Nature and Science of Sleep

Dovepress
open access to scientific and medical research

Open Access Full Text Article

ORIGINAL RESEARCH

# Sleep Deprivation Impairs Human Cognitive Reappraisal Ability: A Randomized Controlled Trial

Zi-Qiang Li[1,*], Ye Qin[2,*], Wen-Peng Cai[1,*], Si-Qi Deng[3], Xiao-Fei Mao[1], Jian-Guo Zhang[1], Tian-Ya Hou[1], Yu Pan[4], Yi Cui[1], Ying-Nan Ge[5], Wei Dong[1,*], Yun-Xiang Tang[1,*]

[1]Faculty of Psychology, Naval Medical University, Shanghai, 200433, People's Republic of China; [2]The School of Mechanical Engineering, Changzhou University, Changzhou, 210046, People's Republic of China; [3]Department of Clinical Psychological Counseling, Shanghai Tongxinjici Health Couseling Center, Shanghai, 200433, People's Republic of China; [4]Department of Medical Psychology, Chinese PLA General Hospital, Beijing, 100830, People's Republic of China; [5]Department of Hepatopancreatobiliary Surgery, the First Affiliated Hospital of Shenzhen University, Shenzhen Second People's Hospital, Shenzhen, 518000, People's Republic of China

*These authors contributed equally to this work

Correspondence: Wei Dong; Yun-Xiang Tang, Faculty of Psychology, Naval Medical University, No. 800 Xiangyin Road, Shanghai, 200433, People's Republic of China, Tel/Fax +86-13524435414; +86-13386271042, Email sophiedongwei@163.com; tangyun7633@sina.com

Nature and Science of Sleep downloaded from https://www.dovepress.com/
For personal use only.

**Purpose:** This study aims to examine the impact of sleep deprivation on individual cognitive reappraisal ability using a standardized behavioral paradigm.

**Methods:** A randomized pretest-posttest control group design was conducted. Thirty-nine participants were eventually enrolled and randomly assigned to receive either the sleep control (SC: n = 17) or the sleep deprivation (SD: n = 22). Both of them were required to perform a standardized behavioral paradigm of measuring cognitive reappraisal ability one time under sleep-rested condition and another time under the condition of different sleep manipulation a week later.

**Results:** Mean valence ratings of SD group were more negative than SC group's ($p < 0.05$) and mean arousal ratings of SD group were higher than SC group's ($p < 0.01$).

**Conclusion:** Sleep deprivation may impair individual cognitive reappraisal ability and could potentially undermine the efficacy of cognitive therapy in terms of emotion regulation.

**Keywords:** sleep deprivation, emotion regulation, cognitive reappraisal, IAPS, CRA

## Introduction

Sleep plays a crucial role in emotional functioning and emotional health.[1,2] Lack of sleep has been found to influence emotional functioning at subjective or behavioral levels,[3] emotional impulsivity,[4] emotional expressiveness,[5] and emotional intelligence.[6] Evidences showed that if sleep was restricted or deprived, individual experience of negative mood states would increase and the occurrence of positive mood states would decrease.[7,8] What was worse, sleep loss or disrupted sleep increases the risk of mood disorder, such as anxiety and depression.[9] Recent studies have investigated the emotion-related processes linking sleep loss and mood disorders to explain the underlying mechanisms.[8–11] Theoretical models and empirical evidence have increasingly suggested that emotion regulation is an important mechanism explaining the relationship between sleep and emotional functioning.[3,12] Nevertheless, only a few studies directly examined the impact of sleep loss on emotion regulation.[13,14]

Emotion regulation enables us to adjust the intensity, the timing, and manner of experiencing emotions and expressing them.[15] The ability to regulate maladaptive emotions is crucial for mental health.[16] In Gross' process model of emotion regulation,[15] emotion regulation comprises situation selection/modification, attentional deployment, cognitive change, and response modulation, which are distinguished by the time points in the emotion generative process. Cognitive change, including reappraisal, refers to regulatory strategies aimed at generating an emotion in the absence of affective cues. The cognitive change also refers to the use of higher-order cognitive processes to change the appraisal or meaning of an emotion-eliciting situation.[11]

Received: 22 May 2023
Accepted: 28 August 2023
Published: 21 September 2023



© 2023 Li et al. This work is published and licensed by Dove Medical Press Limited. The full terms of this license are available at https://www.dovepress.com/terms.php and incorporate the Creative Commons Attribution – Non Commercial (unported, v3.0) License (http://creativecommons.org/licenses/by-nc/3.0/). By accessing the work you hereby accept the Terms. Non-commercial uses of the work are permitted without any further permission from Dove Medical Press Limited, provided the work is properly attributed. For permission for commercial use of this work, please see paragraphs 4.2 and 5 of our Terms (https://www.dovepress.com/terms.php).

