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An Experimental Test of the Effects of Sleep Deprivation on Approach Behavior

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Arts in Psychology

by

Rebecca L. Campbell
University of Pittsburgh
Bachelor of Science in Psychology, and Religious Studies, 2014

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University of Arkansas

This thesis is approved for recommendation to the Graduate Council.

Matthew Feldner, Ph.D.
Thesis Director

Ellen Leen-Feldner, Ph.D.
Committee Member

Lindsay Ham-Holm, Ph.D.
Committee Member

Abstract

Emotion regulation and sleep have been identified as mechanisms that may be involved in the development and maintenance of many mental health disorders. However, there has been little research into the relation between sleep and emotion regulation. To address this gap in knowledge, a novel study was conducted. We hypothesized that sleep deprived individuals would demonstrate less approach behavior toward a negatively valenced stimulus, as well as increased self-reported avoidance, compared to a control group. To test this, a randomized controlled experiment using a behavioral measure of approach and a self-report measure of avoidance was conducted. Fifty-two healthy individuals ages 18-30 years old who did not meet criteria for any current mental health disorders were recruited. Participants were randomly assigned to a full night of sleep deprivation or normal sleep and completed a baseline and post-manipulation behavioral avoidance task (BAT) and self-report of avoidance behavior. Repeated measures ANOVAs demonstrated there were no significant effects of sleep deprivation on approach behaviors. However, self-reported avoidance increased for the sleep deprived participants. Results highlight a discrepancy between predicted and actual behavior, specifically, the effect of sleep deprivation on behavioral approach toward a specific stimulus compared to more resource-intensive cognitive and behavioral approaches found in daily life. This may guide future work investigating top-down and bottom-up processing of emotion regulation.

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Introduction

Emotion regulation has been studied as a mechanism involved in the development or maintenance of various mental health disorders. However, research in the area uses a broad conceptualization of emotion regulation (Berking & Wupperman, 2012). Likewise, sleep has been identified as a mechanism in posttraumatic stress disorder (PTSD), depression, anxiety, bipolar disorder, substance abuse, and attention-deficit hyperactivity disorder (Kryger, Roth, & Dement, 2017). While chronic sleep loss and insomnia are often the focus of the literature (Kryger et al., 2017), acute sleep deprivation also can have an impact on mental health (Kahn-Greene, Killgore, Kamimori, Balkin, & Killgore, 2007). These two mechanisms of sleep and emotion regulation could potentially relate to one another, but that relation has scarcely been explored.

Emotion Regulation

Emotion regulation is defined as how a person controls what emotion they experience, when they experience it, and how it is expressed (Gross, 2014). The modal model of emotion regulation describes a complex process that focuses on the full scope of emotion regulation (Gross, 2014). The core features of the modal model include identifying a situation and emotion and how those interplay with a goal. The second core feature is selecting at least one emotion regulation strategy to adjust toward the goal, and lastly, successfully implementing the emotion regulation strategy (Gross, 2014). These features make up the foundation for Gross' process model comprised of five points where a person can try to regulate their emotions; selecting a situation, modifying a situation, deploying attention, cognitive change and response modulation, but this model relies on the utilization of specific emotion regulation strategies (Gross, 2014). Emotion regulation can also depend on bottom-up affective responses in which a stimulus

activates an immediate amygdala response, or top-down processes in which higher level cognitive functions interpret stimuli and trigger a reaction (Ochsner et al., 2009). Many recent studies in the emotion regulation domain focus on how well people can implement an assigned emotion regulation strategy such as reappraisal or distraction (e.g., Augustine & Hemenover, 2009; Gardener, Carr, MacGregor, & Felmingham, 2013; Mauss, Troy, & LeBourgeois, 2013).

Emotion Regulation Strategies

The number of possible emotion regulation strategies is substantial and variable. Research couched in the process model of emotion regulation typically focuses on strategies such as reappraisal, distraction, situation selection, and attention deployment (Sheppes et al., 2014). In other research focused on emotion, stress, and reactions to them, strategies are categorized into voluntary and involuntary strategies (Connor-Smith, Compas, Wadsworth, Thomsen, & Saltzman, 2000; Phillips, Ladouceur, & Drevets, 2008). Furthermore, these processes are not mutually exclusive, and a person may use many strategies to regulate a single experience, complicating investigation efforts (Aldao & Nolen-Hoeksema, 2013). A way to circumvent these challenges is to examine emotion regulation strategies that are mutually exclusive and discrete such as the approach and avoidance system, in which attention toward negative stimuli results in avoiding and attention toward positive stimuli results in approach (Derryberry & Reed, 1994; Elliot, 2006). Dysfunctional avoidance behaviors are linked to negative outcomes in various forms of psychopathology (Kashdan, Barrios, Forsyth, & Steger, 2006).

Sleep

Disrupted sleep is a factor that may have a negative impact on approach/avoidance behavior. Sleep is defined as a self-regulating process involving decreases in voluntary movement and responsiveness and, while we do not fully understand its function, we are thoroughly investigating its physical and cognitive effects (Fuller, Gooley, & Saper, 2006; Kryger et al., 2017). Emotional reactivity to low-stress and high-stress events increases with sleep loss (Fairholme & Manber, 2015). For example, poor sleep is associated with dysfunctional emotional responses; specifically, heightened responses to negative stimuli with lower prefrontal activation and higher amygdala activation in a veteran sample with PTSD (Germain, 2013). Another study observed sleep deprivation impacted top-down cognitive control but not bottom-up processing (Kusztor et al., 2019).

Emotion Regulation and Sleep

Emotion regulation and sleep research typically focuses on the ability to execute specific emotion regulation strategies. For example, one study found that poor sleep quality was associated with poorer ability to regulate emotions when participants were instructed to reappraise a sad film (Mauss et al., 2013). Although this approach has significantly advanced our understanding of the interplay between sleep and emotion regulation, it focuses on the impact of sleep on only one stage in the emotion regulation process: the ability to execute a single strategy. There has also been work that focuses on the impact of sleep loss on emotion reactivity (Baran, Pace-Schott, Ericson, & Spencer, 2012; Rosales-Lagarde et al., 2012; Wagner, Fischer, & Born, 2002), but less so on the regulation of this reactivity.

For instance, sleep deprivation was associated with higher amygdala activity when exposed to negative stimuli during an fMRI study, as well as weaker connectivity between the

amygdala and the medial-prefrontal cortex (Yoo, Gujar, Hu, Jolesz, & Walker, 2007). This would indicate not only a change in emotional reactivity (as indicated by the amygdala response), but a hindered ability to regulate emotions (as indicated by connectivity between the amygdala and medial prefrontal cortex). The observed, relatively weak, connectivity between the amygdala and the pre-frontal cortex may limit the emotion regulation strategies at one's disposal. For instance, if the top-down control associated with connectivity between prefrontal regions and the amygdala is relatively weak, strategies such as cognitive reappraisal may not be sufficient to effectively regulate emotional reactions. As a result, there may be a relatively limited range of available effective strategies, thereby limited access to strategies. One study randomly assigned participants to a full night of sleep or 24 hours of sleep deprivation then had them complete an 8-minute resting state EEG task (Zhang, Lau, & Hsiao, 2019). They observed left frontal alpha asymmetry and a higher theta/beta ratio, both indicators of affective regulation with minimal frontal control, in the sleep deprived group. Additionally, these EEG patterns were associated with sleepiness and vigilance. This relative limitation may result in resorting to less cognitively demanding strategies such as avoidance behaviors. In contrast, relatively strong connectivity between prefrontal and subcortical regions could access emotion regulation strategies other than avoidance that may be more effective or appropriate to a given situation.

