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Shorter Sleep Duration and Longer Sleep Onset Latency are Related to Difficulty Disengaging Attention from Negative Emotional Images in Individuals with Elevated Transdiagnostic Repetitive Negative Thinking

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Abstract

Background and Objectives:

Repetitive negative thinking (RNT) is often associated with disruptions in sleep and circadian rhythms. Disruptions in sleep and circadian rhythms may deal a “second hit” to attentional control deficits. This study evaluated whether sleep and circadian rhythm disruptions are related to the top-down control of attention to negative stimuli in individuals with heightened repetitive negative thinking.

Methods:

Fifty-two community adults with high levels of transdiagnostic RNT and varying habitual sleep durations and bedtimes participated in a hybrid free-viewing and directed attention task using pairs of emotionally-evocative and neutral images while eye-tracking data were collected. Self-report and clinician-administered interviews regarding sleep were also collected.

Results:

Shorter habitual sleep duration was associated with more time looking at emotionally negative compared to neutral images during a free-viewing attention task and more difficulty disengaging attention from negative compared to neutral images during a directed attention task. In addition, longer sleep onset latencies were also associated with difficulty disengaging attention from negative stimuli. The relations between sleep and attention for positive images were not statistically significant.

Limitations:

A causal link between sleep and attentional control cannot be inferred from these cross-sectional data. The lack of a healthy control sample means that the relations between sleep disruption, attention, and emotional reactivity may not be unique to individuals with RNT

Conclusions:

These findings suggest that sleep disruption may be associated with a specific impact on cognitive resources that are necessary for the top-down inhibitory control of attention to emotionally negative information.

Keywords: sleep, repetitive negative thinking, attention

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The term repetitive negative thinking (RNT) has recently been coined to describe a transdiagnostic process of abstract, perseverative, negative focus on one's problems and experiences that is difficult to control (Ehring & Watkins, 2008; Ehring et al., 2011). RNT is related to several anxiety and mood symptoms (Abela, Brozina, & Haigh, 2002; Blagden & Craske, 1996; Calmes & Roberts, 2007; Demeyer, De Lissnyder, Koster, & De Raedt, 2012; Hong, 2007; McEvoy & Brans, 2013; Nolen-Hoeksema, 1991; Starr & Davila, 2012; Wahl, Ertle, Bohne, Zurowski, & Kordon, 2011), with topographical differences in content (e.g., worry about the future in generalized anxiety disorder, rumination about the past in major depressive disorder), but a shared core process across disorders (Ehring et al., 2011; McEvoy & Brans, 2013). Understanding the mechanisms of RNT is a priority for continuing to develop clinical interventions.

Attentional biases in the presence of emotional stimuli may be a mechanistic risk and/or maintenance factor for RNT. Attention biases related to emotion can be conceptualized as the product of interactions between bottom-up, stimuli-driven associative systems and top-down, rule-based systems (Beevers, 2005; Cisler & Koster, 2010; Ouimet, Gawronski, & Dozois, 2009). For an individual with heightened anxiety, a stimulus may activate numerous threat-related connections in associative systems, thus prioritizing it for attention to maintain safety. For an individual with low mood, a stimulus may activate numerous loss-related associations. Shortly following this orienting, rule-based systems are thought to come into play and the conscious interpretation of the stimulus as threatening or benign impacts the ongoing attention allocation (Ouimet et al., 2009). The top-down integration of the stimulus with information about the given context and on-going goals can influence the allocation of attention toward the stimulus, or divert it (Ouimet et al., 2009). When the context or goals do not require attention to the stimulus and the influence of top-down processes is strong, individuals can disengage their attention from stimuli.

Individuals with heightened levels of RNT have difficulty disengaging their attention (a top-down process) from negatively-valenced emotional information (Ehring & Watkins, 2008). This may reflect a trait-like risk factor that contributes to increased RNT in certain individuals. However, top-down processes may also be affected by an individual's state in ways that produce or exacerbate difficulty disengaging attention from negative emotional information.

Individuals with heightened levels of RNT often experience disruptions in their sleep and circadian rhythms (Belleville, Cousineau, Levrier, & St-Pierre-Delorme, 2011; Harvey, 2011). Disruptions in sleep and circadian rhythms are known to affect basic cognitive functions, like attention (Bocca & Denise, 2006; Lim & Dinges, 2010). For example, chronic sleep restriction (Banks & Dinges, 2007) has been shown to cause impairments in cognitive functioning (Berger, Miller, Seifer, Cares, & Lebourgeois, 2012; Van Dongen, Maislin, Mullington, & Dinges, 2003). Independently, circadian rhythms in attention can also be seen when sleep deprivation is held constant in a forced desynchrony protocol (Valdez, Reilly, & Waterhouse, 2008). Treatment of sleep disorders has been associated with improvements in psychiatric symptoms (Belleville et al., 2011; Harvey et al., 2015) and cognitive functioning appears to improve when sleep and circadian rhythms are restored (Belenky et al., 2003; Berger et al., 2012).

Taken together, this could indicate that interventions focused on sleep/circadian rhythms may be clinically useful to treat individuals with heightened levels of RNT with a treatment mechanism of improving cognitive functioning. Previous studies have found that sleep disruption and circadian rhythms are associated with difficulty disengaging from irrelevant information (May & Hasher, 1998) and ignoring threatening information specifically related to sleep (Spiegelhalder, Espie, & Riemann, 2009), but have not found evidence of difficulty disengaging from general threat (Barclay & Ellis, 2013). A more compelling case for using sleep/circadian rhythm interventions would be based on evidence of specific relations between top-down attention control in the presence of negative emotional information and sleep/circadian rhythms.