Reappraisal is part of antecedent-focused emotion regulation,[15] which can effectively downregulate subjective and physiological components of a negative emotional experience.[11,17,18]

Some studies have provided clues to the relationship between sleep and individuals' cognitive reappraisal ability. In a study utilizing two nights of partial sleep restriction (6.5 hours followed by 2 hours), adults and adolescents who were asked to engage in catastrophizing as a maladaptive form of cognitive appraisal, reported a greater likelihood of catastrophes coming true.[19] Researchers suggested that the results reflected cognitive change on emotional events after sleep restriction, sleep loss could impair individuals' cognitive reappraisal ability. Another study found that participants with poor sleep quality during the last week had impaired CRA for sad feelings induced by video clips.[20] Imaging studies showed that the overactivation of the prefrontal cortex (PFC) occurs during CRA.[10] These findings imply that sleep loss may disrupt individuals' cognition-related emotion processes cognitive reappraisal. However, these studies were cross-sectional and did indicate any causal relationship between sleep loss and CRA.

Despite behavioral and neurobiological evidence for the links between sleep disruption and CRA, only a few studies directly examined this link with valid and standardized laboratory measures.[13,14] Recently, Stenson et al[14] used emotion regulation task taken from McRae et al[21] and trained subjects to recontextualize negative images. However, they did not explicitly instruct subjects on what emotion regulation strategy to use during the formal experiment to ensure using their reappraisal. Another study used a standardized experimental design to investigate the impact of sleep deprivation on cognitive reappraisal ability. However, the study did not find the impact of sleep deprivation on the decline of reappraisal ability in behavioral data due to individual differences were not well control.[13] Taken together, the influence of SD on the use of CRA remains to be known.

In the current study, a 24-hour sleep deprivation was performed, which would not induce any clinical sleep disorders or insomnia but still be sufficient to affect emotional and cognitive functioning.[22,23] A mixed design was conducted to compare the CRA between participants under sleep deprivation and sleep control. Additionally, a standardized behavioral paradigm was employed instead of scales to assess CRA, which could better reflect individual cognitive functioning. Based on the aforementioned literature, it was hypothesized that SD would lead to poor performance in CRA task.

# Materials and Methods

## Participants

A total of 43 healthy participants were selected from 46 applicants to sign informed consent form for a larger study of the effects of sleep deprivation on emotional processing (Using G*power software to calculate the sample size with effect size $f$=0.25, α=0.05, 1-β=0.8, this study needs 36 participants). The recruitment was conducted at the physical examination center of the Naval Medical University affiliated hospital. Participants could registered by scanning the QR code on the posters. Each participant filled out Pittsburgh Sleep Quality Index (PSQI)[24] to exclude subjects with poor sleep quality (PSQI>6, n = 2). Moreover, participants were required to abstain from caffeine and alcohol for 72 hours prior to and during the study, and kept a normal sleep-wake pattern with average sleep duration (7–8 hours per night, went to bed between 10:30 p.m. and 11:30 p.m.) for the same amount of time. Compliance to this sleep schedule was verified with sleep logs. Exclusionary criteria also included any history of sleep disorder (n = 1), psychiatric illness, drug or alcohol abuse, cardiac problems or other health issues that would pose a risk for participating in a sleep deprivation study.

Each time, 6 to 11 participants were recruited randomly assigned to the sleep control or sleep deprivation group. Among them, 4 participants' data were removed from analysis due to the following reasons: 3 participants from SC group was excluded due to failure to complete retest task (1 failure to comply with sleep schedule over two nights before retest and 2 only complete test task), 1 participant from SD group was excluded due to nap during sleep deprivation, leaving a total of 39 participants across two groups (22 in the SD group and 17 in the SC group) (Figure 1). All participants in the lab would be provided with monetary compensation for their time. Furthermore, upon completion of both tests, an additional reward equivalent to 10% of the total subject fee would be granted. The protocol for this study was approved by the Naval Medical university ethics committee (NO. NMUMREC-2021-041). This study was conducted in accordance with the Declaration of Helsinki.

