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Research paper

Sleep deprivation impairs recognition of specific emotions

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ABSTRACT

Emotional processing is particularly sensitive to sleep deprivation, but research on the topic has been limited and prior studies have generally evaluated only a circumscribed subset of emotion categories. Here, we evaluated the effects of one night of sleep deprivation and a night of subsequent recovery sleep on the ability to identify the six most widely agreed upon basic emotion categories (happiness, surprise, fear, sadness, disgust, anger). Healthy adults (29 males; 25 females) classified a series of 120 standard facial expressions that were computer morphed with their most highly confusable expression counterparts to create continua of expressions that differed in discriminability between emotion categories (e.g., combining 70% happiness+30% surprise; 90% surprise+10% fear). Accuracy at identifying the dominant emotion for each morph was assessed after a normal night of sleep, again following a night of total sleep deprivation, and finally after a night of recovery sleep. Sleep deprivation was associated with significantly reduced accuracy for identifying the expressions of happiness and sadness in the morphed faces. Gender differences in accuracy were not observed and none of the other emotions showed significant changes as a function of sleep loss. Accuracy returned to baseline after recovery sleep. Findings suggest that sleep deprivation adversely affects the recognition of subtle facial cues of happiness and sadness, the two emotions that are most relevant to highly evolved prosocial interpersonal interactions involving affiliation and empathy, while the recognition of other more primitive survival-oriented emotional face cues may be relatively robust against sleep loss.

1. Introduction

There is an emerging consensus that sleep plays a vital role in recalibrating the emotional functioning of the brain (Walker and Van Der Helm, 2009; Walker, 2009). Without sufficient sleep, there appears to be a reduction in emotional regulation capacities and a loss of perceptual sensitivity to cues that provide critical emotional information about the external environment and internal milieu (Goldstein-Piekarski et al., 2015). Notably, Yoo and colleagues showed that compared to the sleep-rested state, sleep deprivation was associated with increased amygdala responses to negatively valenced visual images (e.g., mutilated bodies; unsanitary conditions; aggressive scenes), and reduced functional connectivity between the top down emotion regulating regions of the medial prefrontal cortex and the emotionally responsive amygdala (Yoo et al., 2007). The findings suggest that without sleep, there is a weakening of the ability of higher order brain regions to exert regulatory control over more primitive threat detection systems, leading to greater emotional reactivity. In a parallel study from the same lab, Gujar and colleagues demonstrated that sleep deprivation produced similar increases in limbic and paralimbic regions to positively valenced images as well (Gujar et al., 2011), suggesting that sleep loss increases emotional reactivity to both positive and negative stimuli. This has led to the suggestion that sleep deprivation may globally lower the threshold for emotional activation, regardless of valence, thus increasing overall sensitivity to emotional stimuli (Simon et al., 2015).

The effects of sleep deprivation are not limited to emotionally evocative scenes, but also affect how the human brain responds to facial expressions of emotion. Huck and colleagues conducted one of the earliest investigations of the effects of sleep deprivation and stimulant countermeasures on the ability to accurately identify emotional displays depicted in photographs of facial expressions (Huck et al., 2008). In that study, participants completed two tasks, one involving categorization of simple photographs of six basic emotions, and the other involving categorization of complex blended images created by morphing pairs of highly confusable emotions (e.g., fear+surprise) from the same set of six primary emotions. While accuracy for simple emotion perception was not affected by sleep deprivation or stimulants, the ability to accurately identify the dominant emotion within complex emotional blends was adversely affected by sleep deprivation and was

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restored by stimulant medications (Huck et al., 2008). Whereas Huck and colleagues did not examine the effects of sleep loss on accuracy for the six specific emotions, a subsequent study by van der Helm and colleagues focused on recognition of three separate emotions, including happy, sad, and angry facial expressions (Van Der Helm et al., 2010). They presented participants with a set of morphed face photographs that ranged in intensity from neutral to full strength for each prototypical emotion. The authors found that sleep deprivation led to a significant impairment of recognition for angry and happy expressions, but only in the middle range of intensity—an effect that was most prominent in female participants. More recently, Cote and colleagues examined a broader range of facial affects, including happy, sad, angry, and fear and found that sleep deprivation impaired recognition of sadness in simple full face expressions as well as faces morphed to a moderate level of intensity (Cote et al., 2014). Finally, Goldstein-Piekarski and colleagues presented participants with a series of computer generated faces differing on a continuum from safe to highly threatening in appearance and found that sleep deprivation led to a bias toward overestimating the threat in faces, a finding that was associated with altered viscerosensory brain activation (Goldstein-Piekarski et al., 2015). Thus, it is clear that sleep deprivation leads to an impairment in recognition of some aspects of facial affect, particularly when there is some ambiguity in the expressions, but there is no consensus regarding the specific emotions that are most sensitive to these effects.