Understanding the relative strength of relations between sleep (e.g., duration of sleep), circadian rhythms (e.g., timing of sleep/activity) and attention in individuals with heightened levels of RNT will also improve the clinical utility of any observed relations. Sleep and circadian rhythms have documented relations with RNT symptoms in unselected (Coles, Schubert, & Sharkey, 2012) and clinical samples (Coles & Sharkey, 2011; Schubert & Coles, 2013). Indeed, both sleep and circadian rhythm indices are independently related to RNT (Nota & Coles, 2015). A recent study documented that top-down inhibition of inappropriate responses in a go/no-go task was positively related to the amount of sleep reported each night during the past month, but not the timing of sleep, in individuals with relatively heightened RNT (Nota, Schubert, & Coles, 2016b). Sleep and circadian rhythm –focused interventions are not one in the same; therefore, identification of similar unique relations may inform the prescription of sleep restriction or stimulus control interventions for sleep compared to chronotherapy for circadian rhythms.

The current study sampled individuals with heightened levels of RNT as they were hypothesized to have a vulnerability to sleep and circadian disruptions because of a limitation in their inhibitory top-down processing that is served a “second hit” by sleep disruption (Harvey, 2011; Nota & Coles, 2015). These relations were expected to be specific to negatively-valenced and not generalized to positively-valenced stimuli because of the dependence on threat-related associations for these stimuli in individuals with heightened RNT. Acute and chronic disruptions in sleep duration and sleep onset latency were hypothesized to be associated with biases in the allocation of attention in the presence of negatively-valenced stimuli due to impairments in top-down processing. Concurrently, the timing of sleep (reflecting circadian rhythm processes) would be uniquely associated with biases in the allocation of attention. Specifically, shorter sleep duration, longer sleep onset latency, and later bedtimes were hypothesized to be associated with increased time spent engaging with and difficulty disengaging from negative emotional stimuli. Orientation toward negative stimuli was not hypothesized to have a relation with sleep and circadian rhythm disruption (Ouimet et al., 2009).

Methods

Participants

The study was approved by the human subjects committee and in compliance with American Psychological Association standards. Participants were 52 community members from ages 18 to 65 with heightened RNT. A minimum score of 20 on the *Perseverative Thinking Questionnaire* was required. This score approximates the mean in non-clinical samples (Nota & Coles, 2015; Nota et al., 2016b) and individuals who score $\geq$ 20 have been shown to report elevated brooding rumination and worry (Treynor, Gonzalez, & Nolen-Hoeksema, 2003; van Rijsoort, Emmelkamp, & Vervaeke, 1999). Other inclusion criteria (English speaking and normal/corrected to normal vision) and exclusion criteria (current/past psychosis, current substance use disorder, > 1 head injuries or 1 requiring treatment) were minimized for the sake of generalizability.

Recruitment postings were selected to capture heightened RNT (e.g., “Worrying about the future?”, “Bothered by thoughts that keep coming to mind?”) and variability in habitual sleep duration and bedtimes. This included using alternative versions of flyers (e.g., “Are you a night owl?”, “Do you feel like you don’t get enough sleep?”, “Do you have consistent bed and wake times?”) and strategic posting (e.g., posting advertisements on Craigslist, posting flyers at 24-hour stores, etc.). Participants were compensated monetarily ($20).

Ninety-one individuals responded to advertisements. Thirty callers were ineligible at screening for psychosis, age outside of inclusion criteria, substance use, or having insufficiently severe RNT. Nine individuals were invited to participate in the study but subsequently were not included (*n* = 8 did not appear for their appointments, *n* = 1 current substance use disorder diagnosed after screening). Approximately half of the sample was female (55.8%, *n* = 29) and the average age was 35.6 years (*SD* = 13.6). Participants predominantly identified as White (80.8 %, *n* = 42), with smaller proportions endorsing Asian (5.8%, *n* = 3), Hispanic (3.8%, *n* = 2), Black (1.9%, *n* = 1), and other (7.7%, *n* = 4) ethnic identities. Approximately half reported being married (26.9%, *n* =14), living with a partner (11.5%, *n* = 6), or being in a long-term relationship (9.6%, *n* = 5). A minority were living alone at the time of participation (15.4%, *n* = 8). Participants reported between 10 and 22 years of education (*M* = 15.15, *SD* = 2.58).

Measures

Perseverative thinking.

The *Perseverative Thinking Questionnaire (PTQ)* is a content-independent measure of RNT as a process. Higher scores represent increased levels of transdiagnostic RNT (Ehring et al., 2011). Past research supports the psychometric properties of the PTQ (Ehring et al., 2011) and it displayed strong internal consistency in this sample (α = .90).

Sleep and circadian rhythms.

Sleep quality during the past month was assessed via the *Pittsburgh Sleep Quality Index (PSQI;* Buysse, Reynolds III, Monk, Berman, & Kupfer, 1989). The PSQI is a validated self-report measure of global sleep quality across several domains. Notably, higher scores on the PSQI indicate *poorer* sleep quality. The PSQI displayed adequate internal consistency in the current sample (α = .69).

