How Sleep Shapes Emotion Regulation

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Introduction

The relationship between sleep and emotion is one that is understood almost intuitively. Parents recognize that a child's tantrum may be the result of a missed nap or a sleepless night caused by a cold, workers can identify when their boss has had a late night or missed the first cup of coffee, and even strangers can surmise that the person who just cut them off in traffic might have 'woken up on the wrong side of the bed.' The emotional consequences of sleep loss have been noted anecdotally, and include emotional lability, increased irritability, and decreased tolerance for distress or frustration. In psychiatric disorders, like major depressive disorder and post-traumatic stress disorder, the association between impaired emotion and sleep disturbances can be even more striking. Empirical research on the emotional effects of sleep loss, however, is only in its infancy. In this chapter we will present the most recent research demonstrating the relationship between sleep and mood and discuss two ways in which sleep loss may lead to mood dysfunction, with a specific focus on the effects of sleep on emotion regulation. We will conclude with a brief discussion of sleep loss and emotion in psychiatric disorders, possible neurobiological mechanisms, and future directions for research.

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Does Sleep Affect Mood?

Most of what we know about the impact of sleep on mood comes from studies examining sleep loss. Methodology varies tremendously, but several paradigms have provided insight into the importance of sleep to appropriate mood functioning. Sleep loss can be categorized as (1) sleep deprivation, a complete absence of sleep over a 24 hour period, or (2) partial sleep deprivation, which is generally defined as total sleep of less than 6 hours, or (3) sleep fragmentation which may due to a medical or sleep disorder, where sleep is disturbed over the course of the night, but sleep duration or timing is minimally affected. While the cognitive effects of total sleep deprivation such as decreased reaction time and impairments in short term memory are well known (Lim & Dinges, 2010), the effects of sleep deprivation on mood are now starting to be examined. For example, in a seminal meta-analysis of the effects of sleep deprivation in healthy subjects, it was shown that mood was significantly more disturbed compared to measures of performance (Pilcher & Huffcutt, 1996). Specifically, Kahn-Greene and colleagues (2007) showed that following 56 hours of continuous wakefulness, self-reported depressed mood, anger and frustration all increased following sleep loss, while Franzen and colleagues (2008) and Tempesta et al. (2010) both showed that sleep deprivation resulted in increases in negative mood on self-report. There is also evidence to suggest that sleep deprivation may particularly affect females more than males. Goldstein-Piekarski et al. (2018) reported that sleep loss resulted in significantly greater anxiety in females than males, while Short and Louca (2015) demonstrated that healthy female adolescents exhibited greater depressed mood and anxiety following sleep deprivation than their male counterparts, indicating that females are at heightened vulnerability to sleep loss.

Although characterizing the effects of total sleep deprivation on mood is an important endeavor, there has been a greater focus on partial sleep deprivation or sleep restriction paradigms in the literature as they provide a more ecologically valid reflection of real-life conditions. Whereas most adults do not experience regular episodes of total sleep deprivation, the incidence of short sleep duration, defined by the Centers for Disease Control as less than 7 hours per night, is approximately 35% in the United States, and this figure has significantly increased over the last two decades (Luckhaupt, Tak, & Calvert, 2010). In addition to being more prevalent than sleep deprivation, chronic partial sleep deprivation has also been shown to have significantly more deleterious effects. In the same meta-analysis indicating that sleep deprivation significantly affected mood, Pilcher and Huffcutt (1996) also determined that chronic partial sleep deprivation had a greater negative effect on both cognitive performance and mood than did total sleep deprivation. Moreover, Dinges et al. (1997) showed that sleep restriction to 4 hours over a period of 7 days resulted in continued mood degradation, while the negative effects on alertness showed a brief plateau effect.

