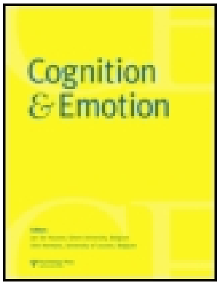

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Poorer sleep quality is associated with lower emotion-regulation ability in a laboratory paradigm

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BRIEF REPORT

Poorer sleep quality is associated with lower emotion-regulation ability in a laboratory paradigm

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Theoretical models suggest a positive relationship between sleep quality and individuals' ability to regulate emotion. However, few studies have empirically tested this hypothesised link using standardised laboratory measures of emotion-regulation ability. The present research examined the relationship between sleep quality and the ability to implement a type of emotion regulation that has particularly important implications for psychological health: cognitive reappraisal (cognitively reframing an emotional event so as to dampen its impact). To do so, 156 participants (86 male) reported on their past week's sleep quality. Their ability to implement cognitive reappraisal (CRA) was then measured with a standardised laboratory challenge. Participants with poorer self-reported sleep quality exhibited lower CRA, even after controlling for fourteen potential key confounds (e.g., age, negative affect, mood disorder symptoms, stress). This finding is consistent with the idea that poorer sleep quality impairs individuals' ability to engage in the crucial task of regulating negative emotions.

Keywords: Sleep quality; Emotion-regulation ability; Cognitive reappraisal.

> Without enough sleep, we all become tall two-year-olds.
>
> JoJo Jensen (2002), *Dirt Farmer Wisdom*

People commonly report that disturbed sleep leads them to experience irritability and mood difficulties (Horne, 1985). This perception is supported by observational and experimental studies, which suggest poorer sleep quality (i.e., difficulties initiating or maintaining sleep and/or non-restorative sleep) is associated with—and may

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causally contribute to—mood instability and even mood disorders (Baglioni, Spiegelhalder, Lombardo, & Riemann, 2010; Bower, Bylsma, Morris, & Rottenberg, 2010; Dinges et al., 1997; Harvey, 2008; Perlis, Giles, Buysse, Tu, & Kupfer, 1997). For example, Ford and Kamerow (1989) showed that sleep disturbance can precede the onset of depression. These observations raise the key question of *how* poor sleep quality may contribute to mood instability and disorders (Harvey, 2008; Walker & van der Helm, 2009).

Several pieces of evidence suggest that the ability to regulate one's emotion (e.g., to decrease experience of negative emotion) may be a key link in the relationship between poor sleep and mood disturbance. First, disturbed sleep disrupts higher cognitive functions such as cognitive control (Goel, Rao, Durmer, & Dinges, 2009; Tucker, Whitney, Belenky, Hinson, & Van Dongen, 2010) which support effective types of emotion regulation such as cognitive reappraisal (the ability to cognitively reframe an emotional event so as to dampen its impact; Ochsner & Gross, 2005). In addition, in experimental studies, participants who had been deprived of sleep (compared to control participants) subsequently exhibited reduced functional connectivity between brain regions responsible for cognitive control (medial prefrontal areas) and emotional responses (amygdala) while viewing negative emotional pictures (Yoo, Gujar, Hu, Jolesz, & Walker, 2007). This decreased connectivity is consistent with decreased emotion-regulatory control by prefrontal brain areas (Ochsner & Gross, 2005). These findings are in line with the idea that poor sleep disrupts people's ability to regulate emotion using strategies such as cognitive reappraisal.

Together, these considerations suggest that one important short-term correlate of disturbed sleep may be impaired ability to regulate one's emotions using cognitive reappraisal. Initial evidence suggests that such impairments occur not only with extreme disturbances of sleep (such as sleep deprivation) but also with milder disturbances (such as subjectively lower sleep quality, i.e., difficulties initiating or maintaining sleep and/or non-restorative sleep; Baglioni et al., 2010; Bower et al., 2010). However, evidence in support of this hypothesis is limited because little research has employed measures of sleep quality in conjunction with valid and standardised laboratory measures of CRA. The goal of the present research was to test the hypothesis that poor subjective sleep quality is associated with lower CRA.

