013) as well as the spectral power of SWA calculated during SWS. Partial correlations were also used to determine whether child age influenced significant correlations.

Results

Attention bias

A repeated measures ANOVA, with condition and emotion entered as within-subjects factors and gender as a between-subjects factor, was used to explore within-subject differences in attention biases between conditions. Overall, the behavior patterns of children tested in-lab were similar to those observed in the classroom (Experiment 1). Although not statistically significant (likely due to the small sample size), these children also showed a greater attention bias following the wake ($M = 32.92$, $SD = 53.62$) relative to the nap interval ($M = 7.51$, $SD = 37.48$; repeated measures ANOVA: $F(1, 9) = 3.41$, $p = .098$, $\eta_p^2 = 0.275$). No other main effects or interactions neared significance ($ps > .250$).

Physiology

Consistent with prior work (Kurdziel *et al*., 2013), naps were approximately 70 minutes long and contained little ($n = 3$; $M = 9.7\%$, $SD = 5.8\%$) to no ($n = 8$) REM sleep (Table 2). Nap length was not significantly correlated with attention bias ($p = .390$) or RT for congruent and incongruent trials (ps > .559). The amount of time spent in nREM 2 and SWS was also not significantly associated with attention bias or RT (ps > .432; Table 3). However, greater SWA was associated with faster RTs; SWA significantly correlated with RTs for congruent ($r(9) = -0.73$, $p = .011$) and incongruent trials ($r(9) = -0.66$, $p = .026$; Figure 5). When controlling for age in a partial correlation, SWA remained significantly correlated with RT to congruent ($r = -0.721$, $p = .019$) and incongruent stimuli ($r = -0.652$, $p = .041$).

Discussion

The purpose of this study was to gain insight into the mechanisms by which sleep influences emotional processing in early childhood. Specifically, our data indicate that attention mechanisms are altered by sleep, reducing the attention bias to emotional stimuli that is present following nap deprivation (Experiment 1). Moreover, SWA may be a physiological property underlying efficient attentional processing in the presence of emotional information that occurs following sleep (Experiment 2**)**.

Table 2 *Sleep characteristics recorded by polysomnography (n = 11)*

	Mean	*SD*
Nap Length (mins)	69.74	16.25
Sleep Latency (mins)	18.86	11.4
WASO (mins)	13.72	17
Sleep Efficiency (%)	69.32	13.84
nREM 1 (%)	9.97	4.63
nREM 2 (%)	30.6	12.13
SWS (%)	56.76	16.71
REM (%)	2.65	5.22
SWA C3 (μV^2/Hz)	289.51	59.52

Note WASO = wake after sleep onset; nREM = non-rapid eye movement sleep; SWS = slow wave sleep; REM = rapid eye movement; SWA = slow wave activity recorded from central electrode (C3).

Table 3 *Bivariate correlations between sleep characteristics, attention bias, and RTs averaged across valence (n = 11)*

Variable	Attention Bias	Congruent RT (ms)	Incongruent RT (ms)
Nap Length (mins)	0.29	−0.20	−0.07
nREM 2 (%)	−0.26	0.18	0.06
SWS (%)	0.13	−0.10	−0.04
SWA C3 (μV^2/Hz)	0.16	−0.73**	−0.66**

Note nREM = non-rapid eye movement sleep; SWS = slow wave sleep; SWA = slow wave activity recorded from central electrode (C3).
**$p \leq .01$

Behaviorally, young children experienced heightened emotional attention biases when nap deprived, as marked by patterns of vigilance to emotional stimuli. This result is consistent with Berger and colleagues' (2012) proposition that sleep loss reduces the attentional 'sharpness' children need to efficiently adjust behavior in emotional situations. Conversely, sleep prepares resources for subsequent emotional challenges. Prior to sleep, there is an accumulation of emotional memories as memory consolidation over wake is inefficient and subject to interference (Payne, Stickgold, Swanberg & Kensinger, 2008). Naps reduce this emotional load: emotional memories are consolidated (Benedict *et al*., 2009; Cairney *et al*., 2015; Groch *et al*., 2011; Payne *et al*., 2015) and reactivity to emotional stimuli is altered (Baran *et al*., 2012; Walker, 2009) possibly in conjunction with synaptic downscaling (Tononi & Cirelli, 2006) or a 'reset' of functional connectivity between mPFC and amygdala (Yoo, Gujar, Hu, Jolesz & Walker, 2007) with sleep. Thus, the current study supports the notion that with reduced emotional load, children are better able to process emotional stimuli, as evidenced by reduced attentional biases in the Dot Probe task following nap.