With specific regard to the effects on mood, studies have shown that sleep restriction results in a loss of positive mood, more so than an increase in negative mood

using the Positive and Negative Affect Schedule (PANAS; Talbot, McGlinchey, Kaplan, Dahl, & Harvey, 2010; Reddy, Palmer, Jackson, Farris, & Alfano, 2017). This is an important distinction as some research has assessed affect or mood on a continuum with positive mood as an anchor on one end and negative mood as an anchor on the other. However, emotion researchers have noted that positive and negative affect are independent constructs that can coexist simultaneously (Watson, Clark, & Tellegen, 1988), and thus should be assessed separately as done here, with measures like the PANAS. Therefore, these studies may suggest that sleep restriction affects the positive valence system more robustly than the negative valence system. In a very recent study, however, Shen and colleagues (2018) showed that while short sleep duration was associated with lower positive affect, poor sleep quality was associated with higher negative affect. Additionally, Krizan and Hisler (2019) showed that sleep restriction was associated with higher negative affect than was the control condition. These studies then indicate that the relationship between sleep and affect may not be simple to characterize.

In the context of examining ecologically valid models of sleep loss and their effects on mood, an important paradigm to consider is that of fragmented sleep. Several medical and sleep disorders, in addition to medications with side effects on sleep, can result in sleep fragmentation defined by repetitive short interruptions of sleep due to brief arousals. In this way, although total sleep time may not be affected, sleep quality is significantly degraded due to disruption of the normal stages and architecture of sleep. Obstructive sleep apnea (OSA), a sleep disorder characterized by repetitive episodes of cessations of breath caused by a blockage of the upper airway, causes significant sleep fragmentation and is associated with mood changes. For example, in their review, Schröder and O'Hara (2005), report that a significant proportion of individuals with OSA show signs of clinical depression. Akashiba et al. (2002) have also showed that patients with severe OSA had significantly higher depression scores than healthy sleepers. In addition to research in OSA, experimental sleep disruption has also been shown to result in decreased positive affect, but not negative affect (Finan et al., 2017), mirroring some partial sleep deprivation studies.

In contrast to the studies that aim to look at the relationship between sleep and mood by examining sleep loss, napping paradigms have also been utilized to elucidate the contribution of brief bouts of supplementary sleep to mood functioning. Napping has been shown to be one of the most effective countermeasures to fatigue and sleepiness (Horne & Reyner, 1996), and although only a limited number of studies have examined the direct effect of naps on mood, the results have been mostly consistent, demonstrating that naps improve mood, with a specific facilitation to positive mood rather than an attenuation of negative mood. For example, Taub and colleagues (1976) demonstrated that napping increased subjective energy, while Hayashi and colleagues (1999) and Luo and Inoue (2000), found that napping increased motivation and joy, respectively. More specifically, Kaida and colleagues (2007) found that a brief nap improved dimensions of positive mood status as measured by the Mood Checklist 3. Similar to sleep restriction, there is also some evidence that napping may provide an additional benefit to females. Looking at women

in the late-luteal phase of their menstrual cycle, Lamarche and colleagues (2010), showed that napping improved mood and alertness. Although the literature on napping and mood is still emerging, these studies provide preliminary support that supplementary sleep can improve mood via improved positive affect.

How Does Sleep Affect Mood?

As discussed above, there is some evidence to suggest that adequate sleep is necessary for proper emotional functioning, and that sleep loss negatively affects mood. However, an important and crucial question remains: How? In what way does sleep affect mood? Two candidate methods have emerged in the literature and will be discussed in more detail. One posits that sleep affects how emotional information is processed thereby rendering certain emotions more or less influential thereby affecting downstream regulation of mood. Another postulates that sleep affects how an individual can regulate their emotions, making individuals who experience sleep loss more vulnerable to emotional dysregulation and worse mood functioning. We will further explore both of these candidate methods below.