We did so by measuring, in a sample of 156 adults, sleep quality using self-reports of five facets of sleep quality (success going to bed; falling asleep after "lights-out"; staying asleep during the night; returning to sleep after night-time arousing or awakening; returning to wakefulness in the morning; Fortunato, LeBourgeois, & Harsh, 2008). The focus of the present research was on a relatively comprehensive measure of sleep quality rather than individual aspects of sleep, such as duration, for two reasons. First, in the present, non-sleep-disordered sample it was unlikely that participants would exhibit the kind of sleep deprivation that led to mood disturbance in previous studies (Horne, 1985). Second, empirical and theoretical considerations led us to hypothesise that overall sleep quality, and not simply duration or other individual aspects of sleep, would lead to decreased cognitive reappraisal ability (CRA) (Baglioni et al., 2010; Bower et al., 2010). To ascertain that results were indeed due to sleep quality rather than simply duration of sleep, sleep duration was controlled for in supplementary analyses. Because we were here interested in relatively acute and recent sleep disturbance and to reduce biases that can be introduced by long-term retrospective reports, we measured sleep quality with respect to the past 24 hours and the past week rather than with respect to a longer time window.

In addition to sleep quality, we measured cognitive reappraisal ability (CRA). Specifically, CRA was indexed by measuring the extent to which participants were able to decrease sadness during a laboratory sadness induction (Troy, Wilhelm, Shallcross, & Mauss, 2010). A laboratory challenge was chosen to measure CRA so as to decrease biases due to self-presentation or limits to memory and introspective insight.

We focused on sadness, because sadness regulation is especially pertinent to psychological functioning (Joormann, Siemer, & Gotlib, 2007). Participants were instructed to use cognitive reappraisal to regulate their emotions because this type of emotion regulation is particularly adaptive (Gross & John, 2003). Moreover, this type of emotion regulation is likely supported by the cognitive functions impaired by disturbed sleep (Goel et al., 2009; Tucker et al., 2010). To isolate variance due to sleep quality and to CRA, fourteen key potential confounds were assessed and controlled for statistically.

We hypothesised that poorer self-reported sleep quality would be associated with poorer CRA.

METHOD

Participants

One hundred seventy-one adults participated in the present study, which was part of a larger study of life stress. Participants were recruited from the greater Denver area through ads in internet and community bulletin boards (e.g., Laundromats, public libraries). Participants who contacted the lab were screened in an initial telephone call. To protect vulnerable participants, participants were excluded from the study if they reported having been hospitalised for any psychological reason in the past six months, or having attempted suicide in the prior six months. To enhance generalisability of the present results, participants were not excluded if they had a sleep, mood, or anxiety disorder. After completing the phone screen, eligible participants were invited into the study (see procedure).

Of the initial 171 participants, eight were omitted because their CRA score was more than three *SD*s above or below the mean. Seven participants did not fill out part of the sleep questionnaire, resulting in 156 participants for analysis (86 male, 70 female). One participant reported currently taking a sleep aid. Because we were interested in the correlates of sleep quality regardless of how it was achieved, we did not exclude her from analyses. Excluding this participant did not alter any of the results. Participants' ages ranged from 26 to 60 years ($M = 43.5$, $SD = 9.8$). Participants were from various self-reported racial backgrounds (1.3% American Indian or Alaskan Native, 1.3% Asian, 5.1% African, 0.6% Pacific-Islander, 82.1% European, and 9.0% mixed race). One participant did not report his racial background.

Procedure

The present study took place in two stages. First, participants filled out an online survey assessing demographic information and psychosocial characteristics (e.g., depression symptoms, trait mood, stress). Second, about a week later, participants came to an individual laboratory session which measured sleep quality and CRA. The CRA task followed the procedures reported by Troy and colleagues (2010). To induce a relatively comparable, neutral mood across participants at the beginning of the task, a two-minute emotionally neutral video clip was presented first ("neutral film clip"). After the clip, participants rated the greatest amount of sadness that they experienced during the clip. To disguise the main purpose of the study, participants also rated their experience of 16 other emotions, which are not the focus of the present investigation. Next, participants were presented with three clips pre-tested to induce moderate amounts of sadness (participant ratings of about 5 on a 1 to 9 scale). Each film was approximately two minutes long, depicted two people discussing an emotional event, and had received similar ratings of sadness during pretesting. The order of the three sad films was the same for all participants so as to isolate participants' ability to decrease negative affect relative to one another as opposed to effects of film clip.