Reports of sleep behavior on the PSQI have been shown to be highly correlated with those obtained from longitudinal sleep diaries (Grandner, Kripke, Yoon, & Youngstedt, 2006). Therefore, we also planned to examine individual items from the PSQI regarding habitual hours slept per night, habitual bedtimes, and average sleep onset latency as measures of these sleep behaviors. This same procedure has been employed in previous studies and has demonstrated these specific aspects of sleep behavior may be differentially associated with arousal and regulatory systems constructs (Nota, Coles, & Sharkey, 2015) and that they may have unique relations with repetitive negative thinking (Nota & Coles, 2015).

Participants also provided their bedtime the night before and their wake time the day of participation; this information was used to calculate hours slept the night before participation (a proximal measure of sleep behavior compared to the monthly average captured by the PSQI) and hours awake on the day of participation (a proximal measure of sleep pressure).

Finally, the first author administered the *Diagnostic Interview for Sleep Patterns and Disorders (DISP)*. The DISP is a structured interview assessing sleep patterns and disorders (Merikangas et al., 2014). Diagnoses made using the DISP scoring algorithms have demonstrated fair to substantial correspondence with those assigned by independent expert clinician interviews

(Merikangas et al., 2014). The second author (a doctoral-level clinical psychologist) confirmed all diagnoses based on chart review.

Attention.

Participant fixation of visual attention was recorded with a Tobii T60XL system. Bright/dark pupil tracking was recorded binocularly at 60 Hz with participants seated 60 cm from a 24" LCD monitor (integrated with the Tobii T60XL) using a refresh rate of 60 Hz. Data were only included for analysis if the validity output provided by the Tobii system indicated that the eye was found and the tracking quality good. No participants were excluded due to calibration issues.

Psychopathology.

The presence of anxiety, mood, substance use, or psychotic disorders were collected to describe the sample and were assessed by the first author (an advanced doctoral-level trainee with rigorous training in the differential diagnosis and comorbidity of anxiety and related disorders using semi-structured and structured interviews) using the structured *Mini International Neuropsychiatric Interview (MINI* for DSM-IV-TR; Sheehan et al., 1997). Symptoms of anxiety and mood disturbance were also assessed via self-report measures. Higher scores on all scales indicate greater severity. Specifically, trait anxiety was assessed with the anxious arousal subscale of the *Mood and Anxiety Symptom Questionnaire (MASQ;* Watson & Clark, 1991; Watson, Weber et al., 1995; Watson, Clark et al., 1995). The MASQ anxious arousal scale displayed good internal consistency in this sample ($\alpha = .92$). Low mood was evaluated with the anhedonic depression subscale of the MASQ. The MASQ anhedonic depression scale had good internal consistency in the current sample ($\alpha = .92$).

Stimuli

Stimuli were selected, based on normative ratings, from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). Specifically, negative images (e.g., guns, knives, threatening animals) were chosen for negative valence and high arousal. Positive images (e.g., sports, natural scenes, and enjoyable activities) were selected for positive valence and high arousal. Neutral images (e.g., household items, individuals engaged in everyday activities) were selected for neutral valence and low arousal. One-factor ANOVAs using Student-Newman-Keuls (S-N-K) post-hoc tests and chi-square tests were used to evaluate the expected characteristics of the stimuli. Consistent with expectations, negative stimuli and positive stimuli had similar valence levels and both groups had valence ratings significantly higher than the neutral images [$F(2,193) = 1290.23$, $p < .001$]. Further, negative and positive stimuli had similar arousal levels and both groups had arousal ratings significantly higher than the neutral images [$F(2,193) = 511.67$, $p < .001$].

Stimuli used in the attention task were randomly assigned to pairs used for all participants. Paired samples t-tests and McNemar chi-square tests were used to ensure that paired images (i.e., negative-neutral, positive-neutral, neutral-neutral) were matched for social content (McNemar Chi Square test, $p = .88$, $n=78$), complexity [$t(77) = 1.54$, $p = .13$, $d = .35$], and luminosity [$t(77) = 1.42$, $p = .16$, $d = .32$]. Further, paired images did not significantly differ in red saturation [$t(77) = -0.24$, $p = .81$, $d = .01$], green saturation [$t(77) = 1.49$, $p = .14$, $d = .34$], or blue saturation [$t(77) = 0.97$, $p = .33$, $d = .22$].

Procedure

Participants were asked several questions over the phone to assess eligibility. Participants provided written informed consent and completed self-report questionnaires (block-randomized across participants). The DISP and MINI interviews were administered in order. Participants were then seated at the Tobii T60XL. After completing a brief calibration procedure, the attention task was administered. Finally, participants were debriefed and compensated.