Hypothesis

To further understand the relation between sleep and emotion regulation strategy selection a multi-modal investigation was conducted. Participants were randomized to either a sleep deprivation group that involved a full night of sleep deprivation or a control group that involved normal sleep. They completed a behavioral avoidance task (BAT) and self-report of avoidance behaviors before and after the sleep manipulation. We hypothesized sleep-deprived

participants would report and exhibit less approach behavior than those in the control condition after the sleep manipulation. Furthermore, sleep-deprived participants would self-report more avoidance behavior after the sleep manipulation compared to their baseline measures.

Method

Participants

All procedures were approved by the University of Arkansas Institutional Review Board (see Appendix 1). A total of 69 students were recruited through the department of psychological science's SONA system, a departmentally administered web-based research management software package; 63 were consented, 4 were excluded for a current mental health disorder, and 59 were randomized. Fifty-two adults ages 18-30 years ($M_{age} = 18.9$, $SD = 1.1$) completed the study. To be eligible, participants did not meet criteria for a current mental health diagnosis, obstructive sleep apnea (OSA), nor could they take any medications that may impact sleep-wake functioning such as stimulants, benzodiazepines, and opioids. It should be noted that there was higher attrition in the sleep deprivation condition as assumed but there were no demographic differences between the experimental and control groups (see Table 1).

Measures

STOPBANG. The STOPBANG is an eight-item questionnaire used to determine risk for OSA. This questionnaire is commonly used in clinical and research settings and has been determined to have high predictive validity (Nagappa et al., 2015; Tan et al., 2016). The alpha level for this study was .68, suggesting acceptable internal consistency. Participants with a score of five or above were excluded due to high risk of OSA. The STOPBANG was administered at baseline as a screening tool (see Table 2).

Mini International Neuropsychiatric Interview (M.I.N.I) version seven. The M.I.N.I is a structured clinical interview to screen for DSM 5 disorders. Participants were administered the M.I.N.I to assess for current mental health disorders as part of the eligibility assessment. It demonstrates good construct validity and reliability when compared to similar measures (Lecrubier et al., 1997; Sheehan et al., 1997, 1998). The principle investigator (PI) has extensive training in clinical interviewing, including in the administration of the M.I.N.I.

Pittsburgh Sleep Quality Index. The Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) is a 19-item questionnaire used to determine sleep quality by collecting information regarding sleep efficiency, sleep disturbances, medication use, and daytime functioning. A global score ranging from 0-21 is then calculated from the component scores. A score above five is considered poor sleep quality. This measure has shown high test-retest reliability in clinical and non-clinical populations (Backhaus, Junghanns, Brooks, Riemann, & Hohagen, 2002). The PSQI also demonstrates criterion validity when correlated with other sleep measures, such as sleep diaries and actigraphy, obtained after an initial administration of the PSQI (Grandner, Kripke, Yoon, & Youngstedt, 2006; Spira et al., 2012). The alpha level for the current study was .56. This was low compared to other studies (Buysse et al. 1989, Backhaus et al. 2002, Spira et al. 2012).

Epworth Sleepiness Scale. The Epworth Sleepiness Scale (ESS; Johns, 1991) is an eight-item questionnaire used to measure daytime sleepiness. Scores range from 0-24 with scores five or lower indicating low levels of daytime sleepiness. This measure has shown high test-retest reliability (Johns, 1992), and good internal consistency (Cho et al., 2011; Gibson et al., 2006; Izci et al., 2008; van der Heide et al., 2015). In addition, the ESS has demonstrated

adequate construct validity when compared to multiple sleep latency tests (Chervin, Aldrich, Pickett, & Guilleminault, 1997). The alpha level for this study was .68.

Positive and Negative Affect Schedule (PANAS). The PANAS (Watson, Clark, & Tellegen, 1988) is a 20-item questionnaire that measures positive and negative affect. The PANAS demonstrates good construct validity and reliability when compared to similar measures (Crawford & Henry, 2004; Watson et al., 1988). The negative affect scale (PANAS-N) had a .89 alpha level and the positive affect scale (PANAS-P) had a .92 alpha level in the current study. The PANAS-N and PANAS-P were used to determine group differences at baseline. While the PANAS was originally formulated to measure trait affect, there is evidence to suggest it can also measure state affect (Kashdan & Roberts, 2004; Trull & Ebner-Priemer, 2009). State affect was measured before the BAT at the baseline appointment and before the post-sleep manipulation BAT to collect information on pre-task variation within subjects.

Cognitive-Behavioral Avoidance Scale (CBAS). The CBAS is a 31-item questionnaire that measures general avoidance behaviors in social, school, and work situations and includes four subscales; cognitive-social (CS), cognitive-nonsocial (CN), behavioral-social (BS), and behavioral-nonsocial (BN). Participants respond on a 1 (*not at all true for me*) to 5 (*extremely true for me*) scale. It has demonstrated good convergent validity with similar measures as well as anxiety and depression measures (Ottenbreit & Dobson, 2004). Test-retest reliability and internal consistency are considered adequate (Ottenbreit & Dobson, 2004). Internal consistency in the present study was an alpha level of .92. Participants completed the CBAS at baseline to collect self-report information on typical avoidance behaviors. A modified version was administered at baseline and post-manipulation to measure likelihood of avoidance in the present moment. Specifically, instructions were changed from “indicate how true *in general*” to “indicate how true

if presented with this situation “*right now*” and the grammatical tense of items were changed. For instance, the modified CBAS included items such as “I would not answer the phone in case people are calling with social invitations” compared to the CBAS item “I do not answer the phone in case people are calling with social invitations.” To date, there is no precedent for the modified version of the CBAS. The alpha level for the CBAS-M was .94.

Barratt Impulsiveness Scale Version 11 (BIS-11). The BIS-11 is a 30-item measure assessing behaviors and preferences related to impulsivity (Patton Stanford & Barratt 1995). The BIS-11 demonstrates high convergent validity with other self-report measures, adequate test-retest reliability, and adequate internal consistency (Stanford et al., 2009). The alpha level in the present study was .56. As it is possible that impulsive tendencies may impact BAT performance, this was used to examine between-group differences at baseline.