The effect of nap deprivation on attention bias was greater for children who napped habitually compared to those who did not. Importantly, napping eliminated attention bias towards emotional stimuli for both habitually and non-habitually napping children; it was the wake condition that differed across groups. Likewise, declarative memory consolidation over naps was shown to be similar for habitually and non-habitually napping children, but the 'impairments' following an interval awake were greater for those who napped habitually (Kurdziel *et al*., 2013). The differential effects of nap deprivation in these two groups may reflect changes in brain maturation that are believed to coincide with the transition from biphasic to monophasic patterns of sleep (Lam, Mahone, Mason & Scharf, 2011). Given the small samples tested in this study, additional research is needed to better understand the effects of napping on attention biases among habitually and non-habitually napping children, particularly with regard to interactions with emotion and gender.

Although sleep measures were not related to post-nap attention bias scores, enhanced efficiency in speed of

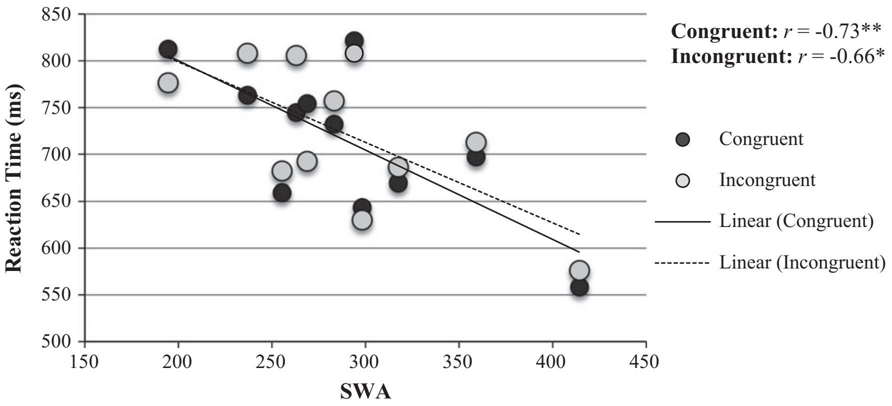

Figure 5 *Correlations between SWA recorded during the nap and reaction time to both congruent and incongruent trials presented during the Dot Probe task following the nap interval (*n *= 11; *p < .05; **p < .01).*

responses made in the presence of emotionally salient stimuli was specifically associated with SWA. Children with greater nap SWA had the fastest RTs for congruent trials during which the probe appeared in place of a happy or angry face. This pattern suggests that SWA may support more efficient processing of emotional stimuli. We also observed a similar relationship between SWA and RTs on incongruent trials. As such, this result may indicate that SWA is associated with an overall improvement in attention allocation, regardless of the emotional salience of stimuli. However, considering that even on incongruent trials emotional stimuli were nonetheless present, SWA may facilitate efficient processing whenever presented with an emotional challenge. Subsequent studies should include blocks of neutral trials alone (in which both faces in a pair are neutral) to better understand the relationship between SWA and processing efficiency for neutral versus emotional stimuli.

Slow wave activity reflects synchronized neocortical oscillations, which have been proposed to contribute to brain plasticity (Greene & Frank, 2010) and memory consolidation (Diekelmann & Born, 2010). As SWA has previously been associated with emotional memory consolidation (Benedict *et al*., 2009; Cairney *et al*., 2015; Groch *et al*., 2011; Kurdziel & Spencer, 2015; Payne *et al*., 2015) and in the current study is linked to enhanced efficiency of attention allocation in the presence of emotional stimuli, we believe these findings support our hypothesis that emotional load is reduced following a nap.