Many studies on sleep and emotion have focused on how sleep loss affects the processing of emotional information, which includes how an individual perceives and reacts to an emotional stimulus as well as how one remembers emotional stimuli. In terms of examining how one perceives emotion stimuli, one method that has been used is to evaluate how individuals rate emotional and neutral images before and after a period of wakefulness or a period of sleep. For example, using this methodology during both partial and total sleep deprivation, Pilcher and Huffcutt (1996) demonstrated that individuals rated emotional images lower in both valence and arousal across the testing period. Although this effect was seen for both positive and negative images, the authors noted greater effects for decreases in the ratings of positive images. A similar result was found by Tempesta and colleagues (2015) who showed that positive stimuli were rated more negatively by sleep deprived individuals and poor sleepers than by those individuals who self-reported as good sleepers.

The processing of neutral information may also be specifically affected during sleep loss. In one study, neutral stimuli were rated as more negative during sleep deprivation, while neither objectively positive nor negative images were rated as more negative (Tempesta et al., 2010). Relatedly, another study demonstrated that after sleep deprivation, neutral images produced an equal amount of reactivity, as assessed by ERP, as emotional images. The authors suggest that these findings indicate that sleep deprivation causes a lack of discrimination between emotional and neutral information via an attentional impairment (Alfarra, Fins, Chayo, & Tartar, 2015). Moreover, Simon et al. (2015) showed that neutral images were equally as distracting as negative emotional images only after sleep deprivation. Similar to Alfarra and colleagues, they suggest that sleep deprivation results in the superfluous processing of potentially non-relevant, neutral stimuli due to altering the threshold for emotional reactivity.

As Tempesta et al. (2018) and Palmer and Alfano (2017) highlight in their respective reviews, it seems that the results of studies examining the effects of sleep loss on ratings of emotional stimuli are inconsistent. Whereas several of the studies mentioned previously have found a negative bias imposed by sleep loss, Baran and colleagues (2012) showed that following a period of wakefulness, individuals rated negative emotional images as less negative, while other studies found no change in the ratings of emotional stimuli following sleep loss (Franzen, Buysse, Dahl, Thompson, & Siegle, 2009). Although Franzen et al. (2009) found that the subjective ratings of emotional images did not change with sleep loss, their study revealed that sleep deprivation did have an effect on physiological reactivity to emotional stimuli. This study highlights an important consideration with regard to study methodology: the use of subjective vs objective assessment. In the majority of the studies examining the effect of sleep loss on the evaluation of emotional stimuli, individuals are asked to report their subjective ratings, which could potentially lead to various forms of response bias. Objective assessment would therefore be preferred to subjective assessment; however, it is significantly more difficult to find an objective way to measure the evaluation of emotional stimuli. The use of subjective ratings also introduces the likelihood that stimuli characteristics including the type of stimuli used or the valence and/or arousal level, may affect the accuracy of the assessment.

Advanced neuroimaging techniques have begun to characterize brain activation to emotional stimuli following sleep loss. Using these methods, several interesting patterns have emerged. First, some studies have noted a decrease in the activation of the prefrontal areas following sleep deprivation (Chuah, Venkatraman, Dinges, & Chee, 2006; Venkatraman, Chuah, Huettel, & Chee, 2007). Because prefrontal areas primarily support executive functions such as attention, memory, and decision-making, it is likely that the patterns of activation associated with sustained wakefulness would result in impaired executive functioning. Second, sleep loss seems to enhance activation in emotion and reward-related areas during the presentation of positive stimuli. For example, Mullin et al. (2013) demonstrated increased ventral striatum activation to behavioral rewards following sleep deprivation, while Gujar et al. (2011) showed increases in the mesolimbic reward areas including the amygdala, putamen, and insula during the presentation of positive images. This pattern of decreased activation in the prefrontal cortex (PFC) coupled with increased activation of emotion-related areas such as the amygdala have led some to theorize that sleep deprivation prevents the top down inhibitory control of emotional responsiveness, resulting in heightened reactivity to emotional stimuli (Goldstein & Walker, 2014). In fact, studies have shown that sleep deprivation does decrease the connectivity of these areas (Yoo, Gujar, Hu, Jolesz, & Walker, 2007), and that this pattern of decreased connectivity is associated with increased reactivity to pleasure-evoking stimuli (Gujar et al., 2011), increased approach-related behavior to rewarding stimuli (Goldstein & Walker, 2014), and increased fear responsiveness (Feng, Becker, Feng, & Zheng, 2018). Taken together, the research on both subjective ratings of emotional stimuli and neuroimaging following sleep deprivation seem to indicate that sleep loss does affect the way in which we process emotional stimuli and may do so via the loss of inhibitory control by the PFC on the amygdala and other emotion-related brain areas.