Behavioral avoidance task (BAT). A BAT was used to measure behavioral approach of an aversive stimulus. Participants were presented with a bedpan made to look and smell dirty using smudges of potting soil, melted chocolate, homemade prank feces, a prank fart spray, and synthetic urine (see Appendix 2). They were instructed to complete seven hierarchical levels of engagement, starting with 1) touching it with a tissue, followed by 2) touching it with a finger, then 3) touching it with a single bare-hand, 4) then both hands, 5) one hand then touch their arm, 6) one hand then touching their chest, and finally 7) one hand then touching their face. Participants had a time limit to complete each level and completed a card sorting task between each level to bring their emotional state to baseline levels. The procedure ended when the participant declined to complete the next step on the hierarchy. It is important to note while the task is labeled as an *avoidance* task, conceptually, steps completed measure how much a person will *approach* the task. Therefore, data from this assessment are discussed as behavioral

approach. Additionally, consistent with precedent (Campbell, Bynion, Forte, Feldner, & Adams, 2019), participants rated their peak disgust and anxiety before seeing the BAT (pre-instruction), after being presented the BAT and informed of the instructions (post-instruction), and after completing the BAT (post-BAT; by either declining to continue or having completed all steps). The rating scale ranged from 0 (*no disgust/anxiety*) to 100 (*extreme disgust/anxiety*) scale (see Table 3). Participants were provided hand sanitizer immediately following the task to reduce the likelihood of carryover effects from the first administration of the task (on day one of the procedure) to the second administration (on day two of the procedure). This BAT has demonstrated convergent validity as suggested by correlations with disgust measures, and reliability in increasing disgust and anxiety (Najmi & Amir, 2010; Najmi, Tobin, & Amir, 2012).

Research Design

This experiment was a randomized controlled study wherein healthy participants were randomized to one of two groups: either total sleep deprivation for a full night (i.e., experimental group), or sleep in accordance with their typical sleep schedule (i.e., control condition). Pre- and post-manipulation measures of approach behaviors were completed. This design allows for an experimental test of the relation between sleep deprivation and approach behavior in response to a laboratory-based stimulus. While the laboratory-based design limits generalizability, this study was designed to be high in internal validity as a test of the impact of sleep deprivation on approach behavior.

Notably, acute sleep deprivation may be associated with relatively elevated emotional reactivity (Rosales-Lagarde et al., 2012; Wagner et al., 2002), negative mood (Babson, Trainor, Feldner, & Blumenthal, 2010), and negative affect (Franzen, Siegle, & Buysse, 2008; Watling, Pawlik, Scott, Booth, & Short, 2017). To address this concern, negative state affect was

measured before the primary outcomes. Any significant differences within or between subjects will be addressed in interpretation.

Procedure

People interested in participating initially provided verbal consent to complete a brief phone screen that yielded a preliminary index of mental health history, risk for OSA, and any increased risk from sleep deprivation to gauge inclusion and exclusion criteria. If a potential participant met the inclusion criteria described above, they were invited to complete a laboratory-based session on a day when they could stay awake through the night. After obtaining written informed consent, participants completed the STOPBANG and were interviewed using the MINI to establish eligibility. Eligible participants then completed a questionnaire battery consisting of basic demographic information, PSQI, ESS, CBAS, CBAS-M, BIS-11, and the PANAS. Eligible participants then were administered the baseline BAT. The task was completed between 0900 and 1030 to control for any potential differences in circadian timing.

Participants were then randomly assigned to either the control or experimental group. The experimental group was asked to stay awake from their wake time on the day of their baseline appointment until the BAT the following day (approximately 26 hours). They were required to make hourly calls into the lab to confirm that they stayed awake for the entire deprivation period. If participants missed one call or reported sleeping more than 60 minutes total, they were excluded from the study. The control group adhered to their standard sleep time and wake time. All participants were asked to not consume any caffeine, alcohol, or other drugs that may impact the sleep-wake cycle. Both sleep adherence and substance use were confirmed via a sleep diary at the post-manipulation visit. Participants returned to the lab in the morning at the same time as their previous appointment to complete a second laboratory-based session. Five participants in

the sleep deprivation condition and two control participants were excluded due to non-adherence. The consent included an agreement that if assigned to the experimental condition participants agreed to not drive themselves to or from their appointment due to safety concerns. During the second session, the PANAS and CBAS-M were administered first, followed by the BAT. Upon completing the second BAT, participants were debriefed and compensated with course credit.

Results

Data Analytic Approach

An *a priori* power analysis was calculated using a small-medium effect size ($f = .2$), alpha level of .05 and power of .8. Results of the power analysis suggested a sample size of 52 participants total. The actual partial eta squared (.014) was lower than predicted, resulting in power of .134. The data were first cleaned and examined to ensure statistical assumptions were met. Three participants skipped a single item in the CBAS-M. After determining they were missing at random, they were replaced using mean replacement. Linearity and homoscedasticity of BAT steps and CBAS-M responses were confirmed by visual inspection of a scatterplot. Sphericity was determined via standard deviation. BAT steps met assumptions, but CBAS-M responses did not and therefore the Greenhouse-Geisser correction was applied. The BAT and CBAS-M data were determined to be normal based on skewness and kurtosis analyses. Levene's test confirmed homogeneity of variance for both variables of interest. Preliminary data analyses were conducted to confirm random assignment and manipulation. Finally, a set of ANOVAs were conducted to examine the within-subjects effects (from baseline to post-manipulation), between-subjects effects (sleep deprivation versus control) and the interaction of these factors on the dependent variables.

Preliminary Data Analyses

First, zero-order correlations were computed for all continuous study variables (see Table 4). Then, groups were compared in terms of theoretically relevant variables measured at baseline to confirm random assignment effectively equated groups. T-tests were conducted comparing group differences at baseline for all variables listed in Table 4. As there were no significant differences in either categorical (Table 1) or continuous (Table 4) variables, randomization was considered adequate.

Second, SUDs ratings were examined as a manipulation check, and descriptive statistics for BAT steps were examined (Table 3). SUDS ratings increased for anxiety ($M = 6$, $SD = 3.1$) and disgust ($M = .67$, $SD = 3.1$) from pre- to post-BAT instruction ($M_{anxiety} = 20.62$, $SD = 25.08$, $M_{disgust} = 39$, $SD = 31.6$), suggesting the BAT induced anxiety and disgust (Table 1). Baseline BAT steps completed ($M = 3.77$, $SD = 2.7$) and post-manipulation steps completed ($M = 3.62$, $SD = 2.83$) both had a mode of 7 suggesting there is not a practice effect but there may be a ceiling effect for BAT performance.

Although there were no baseline differences in PANAS subscale scores, change in these variables across the two testing days was examined in order to provide a comprehensive description of the sample. For the PANAS-P, there was a significant effect from baseline to post-manipulation ($F(1, 49) = 26.01$, $p < .001$), but no effect of group ($F(1, 49) = 3.28$, $p = .076$). The interaction was significant ($F(1, 49) = 9.25$, $p = .004$). With regard to PANAS-N, there was no effect from baseline to post-manipulation ($F(1, 51) = .11$, $p = .737$) nor between the sleep deprivation and control groups ($F(51) = 1.09$, $p = .301$), but there was a significant interaction ($F(1, 51) = 6.59$, $p = .013$). Means are depicted in Figure 1. This pattern of data suggests positive

affect decreased and negative affect increased post-manipulation for the sleep deprivation group only.

Primary Hypothesis Testing

To test the hypothesis that sleep deprivation would decrease approach behavior during the BAT, a repeated measures ANOVA was conducted. There were no significant within-subjects ($F(1, 51) = .73, p = .396$) or group ($F(1, 51) = 1.83, p = .182$) effects, nor was there a significant interaction ($F(1, 51) = 1.65, p = .205$). This suggests sleep deprivation did not impact the number of BAT steps completed. Results are depicted in Figure 2.