Interestingly, we found gender differences in attention biases such that females tended to be more emotionally reactive to positive than negative stimuli whereas males tended to be more reactive to negative than positive stimuli (Figure 3), regardless of condition. Waters and colleagues (2004) likewise found gender differences in emotional attention biases; however, females (9–12 years) showed a stronger attention bias toward fear-related stimuli than toward pleasant stimuli. In contrast, our results in young children are consistent with findings in young adults with high and low levels of anxiety where attention to negative stimuli is greater in males relative to females (Koster, Crombez, Verschuere, Van Damme & Wiersema, 2006). These gender differences are also aligned with the distinct physiological and behavioral stress responses typical of males and females as outlined in the 'Tend and Befriend' theory (Taylor, Klein, Lewis, Gruenewald, Gurung *et al*., 2000). In this theory, it is postulated that under stressful conditions, females seek companionship whereas males respond in a more 'fight' (aggression) or 'flight' (social withdrawal) manner. As sleep loss increases stress in both children and adults (Weissbluth, 1989; Richardson, 2007), nap deprivation may bring about the gender differences that Taylor and colleagues (2000) outline. However, whether or not nap deprivation confers similar stressful outcomes among young children warrants future research.

Although this study underscores the associations between nap deprivation and increased emotional attention bias, a limitation of this work is the number of children that were excluded from our sample due to low accuracy on the task. The average age of children excluded for low accuracy (~45 months) was less than that of children included in final analyses (~55 months), indicating that younger children had more difficulty performing the task. To our knowledge, the Dot Probe task has not been used in samples of children younger than 4 years of age (Swartz *et al*., 2011; Briggs-Gowan *et al*., 2015). Moreover, the loss rate reported in this study is similar to others in the field that report that 15–16% of their young sample did not achieve 60% accuracy criteria on the task (Kujawa, Torpey, Kim, Hajcak, Rose *et al.*, 2011; Pérez-Edgar *et al.*, 2011; Briggs-Gowan *et al.*, 2015).

Conclusions

Collectively, the results of this study suggest that naps have a function in reducing attention to emotional stimuli during early childhood. Without a mid-day nap, attention to emotional stimuli is heightened and may impair the child's ability to regulate emotions. As emotional attention biases (Bradley *et al.*, 1998; Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg & van IJzendoorn, 2010; Cisler & Koster, 2010; Pérez-Edgar *et al.*, 2011; Morales *et al.*, 2015) and sleep impairments (see Walker & Harvey, 2010) coincide with behavior problems and psychological disorders, this study takes an important step in advancing our knowledge of the associations between early childhood sleep and emotional processes. Having used both experimental manipulation (nap vs. wake intervals, within-subject) and individual differences (habitual vs. non-habitual napping), this study provides a more comprehensive understanding of the role that sleep plays in modulating risk for psychopathology via modulation of attention mechanisms and may also contribute to novel intervention and treatment strategies for emotional issues among young children.

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References

Alfarra, R., Fins, A.I., Chayo, I., & Tartar, J.L. (2015). Changes in attention to an emotional task after sleep deprivation: neurophysiological and behavioral findings. *Biological Psychology*, **104**, 1–7. doi:10.1016/j.biopsycho.2014.11.001

American Academy of Sleep Medicine & Iber, C. (2007). *The AASM manual for the scoring of sleep and associated events: Rules, terminology, and technical specifications*. Westchester, IL: American Academy of Sleep Medicine.