Sleep may also affect our emotions through its interaction with our memories. A rich literature has implicated sleep in the encoding and consolidation of memory, and sleep deprivation with the impairment of memory formation (For Review, see Rasch & Born, 2013). Research has also shown that healthy individuals show a memory bias for emotional, as compared to neutral, information (Phelps, 2004) which suggests that sleep may somehow selectively consolidate emotional memories. In a series of elegant studies, Payne et al. (2008, 2011, 2012) demonstrated that a period of sleep can aid in the consolidation of emotion foreground items at the expense of neutral background items, and that this was associated with specific activation of the amygdala and ventromedial prefrontal cortex, providing evidence that sleep does, in fact, preferentially consolidate emotional information. In this way, it has been suggested that emotion during encoding somehow tags the memory for better consolidation during the subsequent sleep period (Diekelmann, Wilhelm, & Born, 2009). It should follow then that sleep deprivation should impair emotional memory performance, although this remains to be established. Tempesta and colleagues (2017) demonstrated that sleep deprived individuals did show memory impairments as compared to the individuals who slept; however, these impairments were seen with both neutral and emotional stimuli. Relatedly, as REM sleep has been shown to be important to emotional memory consolidation (Walker & Stickgold, 2006), one study examined the effect of selective REM-deprivation on emotional memory consolidation and found that accuracy of neutral and emotional memory recall was not affected.

In summary, although there are inconsistencies in the findings, the existing research does seem to suggest that reward-related and executive functioning areas are impacted by sleep loss, that sleep is important in the consolidation of emotional memory, and that this seems to affect the way in which we evaluate and recall emotional information, although a valence-specific pattern has yet to be determined.

Sleep and Emotion Regulation

It is possible that sleep affects mood as a result of the way in which we process emotional stimuli following sleep loss, but sleep loss may also affect mood indirectly by altering how individuals interpret and manage difficult situations, therefore altering one's ability to regulate his emotional response to varied stimuli. For example, toddlers who nap show fewer negative responses to an unsolvable task than do those who do not (Berger, Miller, Seifer, Cares, & Lebourgeois, 2012), which may suggest that sleep can facilitate the control of negative emotions. It has also been shown that sleep loss can prime an individual to experience more negativity; Zohar et al. (2005) demonstrated that medical residents who experienced sleep loss and a disruptive daily event reported more negative emotion than those who did not have limited sleep, while Killgore et al. (2008) showed that sleep deprivation limits coping skills and may increase one's perception of stress.

Emotion regulation has been defined as 'the processes that an individual uses to modify the type, intensity, duration, and expression of emotion thereby fostering an optimal level of engagement with the environment' (Gruber & Cassoff, 2014). In this way, the ability to appropriately adapt one's emotional responses to their situation and environment is a crucial evolutionary mechanism to ensure that individuals can behave appropriately with others around them, and effectively integrate into society. If sleep loss negatively affects the ability to regulate one's emotions, it could affect the individual's social, professional, and personal standings in our very socially connected world. Given the recent increase in prevalence and all-encompassing nature of social media use, the ability to regulate one's emotions may be more important than ever as individuals are interacting with others around the clock. Social media use, however, may not only be affected by sleep loss but may also be the cause of it, as research has shown that the use of social media, especially at night, is associated with greater sleep disturbance in young adults (Levenson, Shensa, Sidani, Colditz, & Primack, 2017; Twenge, Krizan, & Hisler, 2017).