The attention task (Sanchez, Vazquez, Marker, LeMoult, & Joormann, 2013) was selected as it produces indices of both orientation and disengagement of attention capturing both automatic and volitional aspects of behavior (Nelson, Purdon, Quigley, Carriere, & Smilek, 2015). The task included 78 trials, and is described below (see Figure 1):

1. *Initial Orientation*: A white screen was presented for 500 ms, followed by a black fixation cross on a white background for an additional 500 ms. Participants were instructed to fixate on the cross to continue. The program not continued when they fixated for 100 ms.
2. *Free-Viewing Phase*: Next, participants were instructed to freely watch the screen as image pairs were presented for 5,000 ms. Image pairs were either negative-neutral, positive-neutral, or neutral-neutral (26 trials/pair type); presentation order was randomized by participant. The left or right placement of emotional and neutral images was balanced across trials. In six trials for each image pair type, a new fixation cross appeared immediately following the free-viewing phase, to limit participant anticipation of the engage/disengage phase.
3. *Engage/Disengage Phase*: In the remaining trials, a frame appeared around one of the images and participants were instructed to report whether the frame was a circle or square by pressing corresponding keys. The frames were presented after the participant fixated on one image for 100 ms. For *engage* trials (10 for each pair type), the frame appeared around the emotional (e.g., negative) image after the participant fixated on the neutral image. For *disengage* trials (10 for each pair type), the frame appeared around the neutral

image after the participant fixated on the emotional (e.g., negative) image. To avoid bias, 50% of the trials required participants to shift their attention from right to left and 50% required the opposite.

The free-viewing phase utilizes eye-tracking data to index bottom-up and top-down attention processes without demands and across a relatively long period of stimulus presentation. This differs from a more traditional dot-probe task (Asmundson & Stein, 1994) that infers attention from differences in behavioral response times to probes and may vary stimulus presentation duration. The engage/disengage phase is conceptually similar to a dot-probe task, but is able to more accurately index top-down attention processes. By placing a frame around the stimuli, rather than removing them from the screen and presenting a probe, the participants had to disengage their attention or engage their attention while the stimuli are still present.

Statistical Analyses

The distributions of questionnaire scores were checked for normality and outliers. No outliers were identified, however the MASQ anxious arousal scale was positively skewed and therefore log transformed. Findings were identical using both transformed and untransformed values. Therefore, untransformed values are reported for interpretability.

During the free viewing task, initial fixation biases were calculated as the probability of recording an initial fixation to an emotional stimulus (i.e., negative or positive) as opposed to a neutral stimulus and reflect orientation or initial bottom-up attentional capture of the emotional stimuli, with higher proportions reflecting greater attentional capture. Initial fixation latency biases were calculated as the time between image pair presentation and the first fixation in gaze to an emotional stimulus relative to first fixation in gaze to neutral stimuli in neutral-neutral trials and reflect orientation or initial bottom-up attentional capture, with shorter latencies reflecting greater attentional capture. Fixation duration bias was calculated as the proportion of all fixation time during the 5,000 ms in which the participant fixates on an emotional stimulus and reflects the engagement or attentional capture of the emotional stimuli after the initial orientation, with higher proportions reflecting more sustained attentional capture.

During the engage/disengage phase of the task, the participant was considered to have made a first shift to the stimuli surrounded by the frame if the following conditions were met (a) participants were fixated on the opposite stimulus before the frame appeared, (b) gaze was subsequently redirected to the stimulus surrounded by a frame, (c) participants made a fixation of at least 100 ms to the stimulus surrounded by a frame after shifting their gaze to it, (d) eye movements occurred at least 100 ms and at most 5000 ms after the frame appeared, and (e) the participant correctly identified the frame as either a square or circle. Attentional engagement refers to the latency of the first shift from the neutral stimulus to fixation on the emotional stimulus; with negative latencies reflecting relatively biased engagement compared to engaging neutral stimuli. Attentional disengagement refers to the latency of the first shift from the emotional stimulus to the neutral stimulus; with positive latencies reflecting relatively biased disengagement compared to disengaging neutral stimuli.

Before running analyses, trials comprised of over 50% blinks were removed, resulting in the exclusion of an average of 1.11 trials per participant (*range* = 0–19; *SD* = 3.32 trials). Linear interpolation was used to replace blinks throughout the remaining trials. Blinks comprised an average total of 450 ms per trial (*range* = 35-2550; *SD* = 518 ms). The number of samples replaced using linear interpolation was not significantly correlated with participants' repetitive negative thinking symptoms or their sleep (*p*'s >.37). The distribution of all indices was approximately normal and did not contain outliers. Individual general linear models evaluated the relation between sleep duration and timing variables and attention indices, with sleep variables as between-subjects covariates and emotion (negative, positive) as a within-subjects factor. For engagement/disengagement attention indices, task (engage, disengage) was also included as a within-subjects factor. In all models, predictors were entered simultaneously.

Review of the existing literature examining relations between attention and sleep (Martella, Casagrande, & Lupiáñez, 2011; Versace, Cavallero, De Min Tona, Mozzato, & Stegagno, 2006) suggested this study might expect to find moderate effect sizes (i.e., r_{es} = .35). The sample of 52 individuals provides adequate power (1-β = .78) to find such effects.

Results

Sample Description

Descriptive statistics for the study measures are presented in Table 1 and Table 2. Based on the MINI, 50% (*n* = 26) of the sample met criteria for major depressive disorder, 44.2% (*n* = 23) for generalized anxiety disorder, 36.5% (*n* = 19) for social anxiety disorder, 19.2% (*n* = 10) for obsessive-compulsive disorder, and 13.5% (*n* =7) for panic disorder and/or agoraphobia. Based on the DISP, 19.2% (*n* = 10) of the sample met criteria for primary insomnia and 13.5% (*n* = 7) for circadian rhythm sleep disorder: delayed sleep phase type. Approximately one quarter (26.9%, *n* =14) of the sample currently met criteria for both a psychiatric and sleep disorder; 33.3% of the individuals with any psychiatric disorder and 82.4% of the individuals with any sleep disorder.