With regard to the hypothesis that sleep deprivation would increase self-reported avoidance on the CBAS-M, there was a main effect across baseline and post-manipulation ($F(1, 51) = 17.62, p < .001$) but no main effect of group ($F(1, 51) = 1.7, p = .198$). There was, however, a significant interaction effect ($F(1, 51) = 21.27, p < .001$) suggesting CBAS-M scores increased from baseline to post-manipulation group, but only for the sleep deprivation group. Results are depicted in Figure 3.

Exploratory Analyses: CBAS-M Subscales

The CBAS is 31-item questionnaire that measures avoidance behaviors across varying contexts. As the CBAS distinguishes between cognitive (e.g., “When I experience confusion in my relationships, I do not try to figure things out”) and behavioral (e.g., “I avoid trying new activities that hold the potential for failure”), as well as social and non-social avoidance, exploratory analyses were conducted using the CBAS-M to determine if any subscales were driving the total effect. A Bonferroni correction was used ($\alpha = .013$). There were no significant differences between groups for CBAS-M behavioral-social (BS; $F(1,50) = .798, p = .376$), CBAS-M behavioral-nonsocial (BN; $F(1,50) = .499, p = .483$) CBAS-M cognitive-social (CS;

$F(1, 50) = .14, p = .714$) or CBAS-M cognitive-nonsocial (CN; $F(1, 50) = 5.05, p = .029$), meaning sleep manipulation did not have a main effect on CBAS subscale scores. There were main effects from baseline to post manipulation for CBAS-M BS ($F(1, 50) = 27.93, p < .001$), CBAS-M BN ($F(1,50) = 12.53, p = .001$), and CBAS-M CN ($F(1,50) = 9.64, p = .003$) but not CBAS-M CS ($F(1, 50) = 4.4, p = .041$). Lastly, there were significant interactions for CBAS-M BS ($F(1, 50) = 31.40, p < .001$), CBAS-M BN ($F(1,50) = 18.72, p < .001$), CBAS-M CS ($F(1,50) = 10.72, p = .002$), and CBAS-M CN ($F(1,50) = 6.96, p = .011$). The pattern of effects suggested CBAS-M CS scores increased from baseline to post-manipulation for the sleep deprivation group only while CBAS-M BS, CBAS-M BN, and CBAS-M CN scores increased for both groups but more so for the sleep deprivation condition. Means are depicted in Figure 4.

Discussion

Sleep and emotion regulation are interacting mechanisms of mental health disorders (Mauss et al., 2013). This study tested if a night of sleep deprivation would decrease approach behavior and increase self-reported avoidance compared to baseline measures and a control group. Hypotheses were partially supported.

There was no difference in approach behaviors as measured by the BAT between the sleep deprivation group and the control group, nor was there a difference in observed behavioral approach from baseline to post-manipulation. These findings suggest sleep deprivation does not impact performance on a BAT involving disgusting stimuli. However, one must be cautious in interpreting null findings and there are several other explanations for the current pattern of results. First, the operationalization of emotion regulation in the current study (i.e., behavioral approach toward an unpleasant stimulus) may reflect an emotion regulation strategy that does not rely on top-down processing and is therefore less impacted by sleep loss. That is, unlike complex

strategies such as reappraisal, which are mediated by structures in the prefrontal cortex (Parvaz, MacNamara, Goldstein, & Hajcak, 2012), behavioral avoidance of aversive cues is a basic strategy that is observable across species, including those with less complex and differentiated brains. Consistent with this idea, prior work links sleep deprivation to effects on top-down (i.e., cognitive control adjustments during a Stroop task), but not bottom-up (i.e., facilitated processing of repetition during a Stroop task) processes (Gevers, Deliens, Hoffmann, Notebaert, & Peigneux 2015). Similarly, prior work shows that emotion regulation strategies that require more top-down processing and more complex cognitive abilities such as reappraisal are more affected by sleep loss (Kusztor et al., 2019, Yoo et al., 2007, Zhang et al., 2019). Future work would benefit from a direct comparison of the effects of acute sleep deprivation on approach/avoidance versus regulatory strategies like reappraisal. Studies that include an evaluation of neural correlates would provide a particularly important extension to extant work.

Second, hypotheses for the current study were predicated, in part, on research with clinical populations (Briere, Hodges, & Godbout, 2010; Germain, 2013). It stands to reason that the effects of sleep loss on approach/avoidance behaviors may be magnified among individuals with psychopathology and more difficult to detect in the present, healthy sample. As suggested by the effect sizes observed in the current study, a larger sample may be necessary to obtain significant effects.

Finally, methodological issues may have affected findings. The BAT used in this study is part of a larger set used in prior work (Campbell et al., 2019; Najmi & Amir, 2010; Najmi, et al., 2012). These BATs included other disgust-relevant stimuli such as laundry that appeared dirty and dirt containing hair and dead bugs (Campbell et al., 2019). The procedure used in the current study was implemented both for pragmatic reasons and because the focus on bodily disgust has

conceptual relevance to mental health disorders such as PTSD and obsessive-compulsive disorder. Nevertheless, the use of a single stimulus may not have allowed for a full range of responses. Importantly, the BAT adequately induced disgust as evidenced by changes in SUDS ratings, and there did not appear to be a practice effect of the BAT as determined by the lack of main effect of time and stable anxiety and disgust ratings from baseline to post-manipulation (see Table 3). However, there was little change in anxiety and disgust ratings from the point at which participants were presented with the BAT and instructed on the procedure to after they completed the task. Further, the means for these variables were relatively low, given a possible 100-point range. Thus, it appears that the stimulus utilized in the current study did not elicit a robust affective response. Indeed, the modal number of BAT steps completed at both time points was 7, the highest step in the hierarchy, suggesting a possible ceiling effect. Future studies should examine the current study hypotheses using a full set of BATs, including variations in stimulus intensity and type (e.g., stimuli that induce fear).

The hypothesis that self-reported avoidance would increase for the sleep deprivation group post-manipulation was supported. Findings from the current study suggest sleep deprivation increased the degree to which participants thought they would engage in avoidance behavior across multiple contexts. There are important methodological differences between the two outcomes assessed in the current study, which may account for the divergence in findings across hypotheses. Specifically, the behavioral task involved approaching a disgust-relevant stimulus, whereas the CBAS included behavioral, social, and cognitive forms of avoidance. To examine the possibility that specific forms of avoidance were differentially impacted by sleep loss, exploratory analyses were conducted using the CBAS-M subscales. Notably, cognitive-social avoidance increased for the sleep deprivation condition. For instance, compared to those in

the control group, participants in the sleep deprivation group were more likely to avoid activities such as problem-solving or making decisions about relationships. This could be related to effects of sleep on top-down processing (Kusztor et al., 2019) as the types of activities tapped by the cognitive-social subscale not only involve internal reflections and understanding, but interpretation and understanding of others' intentions and emotional experiences. Behavioral-social, behavioral-nonsocial, and cognitive-nonsocial avoidance increased at post-manipulation more for the sleep deprivation group than the control group. While both groups were likely to endorse avoiding challenges, social situations, or future planning, such avoidance was greater for the sleep deprivation group. Again, the consequences of sleep deprivation on avoidance may be unique to more complex activities like thinking about the future. Notably, these findings must be cautiously interpreted because these analyses were exploratory and utilized a modified version of the CBAS that has not been empirically validated. However, this pattern of findings suggests several important research questions that will help scientists determine with greater precision how sleep deprivation affects different types of avoidance. Future studies should implement tasks which involve more social and cognitive forms of avoidance. For instance, gaze avoidance has been implicated in social phobia (Moukheiber et al., 2010). A study measuring gaze avoidance before and after sleep loss may provide a deeper understanding into social avoidance more specifically. Additionally, a negative priming task and free recall task has been used in prior work to examine cognitive avoidance (Cloitre & Liebowitz, 1991; Kindt & Brosschot, 1998) and therefore may be an appropriate tool to further investigate cognitive avoidance as it relates to sleep loss.