Emotion regulation, however, is not a single process. The ability to regulate one's emotions has been theorized to require several distinct and independent steps, each of which is vulnerable to the effects of sleep loss. In their informative review, Palmer & Alfano (2017) utilize a framework of emotion regulation adapted from Gross (2014) to theorize how sleep loss may have a negative impact. They highlight five key components of Gross's model: situation selection, situation modification, attentional deployment, cognitive change, and response modulation. They note that there is evidence from the literature that can support the idea that sleep loss can affect the ability to complete each of these component steps appropriately, resulting in a failure of emotion regulation more broadly.

Emotion Recognition

One important aspect that may facilitate emotion regulation may be our ability to judge another person's emotions. Several studies have investigated the effects of sleep loss on the recognition of facial expressions and emotions, however due to inconsistent results, no definitive conclusions can be drawn. Two studies do suggest, however, that sleep deprivation results in the slowing of emotion recognition. Pallesen et al. (2004) showed that sleep deprived individuals have longer reaction time to recognize emotional expressions, both positive and negative, in cartoon drawings, while another reported that sleep deprivation in females specifically resulted in the blunting of the recognition of angry and happy faces (van der Helm, Gujar, & Walker, 2010). Interestingly, the same group showed that individuals who sustained wakefulness across the day were more likely to rate a face as angry or fearful than those who napped, which they suggested may be an evolutionary strategy to be more sensitive and orienting toward threatening stimuli. Although it is difficult to reconcile that sleep deprivation can cause a blunting in the recognition of angry faces while sustained wakefulness can cause individuals to rate an angry face

more intensely, this work still suggests that sleep may play an important role in the recognition of human emotions. One potential factor which may explain these inconsistencies may be varied methodology. Highlighting the importance of methodological differences, a study using a multi-modal emotion recognition assessment task showed that sleep deprivation had no effect on recognition accuracy (Holding et al., 2017). Similarly, Sack and colleagues (2019) recently reported that when longer video clips of emotional faces were presented, sleep deprived participants demonstrated better recognition accuracy than control participants, but when short video clips were used, no differences were found. The authors suggested that these results reveal the importance of stimulus duration. This is an important concept given that many of the studies examining sleep's effects on emotion recognition ask participants to respond to images of faces presented with short presentation intervals, which could affect the relative salience of emotional versus configural information.

There is also evidence to suggest that individuals who appear sleepy are not only at risk for making inaccurate assessments of others' emotions, but that they are also vulnerable to negative judgments by others. In an innovative study, individuals were presented with two sets of images of faces, those who were well-rested and those who had been sleep deprived. Impartial raters reported that they would rather not socialize with the individuals who appeared sleepy, suggesting that individuals who suffer from sleep loss may not only misjudge the facial expressions of others but may also be subject to bias themselves (Sundelin, Lekander, Sorjonen, & Axelsson, 2017).

Processing Negative Emotions

In addition to affecting the recognition of emotions in facial expressions, sleep loss may also impede emotion regulation in other ways. For example, individuals experiencing sleep deprivation showed impaired frustration tolerance, exhibiting a higher likelihood of blaming others for problems, and decreased willingness to accept blame to reduce conflict (Kahn-Greene, Lipizzi, Conrad, Kamimori, & Killgore, 2006). This finding is supported by other studies showing that both sleep restriction (Krizan & Hisler, 2019) and poor sleep quality (Denis et al., 2017) are associated with an increased tendency to exhibit externalizing behavior suggesting that sleep loss and poor sleep quality may predict a disinhibition of aggressive behaviors. Alternatively, better sleep quality is associated with increased activation in empathy-related brain areas (Guadagni, Burles, Ferrara, & Iaria, 2018), indicating that sleep is essential to perspective-taking and the ability to cooperate to solve problems, while napping has also been shown to increase frustration tolerance (Goldschmied et al., 2015). Increased impulsivity has also been associated with sleep loss. Killgore et al. (2008) showed that the ability to delay gratification, or delay approaching a rewarding experience, was decreased significantly after sleep deprivation, demonstrating that those who experienced sleep loss were more likely

to pursue rewards than those who did not. Taken together, these findings suggest that sleep loss may impede emotion regulation by decreasing the ability to empathize with others and avoid conflict while increasing the likelihood of behaving impulsively and aggressively.