During two of the three sad films, participants were simply asked to "watch the following film clip carefully". During one of the three sad films, participants were asked to use reappraisal. Specifically, they were asked to "think about the situation you see in a more positive light.... Keep in mind that even though a situation may be painful in the moment, in the long run, it could make one's life better, or have unexpected good outcomes". These instructions have been validated in previous research (see Troy et al., 2010, for full instructions).

To avoid confounding emotion-regulation effects with habituation to the sad clips, regression to the mean, or with a specific sad film clip, participants were randomly assigned to use cognitive reappraisal either during the second or during the third sad film. Because no one was instructed to use reappraisal during the first sad film, sadness ratings during this film were used as a sadness baseline ("baseline sad film"). After each film, participants reported the greatest amount of sadness that they experienced during the film. Ratings for the reappraised film were subtracted from ratings for the baseline sad film to index the degree to which participants were able to use reappraisal to decrease negative emotion. After watching the reappraised film clip, participants also rated: "How hard did you try to think about the situation in a positive way?" on a 1 (*Not at all*) to 9 (*Extremely*) scale. An average of 7.01 on this rating ($SD = 1.66$) indicated overall high compliance with the instruction. Excluding the two participants who reported ratings lower than 3 on this measure did not change results. We thus present analyses including these participants. On average, the CRA task lasted about 30 minutes. The degree to which participants were able to decrease their sadness when instructed to use reappraisal versus just watch a sad film clip served as the measure of CRA (see measures).[1]

Measures

Sleep quality. Sleep quality was measured in two ways using a questionnaire participants completed upon coming to the laboratory session. First, participants rated their overall sleep quality referring to the past 24 hours and to the past week with one item each ("Rate success of overall sleep") using 10-point Likert-type scales ranging from 1 (*Very poor*) to 10 (*Very good*). Second, we obtained a more comprehensive assessment of sleep quality based on prior work (Fortunato et al., 2008). Participants reported their success on a 10-point scale from 1 (*Very poor*) to 10 (*Very good*) during the past 24 hours as well as during the past week for the following five facets: (i) going to bed at bedtime; (ii) falling asleep after "lights-out"; (iii) staying asleep during the night; (iv) returning to sleep after waking during the night; and (v) waking in the morning. We formed one composite across the five items for the past 24 hours and one composite across the five items for the past week (see Table 1 for scale descriptives). For all measures, a lower score indicated poorer sleep quality. In an independent sample of 37 female participants ($M_{age} = 28.5$ years, $SD = 4.5$), our measure of past week's sleep quality was positively correlated with the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), which has been validated against sleep log data, clinical interviews and polysomnography data (*r*s = .74 for the composite, .68 for the single item).

Although the single-item and the 5-item composite measures of sleep quality measures were highly related to one another (see Table 1), we present both to enhance consistency with prior research that has used single-item measures of sleep quality (Perlis et al., 1997) while also utilising a more comprehensive measure of sleep quality.

[1] The following publications are based on the dataset from which the present results were obtained:
Hopp, H., Troy, A. S., & Mauss, I. B. (2011). The unconscious pursuit of emotion regulation: Implications for psychological health. *Cognition and Emotion*, *25*, 532–545.
Mauss, I. B., Savino, N. S., Anderson, C. L., Weisbuch, M., Tamir, M., & Laudenslager, M. L. (in press). The pursuit of happiness can be lonely. *Emotion*.
Troy, A. S., Shallcross, A. J., Davis, T. S., & Mauss, I. B. (in press). History of mindfulness-based cognitive therapy is associated with increased cognitive reappraisal ability. *Mindfulness*.
These three articles are concerned with variables and questions different from the one discussed in the present article; therefore, there is no conceptual overlap with the present article.