In addition to those already discussed, several additional limitations should be mentioned. First, the emphasis in the current study was on internal validity, which was achieved at the

expense of external validity. Because of the low ecological validity, findings must be supported by more naturalistic studies of the effects of sleep on approach/avoidance of stimuli people encounter in their day-to-day lives, such as a dirty restroom or social avoidance of engagements, before results are generalized. Second, this study was conducted using a primarily white, female, undergraduate sample compensated with course credit, reducing generalizability. Future studies should focus on community recruitment using different remuneration strategies and an emphasis on recruiting more representative samples. Third, as has been done in prior work (Babson et al. 2010; Cox, Upender, Olatunji, 2020), substantial sleep disruption was achieved by the required hourly calls to the laboratory in the current study. However, we cannot be certain that participants remained awake in between the calls, as instructed. In-lab polysomnography is the gold standard in sleep research as it allows for direct observation of participant compliance with study instructions. Actigraphy is also a useful tool for measuring sleep duration without undue burden on participants (Marino et al. 2013). Future work in this area would benefit from using these types of technologies. Finally, sleep loss is known to decrease positive affect and increase negative affect (Babson & Feldner, 2015). This poses an interpretative challenge for experimental research. For example, the observed changes in positive and negative affect in the sleep-deprived group could be driving effects on self-reported avoidance behavior (as opposed to sleep deprivation itself). This is an important consideration for the current study as emotion regulation strategies are interrelated with individual differences in affective experience (Gross & John, 2003). That is, not only does emotion regulation influence affect, but research indicates that variability in the tendency to experience, for example, positive affect, is associated with emotion regulation difficulties (McLaughlin, Luberto, O'Bryan, Kraemer, McLeish, 2019). To begin to address this issue, future work could include another comparison group in addition to

those employed here, in which an emotion elicitation paradigm is employed to manipulate participant affect, and effects on avoidance behavior are compared across groups.

These limitations notwithstanding, the current experiment provides a novel evaluation of the transdiagnostic factors of sleep loss and approach/avoidance (Hayes, Wilson, Gifford, & Follette, 1996, Harvey, Murray, Chandler, & Soehner, 2011). Findings suggested sleep deprivation did not impact approach behaviors toward a negatively valenced stimulus but did decrease self-reported avoidance behaviors. This is important because it highlights a discrepancy between predicted and actual behavior as well as the potentially unique effects on behavioral approach toward a specific cue as opposed to more resource-intensive cognitive and behavioral approach (e.g., planning for the future) that characterize most people's lives. The current study lays the groundwork for continued investigation of the effects of sleep deprivation on multiple forms of emotion regulation.

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Appendix

Appendix 1. IRB Approval Letter



To: Rebecca L Campbell
From: Douglas James Adams, Chair
IRB Committee
Date: 07/12/2018
Action: Expedited Approval
Action Date: 07/12/2018
Protocol #: 1805125389
Study Title: A Study of Sleep and Emotion Regulation
Expiration Date: 06/10/2019
Last Approval Date:

The above-referenced protocol has been approved following expedited review by the IRB Committee that oversees research with human subjects.

If the research involves collaboration with another institution then the research cannot commence until the Committee receives written notification of approval from the collaborating institution's IRB.

It is the Principal Investigator's responsibility to obtain review and continued approval before the expiration date.

Protocols are approved for a maximum period of one year. You may not continue any research activity beyond the expiration date without Committee approval. Please submit continuation requests early enough to allow sufficient time for review. Failure to receive approval for continuation before the expiration date will result in the automatic suspension of the approval of this protocol. Information collected following suspension is unapproved research and cannot be reported or published as research data. If you do not wish continued approval, please notify the Committee of the study closure.

Adverse Events: Any serious or unexpected adverse event must be reported to the IRB Committee within 48 hours. All other adverse events should be reported within 10 working days.

Amendments: If you wish to change any aspect of this study, such as the procedures, the consent forms, study personnel, or number of participants, please submit an amendment to the IRB. All changes must be approved by the IRB Committee before they can be initiated.

You must maintain a research file for at least 3 years after completion of the study. This file should include all correspondence with the IRB Committee, original signed consent forms, and study data.

cc: Ellen Winifred Leen-Feldner, Investigator
Matthew T Feldner, Investigator

Appendix 2. Behavioral Avoidance Task



Table 1. Sample Demographics

| | Frequency | | |
|---------------------------|-------------|-------------------|---------|
| | Full Sample | Sleep Deprivation | Control |
| Gender | | | |
| Male | 17 | 9 | 8 |
| Female | 35 | 17 | 18 |
| Race | | | |
| White | 44 | 22 | 22 |
| Black | 2 | 1 | 1 |
| Other | 6 | 3 | 3 |
| Ethnicity | | | |
| Hispanic | 5 | 2 | 3 |
| Non-Hispanic | 47 | 24 | 23 |
| Family income | | | |
| > \$100,000 | 18 | 8 | 10 |
| < \$100,000 | 34 | 18 | 16 |
| Sexual orientation | | | |
| Homosexual | 6 | 5 | 1 |
| Heterosexual | 44 | 20 | 24 |
| Bisexual | 2 | 1 | 1 |

Note: Chi-Squared tests indicated that there were no significant differences between groups.

Table 2. Measure Administration

| Measure | Baseline | Post-Manipulation |
|--|---------------------|---------------------|
| STOPBANG | Interview | |
| Mini International Neuropsychiatric Interview | Interview | |
| Pittsburgh Sleep Quality Index | Qualtrics | |
| Epworth Sleepiness Scale | Qualtrics | |
| Positive and Negative Affect Schedule | Qualtrics | Qualtrics |
| Cognitive Behavioral Avoidance Scale | Qualtrics | |
| Cognitive Behavioral Avoidance Scale- Modified | Qualtrics | Qualtrics |
| Barratt Impulsivity Scale | Qualtrics | |
| Behavioral Avoidance Task | Researcher Directed | Researcher Directed |

Above is the administration order of each measure as well as the means of administration.