Emotion Regulation Strategies

Because there is ample evidence to suggest that the component processes of emotion regulation are affected by sleep loss, researchers have also attempted to characterize the effects of sleep loss on the utilization of emotion regulation strategies. Several of these strategies have been defined in the literature, and include *distraction*, i.e., the orienting of one's attention away from an emotional stimulus, *suppression*, i.e., the process of attempting to lessen focus on a specific emotion-laden thought, and *cognitive reappraisal*, i.e., the ability to reframe an emotional thought or experience in order to decrease the emotional impact (Gross, 1998). There is evidence to suggest that sleep deprivation does indeed decrease the utility of using these strategies. In a study looking at an electrophysiological marker of autonomic arousal to emotional images, sleep deprivation impaired the effects of using distraction and cognitive reappraisal (Zhang, Lau, & Hsiao, 2019), suggesting that despite a sleep deprived individual's conscious desire to use these strategies, the lack of sleep may prevent their effectiveness.

As previously mentioned, sleep deprivation may not always be an ecologically valid model of real-life sleep disturbance. Examining how subjective sleep quality may affect the use of emotion regulation strategies, O'Leary and colleagues (2017) showed that the use of maladaptive emotion regulation strategies mediated the relationship between poor sleep quality and depressive symptoms in a 6-month longitudinal study of currently depressed, healthy individuals, and those with remitted depression. This suggests that individuals who don't achieve high quality sleep are unable to select an appropriate emotion regulation strategy which, in turn, leads to an increase in symptoms of depression. Likewise, Mauss et al. (2013) demonstrated that poor sleep quality was associated with worse performance on a cognitive reappraisal task. Similarly, in their review on sleep and emotion regulation, Vandekerckhove and Wang (2017) report that individuals with insomnia, who often report fragmented or low-quality sleep, tended to use suppression more than healthy sleepers who used other, more effective emotion regulation strategies. Taken together, this work demonstrates the importance of sleep quality to the successful implementation of emotion regulation strategies in order to improve mood and functioning. However, this does not preclude that the relationship between sleep and emotional functioning may be more complicated than this, and that the reverse may also be true; that being unable to properly regulate one's emotions may also significantly impair sleep quality.

Interestingly, the use of emotion-focused coping, common in individuals with insomnia (Morin, Rodrigue, & Ivers, 2003), has been shown to increase the amount

of time it takes to fall asleep, but also to decrease the amount of time spent awake in the middle of the night, and increase sleep efficiency and total sleep time. This suggests that although there is an immediate downside to using this type of strategy, there are also tangible benefits in terms of sleep architecture (Vandekerckhove & Wang, 2017). The authors highlight the importance of selecting a coping strategy based on the situation as the research around emotion-focused coping has identified that it can be particularly beneficial when stressors or problems are uncontrollable. Problem-focused coping strategies, on the other hand, are preferred in situations where the stressor has a potential solution. The type and level of stress may also be particularly significant in the relationship between sleep and the ability to regulate one's emotions. Minkel et al. (2012) demonstrated that following sleep deprivation, individuals reported greater stress than those who were well-rested in a low-stressor condition. However, in the high-stressor condition, sleep deprived individuals reported similar stress levels to the control group. The authors suggest that these results indicate that sleep deprivation can lower the threshold for how stress is perceived. This is similar to the theory, mentioned previously in the context of heightened reactivity to neutral stimuli, that suggests that sleep deprivation taxes cognitive resources, resulting in the loss of discrimination of relevant and non-relevant information, or in this case, clouding the discrimination between low and high stress in a low-stress condition.