Table 1. *Means, standard deviations (SD), and scale alphas (present sample) of study variables, and their correlations with the four measures of sleep quality*

				Correlation coefficient (r)			
	Mean	*SD*	α	*1*	*2*	*3*	*4*
1. Overall sleep quality past week (1 item; 1–10)	6.2	2.4	n/a	—			
2. Composite sleep quality past week (1–10)	6.5	2.0	.81	0.82***	—		
3. Overall sleep quality past 24 hours (1 item; 1–10)	6.4	2.5	n/a	0.74***	0.57***	—	
4. Composite sleep quality past 24 hours (1–10)	6.8	1.9	.73	0.69***	0.77***	0.82***	—
Cognitive Reappraisal Ability (CRA; *z*-score)	0.13	1.0	n/a	0.19*	0.17*	0.14	0.18*
Age (years)	43.5	9.8	n/a	−0.02	0.10	−0.04	0.07
Gender (male = 0, female = 1)	0.45	n/a	n/a	0.08	0.09	< .001	0.04
Sadness Reactivity (*z*-score)	−0.04	1.32		0.04	0.07	0.01	0.02
Trait negative affect (PANAS, 1–5)	2.34	0.91	.94	−0.43***	−0.43***	−0.40***	−0.42***
Depression symptoms (BDI, 0–80)	11.34	9.98	.93	−0.53***	−0.50***	−0.46***	−0.43***
Anxiety symptoms (ASQ, 0–46)	6.76	5.07	.94	−0.43***	−0.43***	−0.37***	−0.37***
Impression management (BIDR, 1–7)	3.76	1.03	.86	0.25**	0.29***	0.16*	0.23**
Verbal intelligence (# correct answers Shipley vocabulary score)	33.31	3.34	n/a	−0.04	−0.04	0.01	−0.01
Working memory capacity (word span)	5.54	1.76	n/a	−0.004	−0.01	0.05	−0.01
Life stress (LES impact of cumulative stressful life events; 0–138)	14.94	10.68	n/a	−0.50***	−0.45***	−0.47***	−0.44***
Time of day of lab session (hours: minutes)	11:29	2:44	n/a	−0.06	−0.19*	−0.13	−0.20*
Time since awakening (hours: minutes)	4:50	2:45	n/a	−0.06	−0.08	−0.16*	−0.14
Sleep duration in the past 24 hours (hours: minutes)	7:20	1:33	n/a	0.17*	0.15	0.24**	0.22**
Caffeine consumption in the past 24 hours (# of caffeinated beverages)	1.362	1.4958	n/a	−0.07	−0.03	−0.12	−0.10

Notes: PANAS = Positive and Negative Affect Schedule; BDI = Beck Depression Inventory; BIDR = Balanced Inventory of Desirable Responding; LES = Life Events Scale. *$p < .05$; **$p < .005$; ***$p < .001$.

Cognitive reappraisal ability (CRA). Self-reported sadness was measured immediately after each film clip on a 1 (*Not at all*) to 9 (*Extremely*) Likert scale. Because the reappraised sad film was not the same for all participants, sadness ratings were *z*-scored for each film clip so that scores could be compared across participants. Change scores were calculated by subtracting sadness ratings given after the regulated film clip from sadness ratings given after the baseline sad clip. Thus a greater score indicates better CRA (the ability to decrease sadness by using cognitive reappraisal).