Overall Attention Biases

The attention indices were evaluated for evidence of a bias related to emotional content. The proportion of first fixations bias score did not differ from .50 for either negative [$t(51) = -1.82$, $p = .08$, $d = .51$] or positive stimuli [$t(51) = -0.52$, $p = .61$, $d = .15$]. Latency to first fixation bias did not differ from 0 for either negative [$t(51) = -1.21$, $p = .23$, $d = .34$] or positive stimuli [$t(51) = -0.28$, $p = .78$, $d = .08$]. However, there was a significant fixation duration bias for negative [$t(51) = 4.65$, $p < .001$, $d = 1.30$] but not positive stimuli [$t(51) = 1.76$, $p = .09$, $d = .49$]. Participants were slower engaging with negative compared to neutral stimuli [$t(50) = 2.96$, $p = .005$, $d = .83$], but not positive stimuli compared to neutral stimuli [$t(51) = 0.19$, $p = .85$, $d = .05$]. Participants were also slower disengaging from negative compared to neutral stimuli [$t(50) = 4.24$, $p < .001$, $d = 1.20$] but not positive compared to neutral stimuli [$t(51) = 1.11$, $p = .27$, $d = .31$]. Fixation duration bias and disengaging eye-tracking latency bias were both significantly greater for negative stimuli compared to positive stimuli (see Table 3). This is consistent with the hypothesis that individuals with heightened levels of RNT would demonstrate difficulty disengaging attention from negative stimuli. However, significant differences were not found between emotional stimulus types in the proportion of initial fixation bias, initial fixation latency bias, or engaging eye-tracking latency bias. This is consistent with the hypothesis that there would not be biases in the initial orientation of attention toward negative stimuli.

Sleep, Circadian Rhythms, and Attention Biases

Data from the free viewing phase did not reveal any significant main effects or interactions with any measures of sleep duration or timing predicting biases in the proportion of first fixations or latency to first fixations (see Table 4). There was a significant interaction between habitual hours slept and emotion type predicting fixation duration bias. Follow up correlational analyses showed that shorter habitual sleep duration was associated with more time looking at negative compared to neutral stimuli ($r = -.34$, $p = .01$) and this relation remained statistically significant when controlling for anxious arousal and anhedonic depression symptoms ($r = -.35$, $p = .01$). There was not a significant relation between habitual sleep duration and time looking at positive compared to neutral stimuli (*r* = .12, *p* = .39). This is consistent with the hypothesis that chronic sleep duration would be related to the degree of difficulty that individuals with RNT had disengaging attention from negative stimuli.

Data from the engage/disengage portion of the attention task did not reveal any significant main effects or interactions with bedtime or hours awake on the day of participation. There was a significant three-way interaction between sleep onset latency, emotion type, and task (i.e., engage/disengage, see Table 5). Follow up analyses breaking down the interaction by emotion showed a significant main effect of sleep onset latency [$F(1,47) = 5.23$, $p = .03$, $\eta^2 = .10$] qualified by a significant interaction between sleep onset latency and task [$F(1,47) = 7.65$, $p = .01$, $\eta^2 = .14$] in negative stimuli bias. However, there was not a significant main effect of sleep onset latency [$F(1,49) = 0.58$, $p = .45$, $\eta^2 = .01$] or interaction between sleep onset latency and task [$F(1,49) = 0.99$, $p = .33$, $\eta^2 = .02$] in positive stimuli bias. Correlational analyses showed that longer sleep onset latency was significantly related to slower disengaging from negative compared to neutral stimuli (*r* = .39, *p* = .01) and this relation remained statistically significant when controlling for anxious arousal and anhedonic depression symptoms (*r* = .37, *p* = .01). Sleep onset latency was not significantly related to engaging with negative compared to neutral stimuli ($r < .01$, *p* = .98). This is consistent with the hypothesis that chronic sleep onset latency would be related to the degree of difficulty that individuals with RNT had disengaging attention from negative stimuli.

There was also a significant three-way interaction between habitual hours slept, emotion, and task during the engage/disengage portion of the attention task. Follow up analyses breaking down the interaction by emotion showed no significant main effect of habitual hours slept [$F(1,48) = 1.81$, $p = .19$, $\eta^2 = .04$], but there was a significant interaction between habitual hours slept and task [F(1,48) = 7.16, p = .01, η^2 = .13] in negative stimuli bias. There was not a significant main effect of habitual hours slept [F(1,50) = 0.47, p = .50, η^2 = .01] or interaction between habitual hours slept and task [F(1,50) = 0.66, p = .42, η^2 = .01] in positive stimuli bias. Correlational analyses showed that shorter habitual sleep duration was significantly related to slower disengaging from negative compared to neutral stimuli (r = - .33, p = .02) and this relation remained statistically significant when controlling for anxious arousal and anhedonic depression symptoms (r = - .32, p = .02). Habitual sleep duration was not significantly related to engaging with negative compared to neutral stimuli (r = .13, p = .38). This is consistent with the hypothesis that chronic sleep duration would be related to the degree of difficulty that individuals with RNT had disengaging attention from negative stimuli.