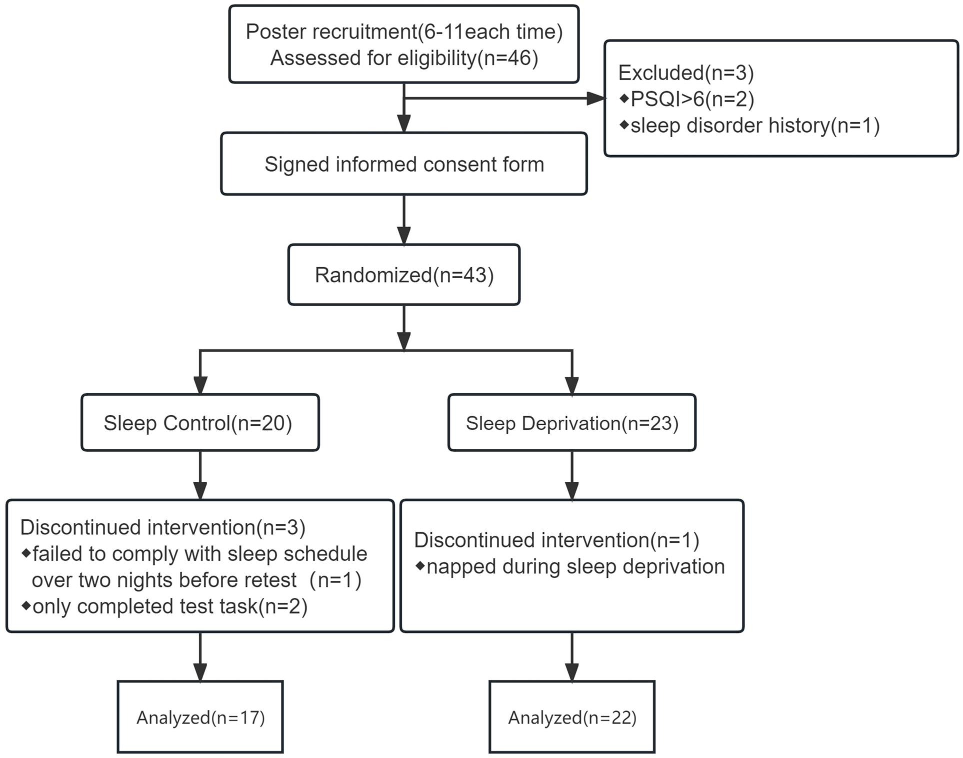


**Figure 1** The CONSORT flow diagram of the experiment.

## Procedure

The study was conducted under controlled laboratory setting of the Sleep Research Center at the Naval Medical University. As part of the larger study, participants completed a standard test battery in two sessions, including two standard 10-min emotional attention tasks, emotional evaluation task, emotional face recognition task, emotional reappraisal tasks and some questionnaires (a Chinese version of the Emotion Regulation Questionnaire (ERQ),[25] Profile of mood states (POMS),[26] the Positive and Negative Affect Scale (PANAS)).[27] Current study only reports the results of emotional reappraisal tasks.

One test session was held after a baseline acclimation night with 8 hours of high-quality sleep from 23:00 p.m. to 7:00 a.m. participants were asked to complete two independent tasks. For the first task, participants were asked to rate the affective valence and arousal of the pictures they were presented with (8 practice, 36 formal trials) using Self-Assessment Manikin (SAM, nine-point, valence: unhappy 1–9 happy, arousal: calm 1–9 excited).[28] For the second task, participants were asked to rate the affective valence and arousal of the picture according to the CRA methods that were widely accepted in previous articles.[29–31] CRA task was taken from Thiruchselvam et al.[17,29]

As mentioned by previous studies, it was necessary to isolate "regulated" versus "unregulated" contexts to avoid participants' habituation of a certain emotion regulation strategy.[20] More specifically, participants learned how to use the CRA strategy in the test phase. It could potentially affect picture evaluation in the WATCH task of the retest phase, particularly if the retest was assigned right after the first test. Therefore, the retest was conducted a week after the primary test (Figure 2A), while the procedure remained exactly the same.

In each trial, participants received a prompt (displayed for 2 seconds) to either attend to (WATCH) or decrease their emotional response to (REAPPRAISAL) an upcoming image. A total of 88 colored pictures were selected from the International Affective Picture System (IAPS).[32] Number of pictures used in the experimental task from IAPS: IAPS No. of negative pictures used in the WATCH task: 6020,2480,9160,7491,9046,2690,7130,9102,3400,3170,6312,9911,9830,9001, 6838,2691,6834,500,9253,2750,4621,9400,6550,3061,3010,2205,3130,3530,3015,6571,6561,3053,9560,6210,9280,307 1,9320,3140,6360,9910,9265,6242,7380,6540; IAPS No. of negative pictures used in the REAPPRAISAL task:

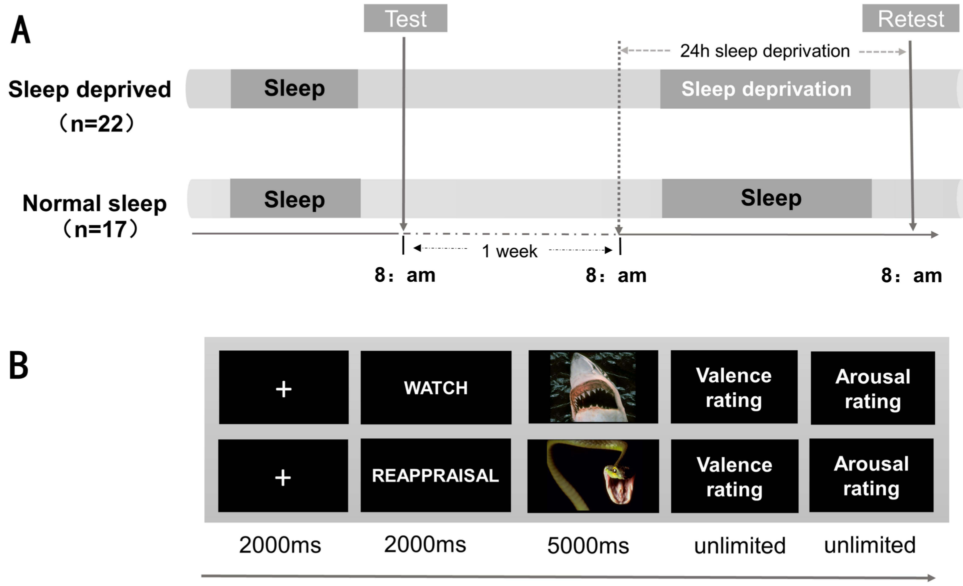


**Figure 2** (**A**) Experimental design. (**B**) Trial structure for the regulation task (an example of a WATCH/REAPPRAISAL trial). This task consisted of two tasks including WATCH and REAPPRAISAL. Each task included 44 trials, 8 for practice and 36 for assessment. Participants had 10 min break.

9102,9584,6020,1275,9373,9160,9621,9046,3168,9921,6244,3064,9042,9300,3062,2276,6821,2053,3063,9415,9041,9006,3261,9120,2753,6831,6530,6370,9430,9810,2900,3181,9530,9290,6570_1,3500,9252,9007,3110,9040,6260,9432,3030,9140. The pictures were divided into 2 samples with equal size and composition (44 for WATCH task, mean valence±S.D: 2.39±0.49, mean arousal: 5.83±0.92 and 44 for REAPPRAISAL task, mean valence±S.D: 2.37±0.49, mean arousal: 5.90 ±0.75) to be presented in test and retest phases, respectively. The pictures were randomly shown for 5 seconds immediately after the prompt. After picture presentation in the WATCH task, participants were required to respond naturally by allowing themselves to experience whatever emotions the image elicited. After picture presentation in the REAPPRAISAL task, participants were instructed to think of something to tell themselves about the picture that would make them feel more positive about the image (Figure 2B).

Participants had a practice session prior to the formal test and were briefly instructed on how to perform each task. They were trained to recontextualize negative images for REAPPRAISAL tasks. This included guiding the participants through a series of trials with negative image recontextualizations. During the tasks, subjects were guided in local language. Researchers confirmed the subjects' skills in using the strategies. In the formal experiment, experimenter no longer interrupted the subjects.

On the other hand, participants in SD group could watch movies, play card games, and interact with other participants and research staffs, but could not engage in any vigorous physical or mental activities. No visitor was allowed. Trained research assistants monitored participants' behavior throughout the study.

## Data Analysis

As a manipulation check to ensure that participants correctly used CRA and not simply responding arbitrarily, we first performed repeated-measures ANOVA with groups (SC vs SD) as between factor, sessions (test vs retest) and instruction type (WATCH vs REAPPRAISAL) as the within factors. If there was a significant main effect of instruction type, an ANCOVA with test scores as covariate, retest scores as dependent variable. The level of significance was always set at $p < 0.05$.