Control variables. Fourteen potential confounds were assessed (see Table 1 for scale descriptives and reliabilities). These variables were important to control for because each of them might be associated with sleep quality, CRA, or both, thus potentially creating spurious correlations between sleep quality and CRA. *Age* and *gender* were assessed in the online survey. *Sadness reactivity* was assessed with the CRA task described above. To quantify sadness reactivity, sadness ratings on the neutral film clip were subtracted from sadness ratings on the baseline sad clip. *Trait negative affect* was assessed in the online survey with the negative affect subscale of the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). *Depression symptoms* were assessed in the online survey with the Beck Depression Inventory (BDI; Beck & Steer, 1984). *Symptoms of panic*, *agoraphobia*, *generalised anxiety disorder*, and *social anxiety* were assessed in the online survey with the Anxiety Screening Questionnaire (ASQ; Wittchen & Boyer, 1998). *Impression management* (the desire to present oneself in a positive light to others, which may lead people to underreport sleep problems) was assessed in the online survey with the 20-item impression management subscale of the Balanced Inventory of Desirable Responding (BIDR; Paulhus, 1984). *Verbal intelligence* was assessed in the laboratory session with the vocabulary subscale of the Shipley Institute of Living Scale (SILS; Zachary, 1986). *Working memory capacity* was assessed in the laboratory session with a reverse word span task, which was based on the digit span subtest of the Wechsler Adult Intelligence Scale (WAIS; Wechsler, 1997). *Stress* was assessed using the Life Experiences Survey (LES; Sarason, Johnson, & Siegel, 1978), which measures the cumulative negative impact of stressful life events that participants had experienced in the previous six months. *Time of day* of the lab session was assessed by noting the beginning of the CRA procedure. *Time since awakening* was assessed by subtracting self-reported rise time from time of day of the lab session. *Sleep duration* in the past 24 hours was computed by taking the difference between time participants fell asleep the night before the laboratory session and time they woke up the day of the laboratory session. For participants who had taken a nap the day of the laboratory session ($n = 3$) we added duration of the nap to the sleep duration measure. *Caffeine consumption* in the past 24 hours was measured in the laboratory session by asking participants how many caffeinated beverages they had consumed in the past 24 hours.

RESULTS

Descriptives and zero-order correlations for study variables are provided in Table 1.

Sleep quality during the past week was associated with CRA such that poorer sleep quality was associated with poorer CRA, overall sleep quality: $r(154) = .19$, $p = .02$; sleep-quality composite: $r(154) = .17$, $p = .03$ (see Figure 1).

We controlled for potential confounds by computing correlations between sleep quality and CRA while partialling out each potential confound. Correlations held when controlling in this way for the 14 potential confounds (rs $> .17$, ps $< .05$).

Sleep quality during the past 24 hours was also associated with CRA although this relationship was only a statistical trend for the single-item measure, overall sleep quality: $r(154) = .14$, $p = .09$; sleep-quality composite: $r(154) = .18$, $p = .03$. The same pattern emerged when controlling for all potential confounds with the exception of controlling for depressive symptoms, which decreased the level of significance for both sleep-quality measures to a statistical trend, ps $< .10$.

Supplemental analyses

To examine whether associations between sleep quality during the past week and CRA were different from those between sleep quality during the past 24 hours and CRA, we used two Steiger's Z-tests comparing the two correlations between sleep quality during the past week and CRA to the two correlations between sleep quality during the past 24 hours and CRA. These tests yielded no significant differences, Zs $< .27$, ps $> .10$, suggesting that associations between sleep quality during the past week and CRA were comparable to those between sleep quality during the past 24 hours and CRA.

Non-linear relationships—as assessed by quadratic and cubic relationships between sleep quality and CRA—did not present a better fit for the data, ps of $R^2_{\text{change}} > .14$ when adding quadratic and cubic sleep quality terms as predictors to the regression. This suggests that the observed effects were not driven by participants at the extreme ends of the distribution.

Associations between sleep quality and CRA were not moderated by age or gender, ps of age by sleep quality interactions $> .48$, ps of gender by sleep quality interactions $> .61$.

Sleep duration was positively associated with all measures of sleep quality, rs$(154) > .17$, ps $< .04$, except for the past-week composite, for which the association between sleep duration and sleep quality was only marginal, $r(154) = .15$, $p = .07$. However, sleep duration was not associated with CRA, $r(154) = -.05$, $p = .57$.