To provide additional insights into this topic, here we provide a further analysis of the data presented in our previous article (Huck et al., 2008). In that paper, we only reported total recognition accuracy scores that were collapsed across all six expressions. However, given the current interest in the topic, we believe that it would be informative to provide additional unpublished data regarding the effects of sleep deprivation and recovery sleep on accuracy for recognizing the dominant emotional expressions in morphed blends of highly confusable emotions based on the six universal facial expressions, including happiness, sadness, surprise, fear, disgust, and anger. Based on the aforementioned literature, we hypothesized that sleep deprivation would lead to sustained accuracy for ambiguous blends of confusable faces with predominantly high threat relevance (i.e., Anger, Fear, Surprise), whereas morphed expressions with predominantly social/affiliative relevance (i.e., Happiness, Sadness) would be most susceptible to degraded recognition from sleep loss.

2. Method

2.1. Participants

A total of 54 (29 male; 25 female) healthy young adults (Mean Age=23.5, SD=4.0) volunteered for a larger study of the effects of sleep deprivation and stimulant countermeasures on various aspects of cognitive functioning. While related findings from this dataset have been reported elsewhere (Huck et al., 2008), here we present previously unpublished findings and re-analysis of those data regarding the effects of sleep deprivation on the ability to recognize the six universal basic emotions. All participants underwent a physical examination prior to entry into the study and were deemed to be physically healthy by the examining physician. Exclusionary criteria included any history of sleep disorder, psychiatric illness, drug or alcohol abuse, cardiac problems, current pregnancy, or other health issue that would pose a risk for participating in a sleep deprivation study. Volunteers were also excluded for any history of tobacco use in the preceding three years or daily caffeine intake in excess of 400 mg/day. Participants were required to abstain from alcohol, stimulants, or other psychoactive drugs for 48 h prior to participation. Abstinence from stimulants was verified via urine drug screen at time of entry into the study and every 24 h thereafter. Written informed consent was obtained prior to enrollment and all participants were compensated for their time in the lab and were also offered a performance bonus for demonstrated effort on all study tasks. The protocol for this study was approved by the Walter Reed Army Institute of Research Human Use Review Committee and the U.S. Army Human Subjects Research Review Board. This material has been reviewed by the Walter Reed Army Institute of Research and there is no objection to its presentation and/or publication.

2.2. Materials and procedure

As part of the larger study, participants underwent a four night continuous in-residence laboratory study, which consisted of a baseline acclimation night involving 8-h enforced time in bed from 2300 to 0700, a 61-h period of monitored continuous wakefulness during which time participants completed a variety of cognitive and performance tasks, a 12-h enforced recovery sleep opportunity from 2000 to 0800, and a post-recovery day involving additional cognitive and performance tasks. The present analysis is focused primarily on the outcome of the Ekman Hexagon Test (EHT; Thames Valley Test Company, Suffolk, UK), which was administered several times during the course of the study. The EHT is a computer-administered task that required the participant to classify each of a series of displayed facial expression photographs according to one of six different emotion labels (happiness, surprise, fear, sadness, disgust, anger). As depicted in Fig. 1, each face was displayed on the screen with six different emotion labels located below the face. Label order was randomized at each presentation. The participant used a mouse to click on the label that best represented the displayed emotion for each trial. Each facial photograph was displayed for up to five seconds, after which the photograph disappeared but the labels remained until a response was made. There was no time limit for responses. The EHT comprised 150 trials and all photographs were of the same male individual poser.

To increase the emotion processing demands of the task, the face stimuli were previously morphed to produce a continuum of facial blends. Briefly, as described in the EHT manual, each basic emotion photograph was computer morphed with its two most similar appearing and frequently confused counterpart emotions (e.g., fear was morphed with surprise and fear was morphed with sadness to create a continuum of expressions from surprise to fear to sadness). For example, two face images would be combined to create a new image depicting 70% fear and 30% surprise. Each morphed image was created in by combining two prototype images according to the following ratios: 90:10; 70:30; 50:50; 30:70; 10:90. As depicted in Fig. 2, this process yielded 30 combinations of facial expressions (6 emotions×5 blend levels), that comprised a continuum of emotional blends, with

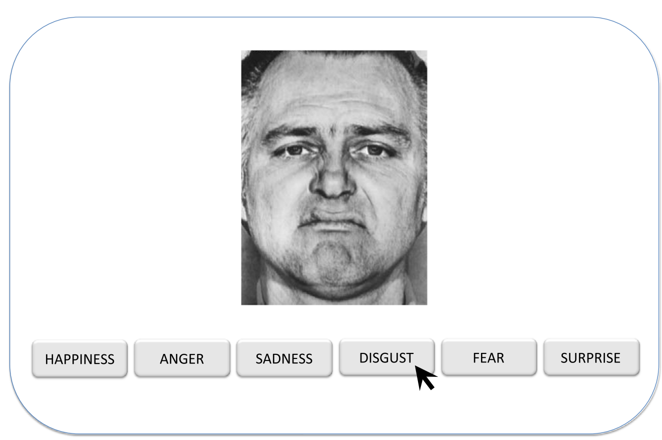

Fig. 1. Example of the Emotion Hexagon Test. Participants were shown a series of 150 facial expressions that comprised morphed blends of pairs of highly confusable emotions (e.g., 70% disgust+30% sadness) for five seconds and used the computer cursor to select the most accurate label for each expression.