# Results

## Demographic and Sleep Information of the Two Groups

The two groups were similar in their age, gender, scores in Pittsburgh Sleep Quality Index (PSQI), all $p>0.05$. Reappraisal scores were calculated from the Chinese version of the Emotion Regulation Questionnaire (6 items), and

**Table 1** Demographic and Sleep Information of the SC and the SD Groups

| | SD Group (n = 22) | SC group (n =17) |
|---|---|---|
| Age | 20.330±1.940 | 20.41±2.002 |
| Gender | 20 males, 2 females | 15males, 2 females |
| ERQ reappraisal | 29.550±2.350 | 28.706±2.756 |
| PSQI | 5.263±1.826 | 5.436±2.321 |
| Sleep duration-session 1 | 458.314±44.327 | 462.359±48.235 |
| Sleep duration-session 2 | – | 456.235±52.314 |

**Abbreviations**: ERQ, Emotion Regulation Questionnaire; PSQI, Pittsburgh Sleep Quality Index.

there was no difference between the two groups, $t(35)=1.199$, $p=0.239$. On session 2 night, participants in the SC group slept an average of 456.2min, similar to their sleep duration on session 1, $t(16) = 0.753$, $p = 0.280$ (see Table 1).

## CRA Manipulation Check

The ANOVA on affective picture showed a significant main effect of instruction type, both in valence ratings ($F_{1,37}$=93.179, $p$<0.001, $\eta^2$=0.716) and arousal ratings ($F_{1,37}$=49.318, $p$<0.001, $\eta^2$=0.571), compared to WATCH condition, using CRA can effectively increase participants' valence ratings and decrease arousal ratings for negative emotional images in both groups and different sessions.

## Comparison of Valence and Arousal Ratings in Two Group After Different Sleep Manipulation

The ANCOVA on affective picture valence ratings showed significant main effect of group ($F_{1,37}$=6.179, $p$=0.018, $\eta^2$=0.146), mean valence ratings of SD group (M = 3.557, SE = 0.178) were more negative than SC group's (M = 4.251, SE = 0.204). While The ANCOVA on affective picture arousal ratings showed significant main effect of group ($F_{1,37}$=12.779, $p$=0.001, $\eta^2$=0.262), mean arousal ratings of SD group (M = 4.876, SE = 0.269) were higher than SC group's (M = 3.421, SE = 0.306) (Figure 3).

# Discussion

The proper use of the CRA strategy is the foundation of this study which aims to investigate the effects of experimental sleep deprivation on using CRA for regulating negative emotions. To achieve this goal, a standardized CRA paradigm was adopted and validated instructions were used to train participants to perform accurately and efficiently. Compared to the WATCH condition where participants did not use any emotion regulation strategies, they reported more positive valence ratings and lower arousal ratings to negative pictures using strategy of CRA. This suggested that participants used the strategy effectively under the guidance of instructions in this experiment. These findings were consistent with previous studies which also used CRA strategy to reduce negative emotional experiences.[33–36]

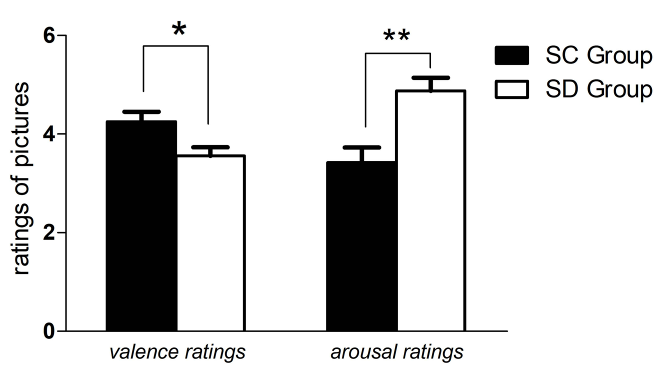


**Figure 3** Valence ratings (left) and arousal ratings (right) among sleep control and sleep deprivation groups. The range of valence ratings was 1 (extremely unhappy) to 9 (extremely happy). The range of arousal ratings was 1 (extremely calm) to 9 (extremely excited). *p < 0.05;**p < 0.01; error bars: 1 SEM.

Model was raised up that sleep deprivation might impair the individual's cognitive reappraisal ability, as it had been found that sleep played an important role in maintaining the normal cognitive functioning, especially the cognitive function of prefrontal cortex, such as cognitive control, and the ability of cognitive reappraisal was dependent on the individual's cognitive control ability.[9,11] The findings indicated that the SD group exhibited more negative valence ratings and higher arousal ratings compared to the SC group. These implied that the effectiveness of CRA was reduced in the SD group following a night of sleep deprivation, potentially impairing their CRA ability. Mauss et al proved that poorer sleep quality was associated with lower ability to reappraise films containing negative contents.[20] Differs from their correlational research design, which cannot conclude that SD damages individual CRA ability. Our research design allows us to confidently confirm this point.