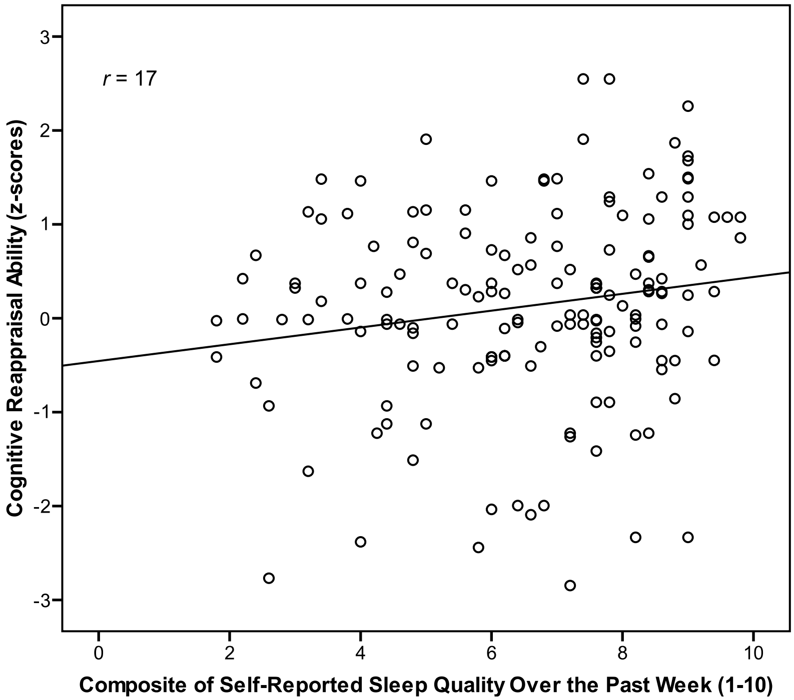

Figure 1. *Scatterplot of cognitive reappraisal ability as a function of the composite of self-reported sleep quality over the past week.*

DISCUSSION

The present results indicate that poorer sleep quality is associated with worse ability to regulate negative emotion by using cognitive reappraisal (CRA). Sleep quality was measured by subjective ratings of overall sleep quality as well as a composite of five facets of sleep quality (success going to bed; falling asleep; staying asleep; returning to sleep after night-time awakening; returning to wakefulness in the morning). The relationship between sleep quality and CRA held when statistically controlling for a large number of potential confounds (age, gender, negative emotional reactivity, trait negative mood, mood and anxiety disorder symptoms, stress, impression management, verbal intelligence, working memory capacity, time since rising, time of day of the laboratory session, sleep duration, and caffeine consumption), suggesting that the relationship between sleep quality and CRA was not due to third-variable confounds. The fact that our results pertained to male and female participants from a wide age range (these variables did not moderate the link between sleep quality and CRA) testifies to their generalisability.

The link between poorer sleep quality and decreased CRA converges with models of sleep that emphasise its role in maintaining higher-level cognitive functions (Goel et al., 2009; Tucker et al., 2010), especially those governed by the prefrontal cortex (Horne, 1993). In other words, poor sleep may impair CRA by disrupting prefrontal functions such as cognitive control, because CRA relies on cognitive control (e.g., it involves directing attention to particular emotional material or assuming new perspectives; Ochsner & Gross, 2005). In line with this idea, participants who have been deprived of sleep exhibit reduced functional connectivity between brain regions responsible for cognitive control (medial prefrontal areas) and emotional responses (amygdala) while viewing negative emotional pictures (Yoo et al., 2007). Future research will be necessary to test the full mediational model these considerations suggest as well as the specificity of these links (e.g., comparing different types of cognitive functioning).

The link between poorer sleep quality and decreased CRA, together with laboratory-experimental research, is further consistent with the idea that disturbed physiological sleep quality may causally contribute to impaired CRA (Walker & van der Helm, 2009; Yoo et al., 2007). Because of the established effects of CRA on a wide range of facets of psychological functioning (e.g., quality of one's social interactions), well-being (e.g., positive emotion), and adjustment (e.g., coping with daily stressors; Gross & John, 2003; Troy et al., 2010), impairments of CRA linked to sleep quality point to potentially quite pervasive ill effects of lowered sleep quality. Such effects could be severe if they occur over longer periods of time as is the case in chronically disturbed sleep. Practically speaking, these considerations lend support to the idea that treating sleep problems can constitute an important element in treating and preventing mood disorders and in enhancing well-being (Harvey, 2008).