Finally, there was a significant main effect of hours slept the night before participation during the engage/disengage portion of the attention task. Follow up correlational analyses showed that having slept fewer hours the night before participation was significantly associated with slower engaging and disengaging with all emotional stimuli compared to neutral stimuli (r = - .41, p = .003). This relation remained statistically significant when controlling for anxious arousal and anhedonic depression symptoms (r = - .39, p = .01). This is partially consistent with the hypothesis that acute sleep duration would be related to the degree of difficulty disengaging that individuals with RNT had disengaging attention from negative stimuli, but did not show the expected specificity to these stimuli compared to positive stimuli.

Discussion

This study tested the hypothesis that sleep disruption would be associated with impairments in top-down attentional processing in individuals recruited for high levels of RNT. Indeed, measures of habitual sleep pressure (i.e., shorter habitual sleep times and longer sleep onset latency) were associated with spending a greater proportion of time looking at negative emotional stimuli and slower disengaging from negative images. Previous studies have found that sleep disruptions are associated with difficulty disengaging from threatening information specifically related to sleep (Spiegelhalder et al., 2009), but have not found evidence of difficulty disengaging from general threat (Barclay & Ellis, 2013). Therefore, this study may be among the first to document a relation between sleep and emotional information processing biases. The pattern of results in this study suggest that individuals with heightened levels of RNT and greater degrees of chronic sleep pressure demonstrate a specific effect on “top-down” direction of attention. Indeed, there were no significant relations between habitual sleep or circadian rhythm measures and orientation of attention in the presence of negative emotional stimuli.

It is notable that this sample of individuals with heightened RNT demonstrated biases in disengagement of attention from negative emotional content, but not orientation. Indeed, there was evidence of attention biases in disengagement from negative compared to neutral stimuli specifically. The current study’s careful control for visual characteristics of stimuli (e.g., luminosity, social content, color saturation) and balancing of emotional characteristics (e.g., valence, arousal) allows for relative confidence that the participants’ difficulty disengaging from the negative stimuli is because of their association with threat (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Rebetez, Rochat, Billieux, Gay, & Van der Linden, 2015; Schmidt, Belopolsky, & Theeuwes, 2015). These data are consistent with increasing evidence that differences in top-down attentional processes may be more consistently found in individuals with heightened RNT (Genet, Malooly, & Siemer, 2013; Nelson et al., 2015; Pacheco-Unguetti, Acosta, Callejas, & Lupianez, 2010; Quigley, Nelson, Carriere, Smilek, & Purdon, 2012; Southworth, Grafton, MacLeod, & Watkins, 2016).

The relation between sleep disruption and disengagement of attention may be explained by a reduction in available cognitive resources, particularly those needed to inhibit information and handle novel information (Boonstra, Stins, Daffertshofer, & Beek, 2007; Drummond, Paulus, & Tapert, 2006). It is possible that sleep disruption deals a “second hit” to attention control in individuals who are already vulnerable in their subjective and/or physiological responses to negative information (Harvey, Murray, Chandler, & Soehner, 2011; Mitchell, Mogg, & Bradley, 2012; Nota et al., 2016b). Therefore, the already difficult task of inhibiting negative information and redirecting attention to more pertinent information is made even more difficult.

Contrary to expectations, there were no significant relations observed between bedtimes, an index of circadian rhythm functioning, and top-down control of attention (Kohyama, 2011). A recent study examining sleep duration, bedtime, and response inhibition demonstrated the same pattern of results (Nota et al., 2016b). Taken together, this may suggest that arousal systems and homeostatic sleep processes may underlie the relations between habitual sleep duration, sleep onset latency, and top-down control of attention (Harvey et al., 2011; Nota, Coles, & Sharkey, 2015; Wulff et al., 2010); further study will continue to elucidate the processes involved (Kalanthroff et al., 2016; Nota, Schubert, & Coles, 2016a).

Several limitations must be considered in the interpretation of these findings. First, a causal link between sleep and attentional control cannot be inferred from these cross-sectional data. The associations reported herein may also indicate that top-down attentional control deficits in the presence of negative stimuli are related to sleep disruptions. Second, the lack of a healthy control sample means that the relations between sleep disruption, attention, and emotional reactivity may not be unique to individuals with RNT. However, the choice of sample was partially based on previous evidence suggesting that the relation between sleep disruption and executive functioning is stronger in individuals with elevated RNT (Nota et al., 2016b). Third, the pattern of findings could indicate that, rather than specific difficulty disengaging attention from negative stimuli, there was a general slowing in overt attention when negative stimuli were presented. Indeed, previous studies have suggested that non task-relevant emotional stimuli may cause a general slowing of reactions (Erthal et al., 2005). Information about the participants' conscious experience of the attention tasks was not collected in the current study. It could be the case that they actively chose to look at the negative stimuli for longer periods, as this is a phenomenon that has been found in other studies (Fawcett et al., 2015). This could reflect a lack of interest or effort in performing the study tasks. However, none of the measures of sleep were associated with the number of trials excluded from analyses. Finally, this study did not have objective measures of sleep to compare with self-reports. Future studies that include actigraphy and sleep diaries may provide complementary information to supplement these findings.