Table 3. BAT and SUDS Descriptive Statistics

| | Full Sample | | Sleep Deprivation | | Control | |
|---------------------|----------------|-------|-------------------|-------|----------------|-------|
| | M(<i>SD</i>) | Range | M(<i>SD</i>) | Range | M(<i>SD</i>) | Range |
| Baseline | | | | | | |
| Disgust SUDS | | | | | | |
| 1) Pre-Instruction | .67(3.1) | 0-20 | 1.27(4.32) | 0-20 | .08(.39) | 0-2 |
| 2) Post-Instruction | 39(31.62) | 0-100 | 38.04(26.11) | 0-95 | 39.9(36.83) | 0-100 |
| 3) Post-BAT | 40.55(27.27) | 0-100 | 40.84(22.7) | 6-85 | 40.27(31.5) | 0-100 |
| Anxiety SUDS | | | | | | |
| 1) Pre-Instruction | 6(12.47) | 0-50 | 6.15(9.2) | 0-30 | 5.85(15.25) | 0-50 |
| 2) Post-Instruction | 20.62(25.08) | 0-90 | 19.92(18.56) | 0-60 | 21.31(30.62) | 0-90 |
| 3) Post-BAT | 22.74(20.53) | 0-90 | 21.4(14.37) | 0-50 | 24.04(25.32) | 0-90 |
| BAT Steps | 3.77(2.7) | 0-7 | 4.38(2.42) | 1-7 | 3.15(2.87) | 0-7 |
| Post-Manipulation | | | | | | |
| Disgust SUDS | | | | | | |
| 1) Pre-Instruction | 1.71(4.39) | 0-20 | 2.15(4.5) | 0-15 | 1.27(4.32) | 0-20 |
| 2) Post-Instruction | 33.67(31.52) | 0-100 | 31.08(27.79) | 0-90 | 36.27(35.21) | 0-100 |
| 3) Post-BAT | 39.59(31.26) | 0-100 | 39.28(28.26) | 0-90 | 39.88(34.46) | 0-100 |
| Anxiety SUDS | | | | | | |
| 1) Pre-Instruction | 5.54(10.57) | 0-55 | 6.01(8.9) | 0-30 | 5(12.17) | 0-55 |
| 2) Post-Instruction | 17.62(21.75) | 0-80 | 17.65(19.1) | 0-70 | 17.58(24.5) | 0-80 |
| 3) Post-BAT | 17.82(21.94) | 0-80 | 16(18.91) | 0-60 | 19.58(24.76) | 0-80 |
| BAT Steps | 3.62(2.83) | 0-7 | 4(2.77) | 0-7 | 3.23(2.89) | 0-7 |

Note: SUDS = Subjective Units of Distress, BAT = Behavioral Avoidance Task.

SUDS ratings were collected 1) before participants saw the BAT, 2) after the BAT was presented and instructions provided, and 3) after participants completed the BAT by either declining to proceed or completing all steps.

Table 4. Baseline Descriptive Statistics and Correlations

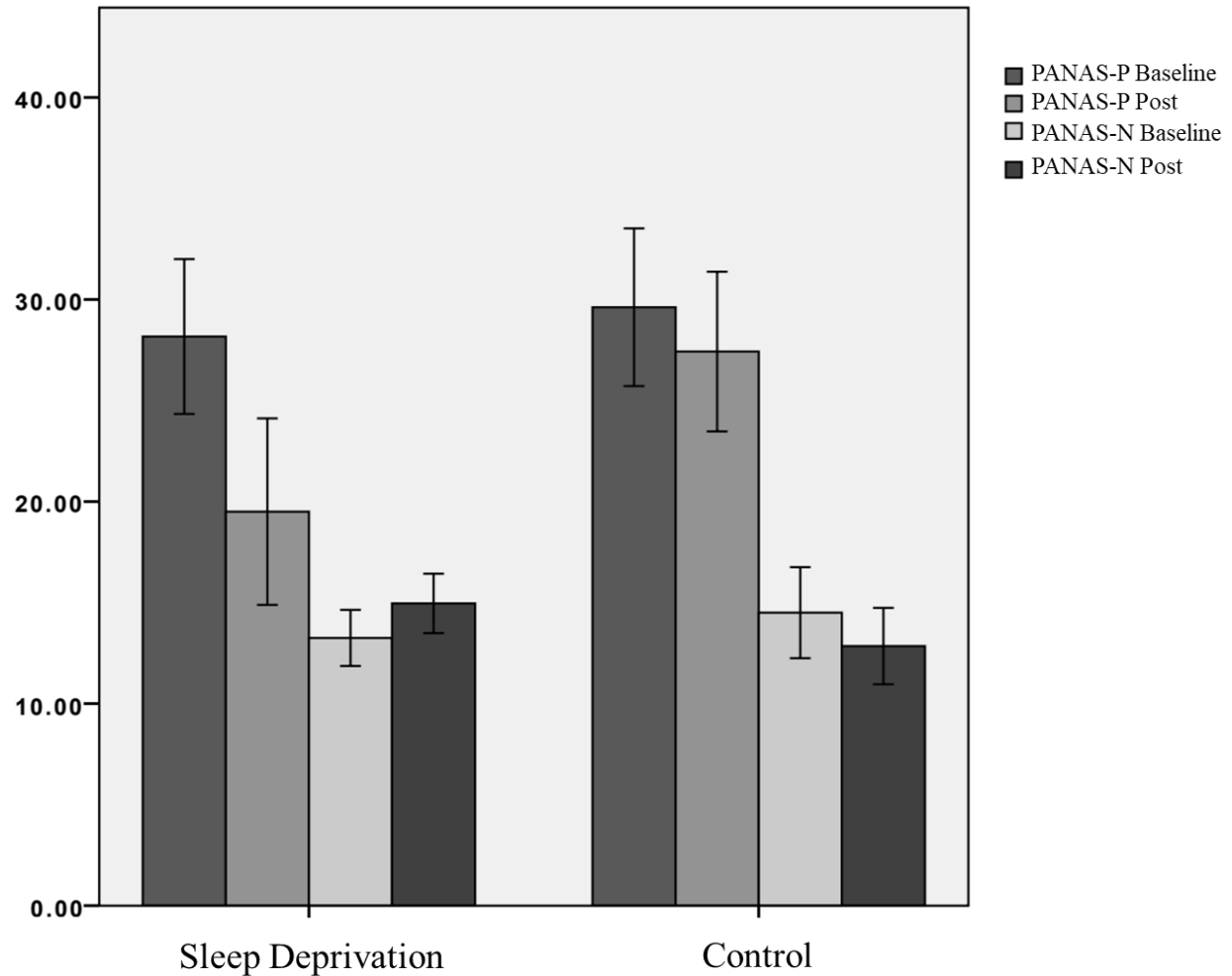
| | M (SD) | | | <i>t</i> | <i>df</i> | <i>p</i> | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|------------|--------------|--------------|-------------|----------|-----------|----------|---|-----|------|------|------|------|------|------|------|
| | Full | SDep | C | | | | | | | | | | | | |
| 1. Age | 18.9(1.1) | 19.04(1.04) | 18.77(.99) | .96 | 50 | .344 | - | .19 | -.05 | .01 | -.05 | -.12 | .05 | -.06 | -.08 |
| 2. PSQI | 6.21(2.11) | 6.08(1.74) | 6.33(2.46) | -.41 | 46 | .687 | | - | .23 | -.08 | .18 | .26 | .21 | -.24 | -.04 |
| 3. ESS | 5.6(3.82) | 5.27(2.52) | 5.92(.49) | -.61 | 50 | .542 | | | - | .03 | .23 | .52* | .51* | .05 | .01 |
| 4. PANAS-P | 28.92(9.32) | 28.17(9.07) | 29.62(9.66) | -.55 | 48 | .588 | | | | - | .34* | -.25 | -.17 | .09 | -.03 |
| 5. PANAS-N | 14.48(5.9) | 14.46(6.31) | 14.5(5.58) | -.02 | 50 | .982 | | | | | - | .47* | .46* | .06 | -.03 |
| 6. CBAS | 48.04(14.58) | 45.35(13.68) | 50.42(15.2) | -1.22 | 47 | .228 | | | | | | - | .94* | -.12 | -.07 |
| 7. CBAS-M | 44.48(15.07) | 42.27(14.59) | 46.69(15.5) | -1.06 | 50 | .295 | | | | | | | - | -.05 | -.09 |
| 8. BIS-11 | 63.18(5.8) | 64.19(5.98) | 62.12(5.53) | 1.27 | 49 | .205 | | | | | | | | - | .12 |
| 9. BAT | 3.77(2.7) | 4.38(2.42) | 3.23(2.89) | 1.67 | 50 | .100 | | | | | | | | | - |