Given that earlier research found effects of sleep *deprivation* on cognitive and emotional processing (Tucker et al., 2010; Yoo et al., 2007), the question might arise whether the link between sleep quality and CRA can be explained by sleep duration. However, the present sample was not sleep deprived (reported sleep duration over the past 24 hours was on average 7 hours and 20 minutes, $SD = 1$ hour 33 minutes). In addition, while sleep quality was positively associated with sleep duration (see Table 1), sleep duration was not associated with CRA, and the relationship between sleep quality and CRA held when statistically controlling for sleep duration. The lack of relationship between sleep duration and CRA might be due to the restricted range of sleep duration in the present sample. It might also be due to the fact that the amount of sleep needed varies substantially among individuals. For example, six hours are too little for one person but enough for another person, yielding no relationship across participants between sleep duration and CRA. Such a proposal is consistent with findings demonstrating that physiological sleep quality, beyond sleep quantity, offers the strongest predictive relationships with next-day mood and emotional functioning (Walker & van der Helm, 2009). Together, these considerations suggest that in non-sleep-deprived individuals sleep quality and not sleep duration is associated with impaired CRA.

It bears noting that sleep quality over the past 24 hours was only marginally associated with CRA when assessed with a single item and when depressive symptoms were statistically controlled. In contrast sleep quality over the past week was consistently associated with CRA. This pattern is consistent with the idea that poor sleep quality has cumulative effects (i.e., several nights of bad sleep might affect individuals' CRA more than one night of bad sleep). However, the fact that associations between CRA and sleep quality over the past 24 hours versus sleep quality over the past week were not significantly different from one another suggest that caution must be used when interpreting this pattern. Future research may explore whether effects of sleep quality on CRA accumulate over time by assessing sleep quality and CRA over extended periods of time.

Limitations and future directions

The present study focused on one particular type of emotion regulation that is especially important for mood and mental health: cognitive reappraisal aimed to decrease negative emotion (Gross & John, 2003; Troy et al., 2010). This type of emotion regulation is thus a particularly important candidate to consider as a correlate of sleep quality. However, other types of emotion regulation are also important, and different types of emotion regulation may be affected to varying degrees by sleep quality in that they rely to different extents on cognitive-control functions (Mauss, Bunge, & Gross, 2007). To glean insight into relationships between sleep quality and emotion regulation more generally, future studies should compare the relationships between sleep quality on the one hand and different types of emotion regulation (e.g., reappraisal used to increase positive emotion, distraction, automatic emotion regulation) on the other hand. In addition, future studies should be conducted that examine CRA in emotional contexts other than the particular film clips used here. Lastly, it may be fruitful to further isolate regulated versus "unregulated" contexts by either measuring the extent to which participants engage in spontaneous regulation during the unregulated task or by specifically instructing them not to regulate their emotion during the unregulated task.

The present study was correlational, a design choice that allowed for a large sample and an ecologically valid and multi-faceted measure of sleep quality. However, this also means that we cannot draw causal inferences from our results. For instance, it may be that poorer CRA causes greater negative mood which in turn leads to worse sleep quality. The fact that the present relationship between sleep quality and CRA held when controlling for 14 potential confounds, with trait mood and symptoms of mood and anxiety disorders among them, render such explanations less likely. Moreover, our measure of CRA is a performance measure that is relatively immune to biases that can affect measures based on hypothetical scenarios or trait surveys (Troy et al., 2010). In addition, the present results converge with those from experimental sleep-deprivation studies (Yoo et al., 2007). Ultimately, to further examine bidirectional relationships among sleep quality and emotion regulation, additional studies are needed that combine experimental, longitudinal, and correlational designs which ideally assess sleep with more objective measures such as polysomnography or actigraphy.

Lastly, the effect sizes of the effects we found are relatively modest (key effects range from .14 to .19). However, we note that the present laboratory study isolated one context and one time point to examine the effects of sleep quality. Given that for many people sleep quality might be poor for longer periods of time, and given that CRA has effects across a range of situations, the small momentary effect we documented may affect people cumulatively to generate important and severe consequences. Future research should formally examine whether effects of prolonged sleep disturbance accumulate over time. Moreover, the effect sizes reported here are likely lower-bound estimates because they are based on a relatively heterogeneous community sample. It stands to reason that effect sizes would be greater if a more homogeneous sample was examined.

Concluding comment

Despite these limitations, several study features, including a large and diverse sample, an ecologically valid and multi-faceted measure of sleep quality, and a standardised laboratory performance measure of CRA, allow us to add unique empirical support for the model that disturbed sleep quality impairs individuals' ability to engage in the crucial task of regulating negative emotions.

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