Conclusions and Future Directions

Sleep is crucial to the maintenance of appropriate emotional regulation. Sleep loss and sleep disturbance have been shown to be associated with decreased positive affect, and sometimes increased negative affect, and this relationship may be mediated by an increased reactivity to negative stimuli or the inability to properly regulate negative emotions such as aggression or impulsivity using appropriate strategies. That sleep and emotion regulation are intricately tied together, however, has frequently been noted in the context of psychiatric disorders. Sleep disturbances are included as a potential symptom of every known psychiatric illness. It is therefore possible to speculate that sleep is associated with emotion dysregulation specifically in these disorders. In fact, there is evidence to suggest that both major depressive disorder (MDD) and post-traumatic stress disorder (PTSD) may be developed or maintained due to sleep abnormalities. MDD, for example, has been shown to be associated with impaired sleep homeostasis (Goldstein et al., 2012; Plante et al., 2013), and it is suggested that the inability to generate a drive to sleep may be related to mood impairments (Borbely & Wirz-Justice, 1982), although the exact neurobiological mechanism driving this relationship has yet to be identified.

One potential mechanism linking sleep and emotion regulation in psychiatric disorders may be alterations in REM sleep. REM sleep has been implicated in sustaining the noradrenergic balance in the brain (Goldstein & Walker, 2014). It has been postulated that increased REM activity during sleep, historically noted in

MDD, could result in the depletion of noradrenergic activity during the following wake period thus causing an impairment in 'emotional salience detection,' and increased reactivity to both neutral and emotional stimuli (Goldstein & Walker, 2014). Similarly, Goldstein & Walker posit that REM sleep could also be implicated in PTSD. They propose that individuals with PTSD frequently experience sleep loss and a lack of REM sleep which could subsequently impair the noradrenergic balance thus producing an impairment in emotional discrimination and associated hypervigilance. Although compelling, because it is currently not possible to measure neurotransmitter concentrations in humans, these theories remain speculative.

Unfortunately, because much of the research in the area of sleep and emotion has been inconsistent, with some results showing that sleep loss has large effects on certain valence systems and stimuli while others have shown that sleep loss has no effects on certain emotional constructs, it is difficult to draw any definitive conclusions as to how and why sleep shapes emotion regulation. To that end, large scale studies are needed to elucidate this intimate relationship. As previously mentioned, it will be crucial that any future studies consider (a) examining the effect of both sleep duration and sleep quality on the processing of neutral stimuli, (b) assessing both positive and negative affect, (c) utilizing multi-modal, dynamic stimuli (e.g. images and video clips), (d) for varying lengths of time, (e) under both low and high demand conditions, (f) in equal samples of males and females, and (g) using both subjective and objective measures as all of these factors have been shown to impact study results.

Several researchers have also noted that 1 day of total sleep deprivation may not be a robust enough challenge to produce significant changes in mood (Palmer & Alfano, 2017; Vandekerckhove & Wang, 2017; Killgore et al., 2011). For example, Killgore and colleagues (2011) have shown a distinction in performance at 51 hours of sleep deprivation vs 75 hours, suggesting that even small increases in the amount of sleep deprivation can potentially have significant changes on mood. Therefore, future studies should consider using partial, chronic sleep deprivation paradigms or longer sleep deprivation protocols. It will also be critically important to begin to examine potential mechanisms. Although it is an important first step to characterize the effects that sleep loss has on emotion regulation and mood, it will be even more informative for researchers to identify *how* sleep loss effects them in order to develop treatments for psychiatric disorders like major depression and post-traumatic stress or strategies to improve emotion regulation in individuals who may suffer from sleep loss or sleep disturbance.

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