Further study is needed to understand how sleep and circadian rhythm disruptions interact with the allocation of attention. Thus far, the evidence suggests a bidirectional relation between RNT and sleep disruption (Guastella & Moulds, 2007; Takano, Iijima, & Tanno, 2012; Takano, Sakamoto, & Tanno, 2014; Thielsch et al., 2015). Researchers have hypothesized that executive functioning may be a mechanism of this relation (Cox, Ebesutani, & Olatunji, 2016; Harvey et al., 2011; Takano et al., 2012) and further study is needed. This study supports other evidence that sleep disruption is common in a population recruited for high levels of RNT and is a novel demonstration that sleep duration is related to top-down, but perhaps not bottom-up, attentional functioning. Given the paucity of research on these relations, various top-down and bottom-up attention indices were examined in relation to theoretically distinct sleep-related indices without a correction for Type I error. It may be the case that these findings are due to chance. Nonsignificant relations with bottom-up measures of attention may also be attributable to insufficient power (i.e., Type II error). However, these preliminary findings are consistent with hypotheses and suggest further study with larger samples. If future studies replicate this pattern of findings in longitudinal and experimental designs with healthy control groups, this would support attentional allocation as a mechanism for the demonstrated longitudinal relationship between improvements in sleep duration and sleep timing and reductions in psychopathology symptoms (Belleville et al., 2011; Harvey et al., 2015).

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Table 1.

Sleep, Repetitive Negative Thinking, and Psychopathology Descriptive Statistics

	M (*SD*)	Min - Max
Bedtime	12:01 AM (2 h : 37 m)	4:30 PM - 11 AM
Sleep Onset Latency	38 m : 9s (29 m : 53s)	4 m - 150 m
Habitual Hours Slept	6 h : 12 m (1 h : 19 m)	3 h - 9 h
Sleep Quality	9.79 (3.81)	1 – 18
Hours Awake Today	5 h : 27 m (2 h : 57 m)	1 – 14
Hours Slept Last Night	7 h : 20 m (3 h : 8 m)	3 – 26
PTQ	38.35 (9.20)	20 – 58
MASQ-Anxious Arousal	30.13 (11.91)	17 – 77
MASQ- Anhedonic Depression	69.54 (15.06)	34 – 101

Note. STAI = State-Trait Anxiety Inventory, MASQ = Mood and Anxiety Symptom Questionnaire, PTQ = Perseverative Thinking Questionnaire.

Table 2.

Zero-Order Correlations Among Sleep, Repetitive Negative Thinking and Psychopathology.

	Bedtime	Sleep Onset Latency	Hours Slept	Sleep Quality	Hours Awake Today	PTQ	MASQ-Anxious Arousal	MASQ-Anhedonic Depression
Bedtime	--					.08	.10	.12
Sleep Onset Latency	- .15	--				- .11	.27*	.14
Habitual Hours Slept	.03	- .45**	--			.25	- .12	- .06
Sleep Quality	- .07	.63**	- .65**	--		- .01	.39**	.19
Hours Awake Today	- .20	.06	- .12	.09	--	- .17	- .06	.08
Hours Slept Last Night	.11	- .10	.16	- .05	.09	- .04	- .12	- .30*

Note. * $p < .05$, ** $p \leq .01$

Table 3.

Orienting and Disengaging Biases By Stimulus Valence

	Negative *M (SD)*	Positive *M (SD)*	*F*	*df*	*p*	η^2
Orienting						
Proportion Initial Fixations Bias	.479 (.08)	.495 (.07)	1.25	1, 51	.27	.02
Initial Fixation Latency Bias	-5.32 (31.60)	- 1.50 (38.79)	0.55	1, 51	.46	.01
Eye-Tracking Engage Bias	49.29 (119.11)	3.94 (148.16)	2.97	1, 50	.09	.06
Disengaging						
Proportion Fixation Duration Bias	.545 (.05)	.514 (.04)	9.48	1, 51	.003	.16
Eye-Tracking Disengage Bias	124.68 (209.83)	26.32 (171.52)	9.08	1, 50	.004	.15

Table 4.

General Linear Models Evaluating Relations Between Free-Viewing Attention Indices and Sleep

	Proportion Initial Fixation Bias			Initial Fixation Latency Bias			Proportion Fixation Duration Bias		
	F	*df*	η^2	*F*	*df*	η^2	*F*	*df*	η^2
Bedtime									
Emotion	1.25	1,50	.02	0.54	1,50	.01	5.83*	1,50	.10
Bedtime	0.06	1,50	< .01	0.01	1,50	< .01	0.11	1,50	< .01
Emotion x Bedtime	0.75	1,50	.02	< 0.01	1,50	< .01	0.94	1,50	.02
Sleep Onset Latency									
Emotion	2.22	1,49	.04	1.59	1,49	.03	0.11	1,49	< .01
Sleep Onset Latency	0.42	1,49	.01	1.16	1,49	.02	1.66	1,49	.03
Emotion x Sleep Onset Latency	1.04	1,49	.02	0.92	1,49	.02	2.02	1,49	.04
Habitual Hours Slept									
Emotion	0.23	1,50	.01	0.28	1,50	.01	8.88**	1,50	.15
Habitual Hours Slept	0.48	1,50	.01	0.10	1,50	< .01	1.98	1,50	.04
Emotion x Habitual Hours Slept	0.52	1,50	.01	0.48	1,50	.01	6.30*	1,50	.11
Sleep Quality									
Emotion	0.12	1,50	< .01	0.88	1,50	.02	0.31	1,50	.01
Sleep Quality	0.14	1,50	< .01	1.92	1,50	.04	0.63	1,50	.01
Emotion x Sleep Quality	< 0.01	1,50	< .01	0.52	1,50	.01	2.38	1,50	.05
Hours Awake Today									
Emotion	0.31	1,50	.01	0.60	1,50	.01	7.42**	1,50	.13
Hours Awake Today	2.26	1,50	.04	0.43	1,50	.01	< 0.01	1,50	< .01
Emotion x Hours Awake Today	< 0.01	1,50	< .01	0.23	1,50	.01	3.12	1,50	.06
Hours Slept Last Night									
Emotion	4.78*	1,50	.09	4.36*	1,50	.08	6.64**	1,50	.12
Hours Slept Last Night	2.98	1,50	.06	0.16	1,50	< .01	0.04	1,50	< .01
Emotion x Hours Slept Last Night	3.57	1,50	.07	3.78	1,50	.07	3.08	1,50	.06