Baran, B., Pace-Schott, E.F., Ericson, C., & Spencer, R.M.C. (2012). Processing of emotional reactivity and emotional memory over sleep. *Journal of Neuroscience*, **32** (3), 1035–1042.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M.J. *et al.* (2010). Life-threatening danger and suppression of attention bias to threat. *American Journal of Psychiatry*, **167** (6), 694–698. doi:10.1176/appi.ajp.2009.09070956

Benedict, C., Scheller, J., Rose-John, S., Born, J., & Marshall, L. (2009). Enhancing influence of intranasal interleukin-6 on slow-wave activity and memory consolidation during sleep. *FASEB Journal*, **23** (10), 3629–3636. doi:10.1096/fj.08-122853

Berger, R.H., Miller, A.L., Seifer, R., Cares, S.R., & LeBourgeois, M.K. (2012). Acute sleep restriction effects on emotion responses in 30- to 36-month-old children: sleep restriction and emotion in toddlers. *Journal of Sleep Research*, **21** (3), 235–246. doi:10.1111/j.1365-2869.2011.00962.x

Bradley, B.P., Mogg, K., Falla, S.J., & Hamilton, L.R. (1998). Attentional bias for threatening facial expressions in anxiety: manipulation of stimulus duration. *Cognition and Emotion*, **12** (6), 737–753. doi:10.1080/026999398379411

Briggs-Gowan, M.J., Pollak, S.D., Grasso, D., Voss, J., Mian, N.D. *et al.* (2015). Attention bias and anxiety in young children exposed to family violence. *Journal of Child Psychology and Psychiatry*, **56** (11), 1194–1201. doi:10.1111/jcpp.12397

Broeren, S., & Lester, K.J. (2013). Relevance is in the eye of the beholder: attentional bias to relevant stimuli in children. *Emotion*, **13** (2), 262–269. doi:10.1037/a0030598

Cairney, S.A., Durrant, S.J., Power, R., & Lewis, P.A. (2015). Complementary roles of slow-wave sleep and rapid eye movement sleep in emotional memory consolidation. *Cerebral Cortex*, **25** (6), 1565–1575. doi:10.1093/cercor/bht349

Cella, D.F., & Perry, S.W. (1986). Reliability and concurrent validity of three visual-analogue mood scales. *Psychological Reports*, **59** (2), 827–833.

Cisler, J.M., & Koster, E.H.W. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: an integrative review. *Clinical Psychology Review*, **30** (2), 203–216. doi:10.1016/j.cpr.2009.11.003

Cremeens, J., Eiser, C., & Blades, M. (2007). Brief report: Assessing the impact of rating scale type, types of items, and age on the measurement of school-age children's self-reported quality of life. *Journal of Pediatric Psychology*, **32** (2), 132–138. doi:10.1093/jpepsy/jsj119

Dahl, R.E. (1996). The regulation of sleep and arousal: development and psychopathology. *Development and Psychopathology*, **8** (01), 3–27. doi:10.1017/S0954579400006945

Diekelmann, S., & Born, J. (2010). The memory function of sleep. *Nature Reviews Neuroscience*, **11**, 114–126.

Durmer, J.S., & Dinges, D.F. (2005). Neurocognitive consequences of sleep deprivation. *Seminars in Neurology*, **25**, 117–129.

Folstein, M.F., & Luria, R. (1973). Reliability, validity, and clinical application of the visual analogue mood scale. *Psychological Medicine*, **3** (04), 479–486. doi:10.1017/S0033291700054283

Gaffrey, M.S., Luby, J.L., Belden, A.C., Hirshberg, J.S., Volsch, J. *et al.* (2011). Association between depression severity and amygdala reactivity during sad face viewing in depressed preschoolers: an fMRI study. *Journal of Affective Disorders*, **129** (1–3), 364–370. doi:10.1016/j.jad.2010.08.031

Gais, S., & Born, J. (2004). Declarative memory consolidation: mechanisms acting during human sleep. *Learning & Memory*, **11** (6), 679–685.

Grafton, B., Ang, C., & MacLeod, C. (2012). Always look on the bright side of life: the attentional basis of positive affectivity. *European Journal of Personality*, **26** (2), 133–144. doi:10.1002/per.1842

Greene, R.W., & Frank, M.G. (2010). Slow wave activity during sleep: functional and therapeutic implications. *Neuroscientist*, **16**, 618–633.