Note: Full: full sample, SDep: sleep deprivation group, C: control group, PSQI: Pittsburgh Sleep Quality Index, ESS: Epworth Sleepiness Scale, PANAS-P: Positive and Negative Affect Scale-Positive, PANAS-N: Positive and Negative Affect Scale-Negative, CBAS: Cognitive-Behavioral Avoidance Scale, CBAS-M: Cognitive- Behavioral Avoidance Scale Modified, BIS-11: Barratt Impulsivity Scale version 11, BAT: Behavioral Avoidance Task

**p* value < .05

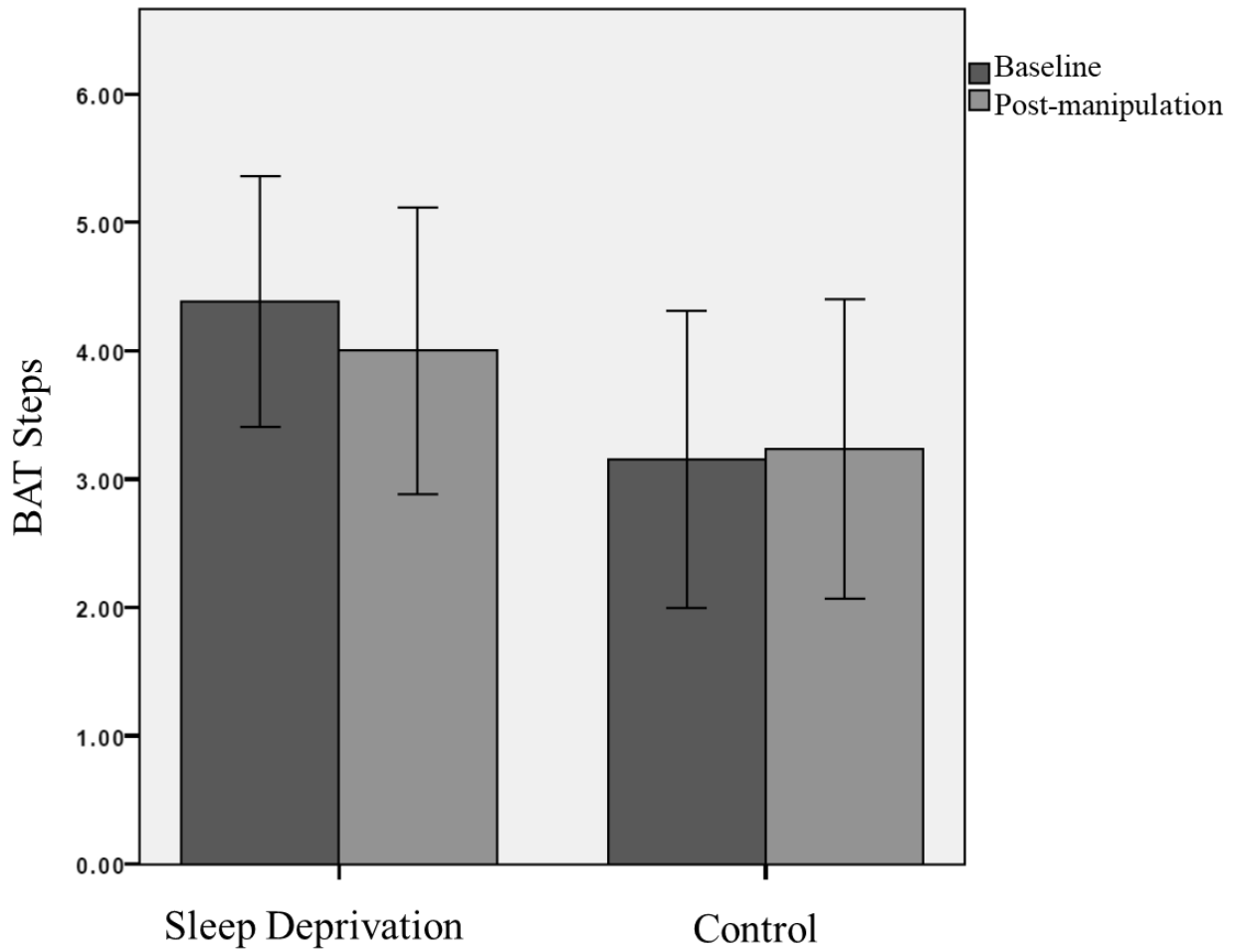
T-tests for all continuous variables at baseline confirmed no significant differences, confirming the efficacy of random assignment.