Note. * $p < .05$, ** $p \leq .01$

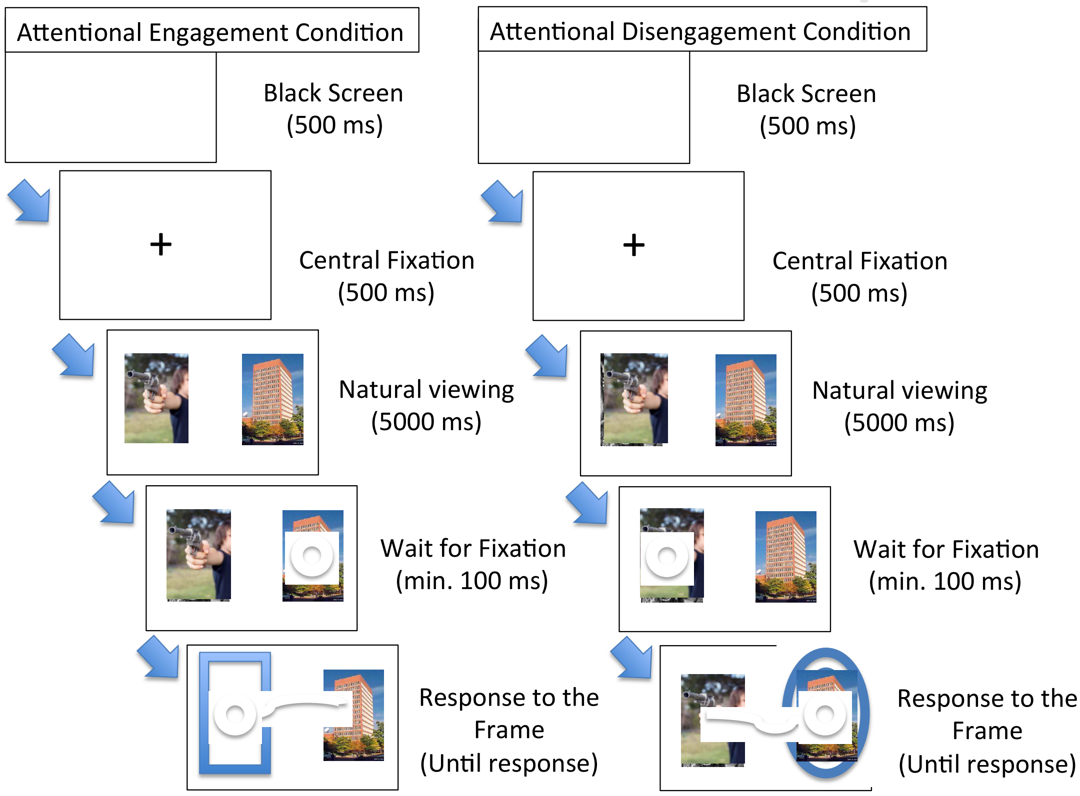
Table 5.

General Linear Models Evaluating Relations Between Engage/Disengage Attention Indices and Sleep

	Bedtime (df = 1,48)		Sleep Onset Latency (df = 1,47)		Habitual Hours Slept (df = 1,48)		Sleep Quality (df = 1,48)		Hours Awake Today (df = 1,48)		Hours Slept Last Night (df = 1,48)	
	F	η^2	F	η^2	F	η^2	F	η^2	F	η^2	F	η^2
Emotion	13.68**	.22	1.28	.03	9.79**	.17	< 0.01	< .01	5.39*	.10	6.86**	.13
Task	6.81**	.12	0.29	.01	4.72*	.09	0.33	.01	1.74	.04	0.16	< .01
Sleep	1.17	.02	2.93	.06	0.03	< .01	1.54	.03	1.73	.04	9.64**	.17
Emotion x Sleep	0.09	< .01	2.17	.04	5.66*	.11	2.25	.05	0.43	.01	1.52	.03
Task x Sleep	< 0.01	< .01	2.42	.05	2.74	.05	2.72	.05	0.01	< .01	0.50	.01
Emotion x Task	2.49	.05	1.00	.02	7.52**	.14	1.42	.03	1.93	.04	0.02	< .01
Emotion x Task x Sleep	1.03	.02	7.08**	.13	5.99*	.11	3.65	.07	0.52	.01	0.27	.01

Note. * $p < .05$, ** $p \leq .01$

Figure 1. Attention Task Schematic



Highlights

- Relations between sleep duration, sleep timing, and attention were examined
- Shorter sleep duration correlated with more time looking at negative stimuli
- Shorter sleep duration correlated with slower disengaging from negative stimuli
- Longer sleep onset latency correlated with slower disengaging from negative stimuli
- Fewer hours of sleep last night correlated with slower overall engaging/disengaging

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