Groch, S., Wilhelm, I., Diekelmann, S., Sayk, F., Gais, S. *et al.* (2011). Contribution of norepinephrine to emotional memory consolidation during sleep. *Psychoneuroendocrinology*, **36** (9), 1342–1350. doi:10.1016/j.psyneuen.2011.03.006

Iglowstein, I., Jenni, O.G., Molinari, L., & Largo, R.H. (2003). Sleep duration from infancy to adolescence: reference values and generational trends. *Pediatrics*, **111** (2), 302–307. doi:10.1542/peds.111.2.302

Jenni, O.G., & Carskadon, M.A. (2004). Spectral analysis of the sleep electroencephalogram during adolescence. *Sleep*, **27**, 774–783.

Kollins, S.H., López, F.A., Vince, B.D., Turnbow, J.M., Farrand, K. *et al.* (2011). Psychomotor functioning and alertness with guanfacine extended release in subjects with attention-deficit/hyperactivity disorder. *Journal of Child and Adolescent Psychopharmacology*, **21** (2), 111–120. doi:10.1089/cap.2010.0064

Koster, E., Crombez, G., Verschuere, B., Van Damme, S., & Wiersema, J. (2006). Components of attentional bias to threat in high trait anxiety: facilitated engagement, impaired disengagement, and attentional avoidance. *Behaviour Research and Therapy*, **44** (12), 1757–1771. doi:10.1016/j.brat.2005.12.011

Kujawa, A.J., Torpey, D., Kim, J., Hajcak, G., Rose, S. *et al.* (2011). Attentional biases for emotional faces in young children of mothers with chronic or recurrent depression. *Journal of Abnormal Child Psychology*, **39** (1), 125–135. doi:10.1007/s10802-010-9438-6

Kurdziel, L., Duclos, K., & Spencer, R.M.C. (2013). Sleep spindles in midday naps enhance learning in preschool children. *Proceedings of the National Academy of Sciences, USA*, **110** (43), 17267–17272. doi:10.1073/pnas.1306418110

Kurdziel, L.B.F., & Spencer, R.M.C. (2015, June). The delayed benefit of a nap on emotional memory consolidation in preschool-aged children. Poster presented at the 29th annual meeting of the Associated Professional Sleep Societies, Seattle, WA.

Lam, J.C., Mahone, E.M., Mason, T., & Scharf, S.M. (2011). The effects of napping on cognitive function in preschoolers. *Journal of Developmental and Behavioral Pediatrics*, **32** (2), 90–97. doi:10.1097/DBP.0b013e318207ecc7

Lim, J., & Dinges, D.F. (2008). Sleep deprivation and vigilant attention. *Annals of the New York Academy of Sciences*, **1129** (1), 305–322. doi:10.1196/annals.1417.002

Lindstrom, K.M., Guyer, A.E., Mogg, K., Bradley, B.P., Fox, N.A. *et al.* (2009). Normative data on development of neural and behavioral mechanisms underlying attention orienting toward social-emotional stimuli: an exploratory study. *Brain Research*, **1292**, 61–70. doi:10.1016/j.brainres.2009.07.045

LoBue, V., Matthews, K., Harvey, T., & Thrasher, C. (2014). Pick on someone your own size: the detection of threatening facial expressions posed by both child and adult models. *Journal of Experimental Child Psychology*, **118**, 134–142. doi:10.1016/j.jecp.2013.07.016

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology*, **95** (1), 15–20.

Maldonado, C.C., Bentley, A.J., & Mitchell, D. (2004). A pictorial sleepiness scale based on cartoon faces. *Sleep*, **27** (3), 541–550.