Figure 1. State Affect



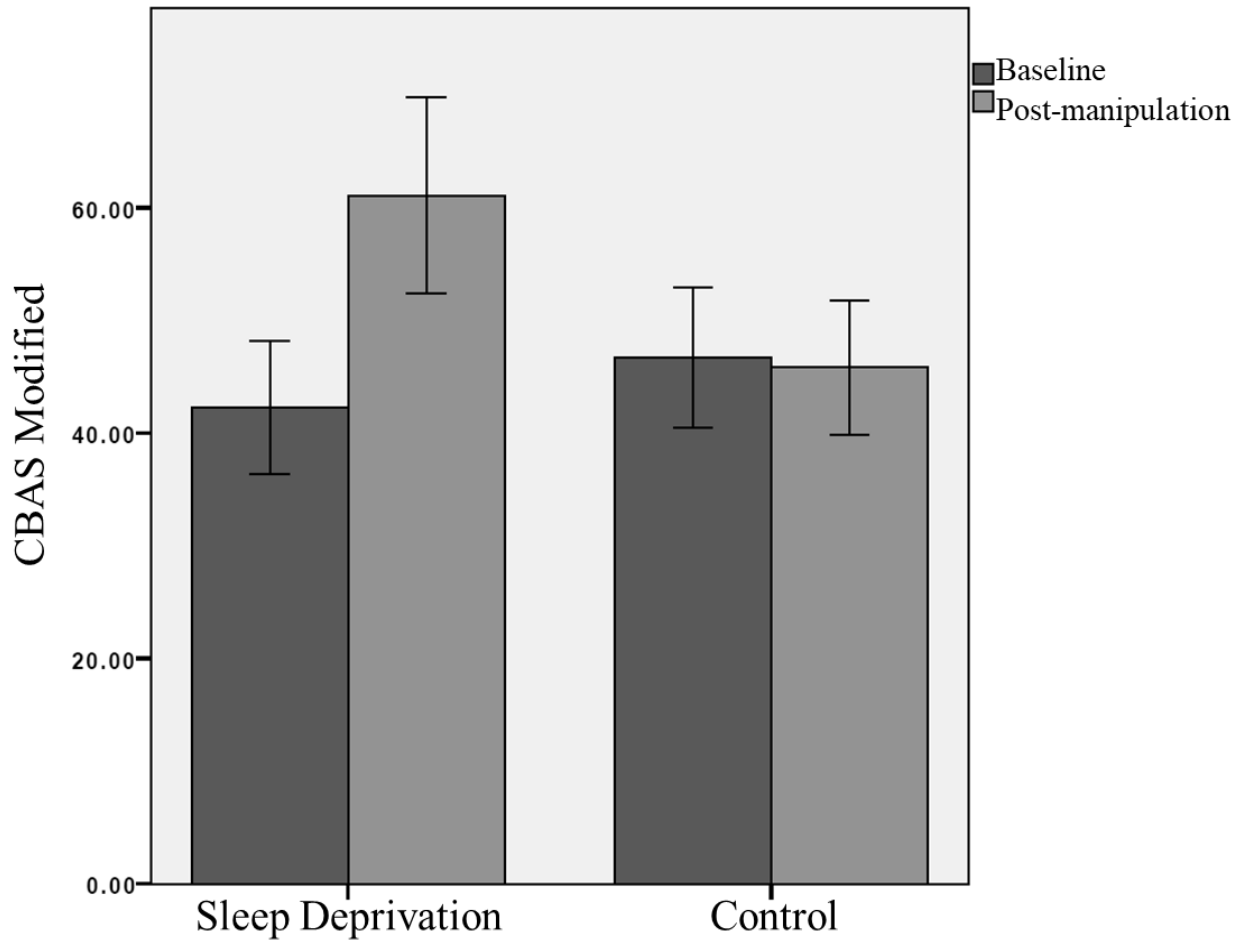
Means for the Positive and Negative Affect Scale Positive (PANAS-P) and Negative (PANAS-N) before and after sleep manipulation are displayed by group. While there were no significant differences between conditions at baseline, positive affect decreased, and negative affect increased post-manipulation for the sleep deprivation condition only.

Figure 2. BAT Steps



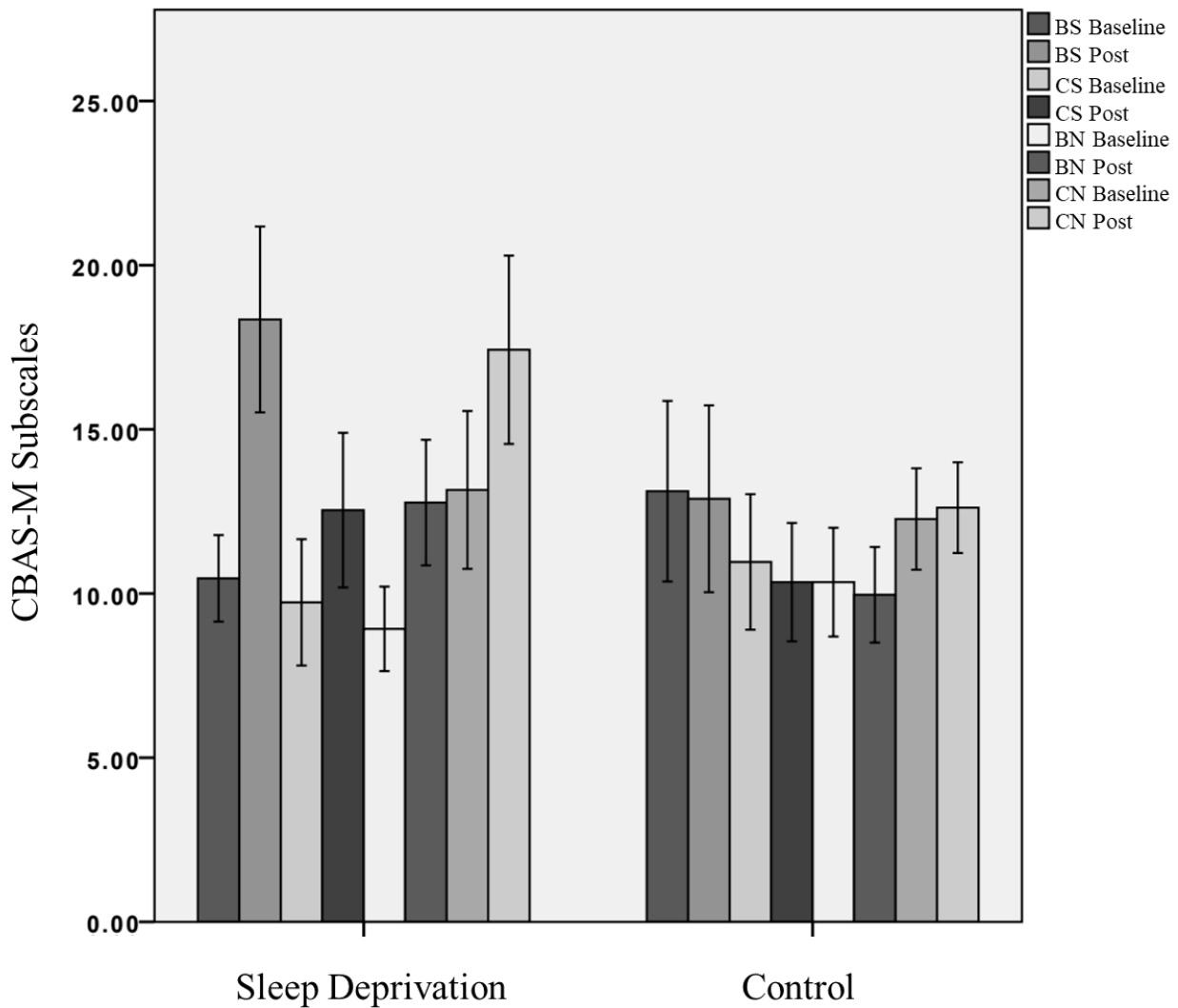
Mean Behavioral Avoidance Task (BAT) steps at baseline and post-manipulation by group. Sleep deprivation did not have a significant impact on approach behaviors.

Figure 3. CBAS-M



Means for the Cognitive Behavioral Avoidance Scale – Modified (CBAS-M) at baseline and post-manipulation by group. Sleep deprivation increased self-reported avoidance behaviors.

Figure 4. CBAS-M Subscales



The means for the Cognitive Behavioral Avoidance Scale- Modified (CBAS-M) subscales are presented by group at baseline and after sleep manipulation. CBAS-M CS scores increased from baseline to post-manipulation for the sleep deprivation group only while CBAS-M BS, CBAS-M BN, and CBAS-M CN scores increased for both groups but more so for the sleep deprivation condition.

BS = Behavior-Social, CS = Cognitive-Social, BN = Behavior-Nonsocial, CN = Cognitive-Nonsocial