The current findings are consistent with two other experimental studies. Stenson et al confirmed that sleep deprived individuals had higher valence ratings on negative emotion picture than the control group when using CRA.[14] Unfortunately, their research did not consider another dimension of emotional evaluation – arousal – which is clinically also very important. Zhang et al also studied the effect of sleep deprivation on individual CRA ability.[13] They found the behavioral ratings did not show effects of sleep deprivation on the effectiveness of emotion regulation strategies, while the LPP data indicated reappraisal were impaired by SD. The author explained these dissociations as the experimenter's expectation or individual differences and suggested future studies taking baseline variables pertaining to emotions into consideration. Current study makes up for the limitations of the above researches. On the one hand, both dimensions of emotional evaluation were taken into account, on the other hand, a randomized pretest-posttest control group design was used in the current study to examine the effect of SD on CRA ability, which could control factors that affect internal validity effectively.[37] Taking together, combining these evidences give us more confidence in concluding that sleep deprivation damages individual CRA ability.

A growing body of research suggests that disrupted sleep is a robust risk and maintenance factor for a range of psychiatric conditions.[1,3,9,11,15–17,38,39] One explanatory mechanism linking sleep and psychological health is emotion regulation.[11] The study results undoubtedly provide more direct evidence that we found SD impairs CRA ability, an important part of emotion regulation. The result can also be used to explain the high comorbidity of emotional disorders and sleep problems. Sleep disorders may be a risk for continued deterioration of mood disorders. In addition, the emotional regulation system is closely related to the performance of emotional intelligence.[6,40] Both poor emotional regulation ability and poor emotional intelligence will seriously affect social performance and thereby affecting mental health.[16] The experimental results undoubtedly alert the public to pay attention to the role of sleep as insufficient sleep is common in modern society.

Although the present study employed an experimental sleep deprivation paradigm, our results may have relevance to insomnia. Consistent with findings from Mauss et al,[20] our data showed that sleep disruption impairs emotion regulation ability and even increases stress-related hyperarousability. Given that emotion dysregulation and hyperarousal are central etiological factors in insomnia,[41] our observations indicated that sleep deprived individuals who successfully employed CRA strategies nevertheless maintain high arousal responses to negative stimuli. This finding offers important insights into the harmful consequences of disrupted or disturbed sleep on cognitive-emotional regulation despite engaging in adaptive behaviors. Future experimental study is needed in an insomnia population to determine whether similar processes observed in this study are relevant to the etiology and maintenance of insomnia.

## Limitations and Future Directions

This study focused on the effects of SD on a particular type of emotion regulation, cognitive reappraisal, and found that SD impaired individual CRA. According to the process model, emotion regulation processes also include situation selection, situation modification, attentional deployment and response modulation, these processes are also very important in terms of emotion regulation. However, there are few studies on the effects of SD on these processes. Future studies could potentially explore the effects of SD on the other emotion regulation processes.

Meanwhile, this study used subjective ratings of emotional pictures for data analysis, which is usually used for emotional measurements. However, more and more objective physiological indexes, such as galvanic skin response (GSR), event-related potential (ERP) and brain function imaging (fMRI), have been developed in recent years. These physiological indicators cannot yet fully reflect the different dimensions of emotion. For example, LPP amplitude is a good indicator of the arousal level, but not a good indicator of the valence level. Combining subjective evaluations and objective indicators will be more helpful in the future. Future studies may further use these techniques to explore the effects of sleep on emotion regulation.

## Conclusion

The current study demonstrates that a lack of sleep can hinder cognitive reappraisal, which is a crucial strategy for emotion regulation. Given that reappraisal plays a significant role in cognitive therapy, this study suggests that sleep deprivation could potentially undermine the efficacy of cognitive therapy in terms of emotion regulation.

## Data Sharing Statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author Tang.

## Ethics Statement

The studies involving human participants were reviewed and approved by Ethics Committee of the Naval Medical University. The participants provided their written informed consent to participate in this study.

## Acknowledgments

We would like to express our gratitude to EditSprings for the expert linguistic services provided.

## Funding

This work was supported by Key Scientific and Research Projects of Logistics in PLA (20BJZ09).