Miller, A.L., Seifer, R., Crossin, R., & LeBourgeois, M.K. (2014). Toddler's self-regulation strategies in a challenge context are nap-dependent. *Journal of Sleep Research*, **24** (3), 279–287. doi:10.1111/jsr.12260

Morales, S., Pérez-Edgar, K.E., & Buss, K.A. (2015). Attention biases towards and away from threat mark the relation between early dysregulated fear and the later emergence of social withdrawal. *Journal of Abnormal Child Psychology*, **43**, 1067–1078. doi:10.1007/s10802-014-9963-9

Nozadi, S.S. (2014). Preschoolers' selective attention towards emotional information. Arizona State University. Retrieved from http://repository.asu.edu/attachments/143441/content/seyednozadi_asu_0010E_14580.pdf

Payne, J.D., Kensinger, E.A., Wamsley, E.J., Spreng, R.N., Alger, S.E. *et al.* (2015). Napping and the selective consolidation of negative aspects of scenes. *Emotion*, **15** (2), 176–186. doi:10.1037/a0038683

Payne, J.D., Stickgold, R., Swanberg, K., & Kensinger, E.A. (2008). Sleep preferentially enhances memory for emotional components of scenes. *Psychological Science*, **19** (8), 781–788.

Pérez-Edgar, K., Reeb-Sutherland, B.C., McDermott, J.M., White, L.K., Henderson, H.A. *et al.* (2011). Attention biases to threat link behavioral inhibition to social withdrawal over time in very young children. *Journal of Abnormal Child Psychology*, **39** (6), 885–895. doi:10.1007/s10802-011-9495-5

Richardson, G.S. (2007). Human physiological models of insomnia. *Sleep Medicine*, **8**, S9–S14. doi:10.1016/S1389-9457(08)70003-0

Swartz, J.R., Graham-Bermann, S.A., Mogg, K., Bradley, B.P., & Monk, C.S. (2011). Attention bias to emotional faces in young children exposed to intimate partner violence. *Journal of Child & Adolescent Trauma*, **4** (2), 109–122. doi:10.1080/19361521.2011.573525

Taylor, S.E., Klein, L.C., Lewis, B.P., Gruenewald, T.L., Gurung, R.A. *et al.* (2000). Biobehavioral responses to stress in females: tend-and-befriend, not fight-or-flight. *Psychological Review*, **107** (3), 411–429.

Tononi, G., & Cirelli, C. (2006). Sleep function and synaptic homeostasis. *Sleep Medicine Reviews*, **10**, 49–62. doi:10.1016/j.smrv.2005.05.002

Tottenham, N., Tanaka, J.W., Leon, A.C., McCarry, T., Nurse, M. *et al.* (2009). The NimStim set of facial expressions: judgments from untrained research participants. *Psychiatry Research*, **168** (3), 242–249. doi:10.1016/j.psychres.2008.05.006

Troller-Renfree, S., McDermott, J.M., Nelson, C.A., Zeanah, C.H., & Fox, N.A. (2015). The effects of early foster care intervention on attention biases in previously institutionalized children in Romania. *Developmental Science*, **18** (5), 713–722. doi:10.1111/desc.12261

Walker, M.P. (2009). The role of sleep in cognition and emotion. *Annals of the New York Academy of Sciences*, **1156** (1), 168–197. doi:10.1111/j.1749-6632.2009.04416.x

Walker, M.P., & Harvey, A.G. (2010). Obligate symbiosis: sleep and affect. *Sleep Medicine Reviews*, **14** (4), 215–217. doi:10.1016/j.smrv.2010.02.003

Waters, A.M., Lipp, O.V., & Spence, S.H. (2004). Attentional bias toward fear-related stimuli: an investigation with nonselected children and adults and children with anxiety disorders. *Journal of Experimental Child Psychology*, **89** (4), 320–337. doi:10.1016/j.jecp.2004.06.003

Weissbluth, M. (1989). Sleep-loss stress and temperamental difficultness: psychobiological processes and practical considerations. In G.A. Kohnstamm, J.E. Bates, & M.K. Rothbart (Eds.), *Temperament in childhood* (pp. 357–375). Chichester: Wiley.

Yoo, S.-S., Gujar, N., Hu, P., Jolesz, F.A., & Walker, M.P. (2007). The human emotional brain without sleep: a prefrontal amygdala disconnect. *Current Biology*, **17** (20), R877–R878.

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