## Disclosure

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## References

1. Vanek J, Prasko J, Genzor S, et al. Insomnia and emotion regulation. *Neuro Endocrinol Lett*. 2020;41(5):255–269.
2. Andrews S, Hanna P. Investigating the psychological mechanisms underlying the relationship between nightmares, suicide and self-harm. *Sleep Med Rev*. 2020;54:101352. doi:10.1016/j.smrv.2020.101352
3. Watling J, Pawlik B, Scott K, Booth S, Short MA. Sleep loss and affective functioning: more than just mood. *Behav Sleep Med*. 2017;15 (5):394–409. doi:10.1080/15402002.2016.1141770
4. Anderson C, Platten CR. Sleep deprivation lowers inhibition and enhances impulsivity to negative stimuli. *Behav Brain Res*. 2011;217(2):463–466. doi:10.1016/j.bbr.2010.09.020
5. Minkel J, Htaik O, Banks S, Dinges D. Emotional expressiveness in sleep-deprived healthy adults. *Behav Sleep Med*. 2011;9(1):5–14. doi:10.1080/15402002.2011.533987
6. Killgore WDS, Vanuk JR, Persich MR, Cloonan SA, Grandner MA, Dailey NS. Sleep quality and duration are associated with greater trait emotional intelligence. *Sleep Health*. 2022;8(2):230–233. doi:10.1016/j.sleh.2021.06.003
7. Short MA, Louca M. Sleep deprivation leads to mood deficits in healthy adolescents. *Sleep Med*. 2015;16(8):987–993. doi:10.1016/j.sleep.2015.03.007
8. Tomaso CC, Johnson AB, Nelson TD. The effect of sleep deprivation and restriction on mood, emotion, and emotion regulation: three meta-analyses in one. *Sleep*. 2021;44(6):zsaa289. doi:10.1093/sleep/zsaa289
9. Deliens G, Gilson M, Peigneux P. Sleep and the processing of emotions. *Exp Brain Res*. 2014;232(5):1403–1414. doi:10.1007/s00221-014-3832-1
10. Ochsner KN, Gross JJ. *The Neural Bases of Emotion and Emotion Regulation: A Valuation Perspective*. The Guilford Press; 2014.
11. Palmer CA, Alfano CA. Sleep and emotion regulation: an organizing, integrative review. *Sleep Med Rev*. 2017;31:6–16. doi:10.1016/j.smrv.2015.12.006
12. O'Leary K, Bylsma LM, Rottenberg J. Why might poor sleep quality lead to depression? A role for emotion regulation. *Cogn Emot*. 2017;31 (8):1698–1706. doi:10.1080/02699931.2016.1247035
13. Zhang J, Lau EYY, Hsiao JH. Using emotion regulation strategies after sleep deprivation: ERP and behavioral findings. *Cogn Affect Behav Neurosci*. 2019;19(2):283–295. doi:10.3758/s13415-018-00667-y
14. Stenson AR, Kurinec CA, Hinson John M, Whitney P, Van Dongen HPA. Total sleep deprivation reduces top-down regulation of emotion without altering bottom-up affective processing. *PLoS One*. 2021;16(9):e0256983. doi:10.1371/journal.pone.0256983
15. Gross JJ. Emotion regulation: conceptual and empirical foundations. *Handbook Emot Regul*. 2014;2:3–20.
16. Gross JJ, Muoz RF. Emotion regulation and mental health. *Clin Psychol Sci Pract*. 1995;2(2):151–164. doi:10.1111/j.1468-2850.1995.tb00036.x

17. Gross JJ, Jazaieri H. Emotion, emotion regulation, and psychopathology: an affective science perspective. *Clin Psychol Sci*. 2014;2(4):387–401. doi:10.1177/2167702614536164
18. Urry HL. Seeing, thinking, and feeling: emotion-regulating effects of gaze-directed cognitive reappraisal. *Emotion*. 2017;10(1):125. doi:10.1037/a0017434
19. Talbot LS, McGlinchey EL, Kaplan KA, Dahl RE, Harvey AG. Sleep deprivation in adolescents and adults: changes in affect. *Emot Wash DC*. 2010;10(6):831–841. doi:10.1037/a0020138
20. Mauss IB, Troy AS, LeBourgeois MK. Poorer sleep quality is associated with lower emotion-regulation ability in a laboratory paradigm. *Cogn Emot*. 2013;27(3):567–576. doi:10.1080/02699931.2012.727783
21. McRae K, Hughes B, Chopra S, Gabrieli JDE, Gross JJ, Ochsner KN. The neural bases of distraction and reappraisal. *J Cogn Neurosci*. 2010;22(2):248–262. doi:10.1162/jocn.2009.21243
22. Shermohammed M, Kordyban LE, Somerville LH. Examining the causal effects of sleep deprivation on emotion regulation and its neural mechanisms. *J Cogn Neurosci*. 2020;32(7):1289–1300. doi:10.1162/jocn_a_01555
23. Babson KA, Trainor CD, Feldner MT, Blumenthal H. A test of the effects of acute sleep deprivation on general and specific self-reported anxiety and depressive symptoms: an experimental extension. *J Behav Ther Exp Psychiatry*. 2010;41(3):297–303. doi:10.1016/j.jbtep.2010.02.008
24. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res*. 1989;28(2):193–213. doi:10.1016/0165-1781(89)90047-4
25. Gross JJ, John OP. Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. *J Pers Soc Psychol*. 2003;85:348–362. doi:10.1037/0022-3514.85.2.348
26. Searight HR, Montone K. Profile of Mood States. *Encyc Personal Individ Diff*. 2017;2017:4057–4062. doi:10.1007/978-3-319-28099-8_63-1
27. Qiu L, Zheng X, Wang YF. Revision of the positive affect and negative affect scale. *Chin J Appl Psychol*. 2008;2008:1.
28. Bradley MM, Lang PJ. Measuring emotion: the self-assessment manikin and the semantic differential. *J Behav Ther Exp Psychiatry*. 1994;25(1):49–59. doi:10.1016/0005-7916(94)90063-9
29. Thiruchselvam R, Blechert J, Sheppes G, Rydstrom A, Gross JJ. The temporal dynamics of emotion regulation: an EEG study of distraction and reappraisal. *Biol Psychol*. 2011;87(1):84–92. doi:10.1016/j.biopsycho.2011.02.009
30. Troy AS, Wilhelm FH, Shallcross AJ, Mauss IB. Seeing the silver lining: cognitive reappraisal ability moderates the relationship between stress and depressive symptoms. *Emot Wash DC*. 2010;10(6):783–795. doi:10.1037/a0020262
31. Goldin PR, McRae K, Ramel W, Gross JJ. The neural bases of emotion regulation: reappraisal and suppression of negative emotion. *Biol Psychiatry*. 2008;63(6):577–586. doi:10.1016/j.biopsych.2007.05.031
32. Lang PJ, Bradley MM, Cuthbert B. *International Affective Picture System (IAPS): Affective Ratings of Pictures and Instruction Manual*. NIMH, Center for the Study of Emotion; 2008.
33. Hermann A, Kress L, Stark R. Neural correlates of immediate and prolonged effects of cognitive reappraisal and distraction on emotional experience. *Brain Imaging Behav*. 2017;11(5):1227–1237. doi:10.1007/s11682-016-9603-9
34. Shafir R, Schwartz N, Blechert J, Sheppes G. Emotional intensity influences pre-implementation and implementation of distraction and reappraisal. *Soc Cogn Affect Neurosci*. 2015;10(10):1329–1337. doi:10.1093/scan/nsv022
35. Cao D, Li Y, Niznikiewicz MA. Neural characteristics of cognitive reappraisal success and failure: an ERP study. *Brain Behav*. 2020;10(4). doi:10.1002/brb3.1584
36. Uccella S, Cordani R, Salfi F, et al. Sleep deprivation and insomnia in adolescence: implications for mental health. *Brain Sci*. 2023;13(4):569. doi:10.3390/brainsci13040569
37. Spyridakis JH. Conducting research in technical communication: the application of true experimental designs. *Tech Commun*. 1992;39(4):607–624.
38. Lustberg L, Reynolds CF. Depression and insomnia: questions of cause and effect. *Sleep Med Rev*. 2000;4(3):253–262. doi:10.1053/smrv.1999.0075
39. Baum KT, Desai A, Field J, Miller LE, Rausch J, Beebe DW. Sleep restriction worsens mood and emotion regulation in adolescents. *J Child Psychol Psychiatry*. 2014;55(2):180–190. doi:10.1111/jcpp.12125
40. Killgore WDS, Kahn-Greene ET, Lipizzi EL, Newman RA, Kamimori GH, Balkin TJ. Sleep deprivation reduces perceived emotional intelligence and constructive thinking skills. *Sleep Med*. 2008;9(5):517–526. doi:10.1016/j.sleep.2007.07.003
41. Fernández-Mendoza J, Vela-Bueno A, Vgontzas AN, et al. Cognitive-emotional hyperarousal as a premorbid characteristic of individuals vulnerable to insomnia. *Psychosom Med*. 2010;72(4):397–403. doi:10.1097/PSY.0b013e3181d75319



**Nature and Science of Sleep** Dovepress

## Publish your work in this journal

Nature and Science of Sleep is an international, peer-reviewed, open access journal covering all aspects of sleep science and sleep medicine, including the neurophysiology and functions of sleep, the genetics of sleep, sleep and society, biological rhythms, dreaming, sleep disorders and therapy, and strategies to optimize healthy sleep. The manuscript management system is completely online and includes a very quick and fair peer-review system, which is all easy to use. Visit http://www.dovepress.com/testimonials.php to read real quotes from published authors.

**Submit your manuscript here:** https://www.dovepress.com/nature-and-science-of-sleep-journal