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Effects of Sleep Deprivation on Sociability, Closeness, and Interdependence

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Abstract of the Dissertation

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Close relationships are integral to who we are; they influence our sense of self (Berscheid, 1994), emotional well-being (Deci et al., 2006), and physical health (Cohen, 2004). However, close relationships are not immune to external stressors. One stressor that has been understudied with respect to close relationships is sleep loss (Troxel et al., 2007). Sleep loss is common in the general population (National Sleep Foundation, 2008), and pervasive in that it leads to psychomotor, affective, and cognitive deficits (Pilcher & Huffcutt, 1996). The present research investigated whether sleep loss hindered individual and interpersonal functioning. Participants were healthy undergraduate students who were in established romantic relationships of one year or longer. Sleep loss was experimentally manipulated such that participants experienced either a full night of sleep in their own homes or sleep deprivation in the laboratory. Affective, cognitive, and relationship measures were administered before and after the sleep manipulation. As expected, total sleep deprivation led to increased sleepiness and negative mood, as well as decreased self-reported sociability. In addition, sleep condition emerged as a significant moderator of closeness and interdependence when considering gender, relationship length, and attachment. These findings indicate that sleep loss does have a negative impact on close relationships, and this research is an important step in evaluating the proposed theoretical model.

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Introduction

Who we are is determined in part by our relationships. Several theoretical perspectives (e.g., the self-expansion model, interdependence theory, attachment theory) suggest that people have elaborate mental models involving their selves and close others. Stressors external to our close relationships inevitably occur and may temporarily undermine our mental models relevant to those relationships and our interpersonal functioning more generally. Sleep loss is one very common type of stressor that disrupts an individual's functioning in multiple areas (e.g., psychological, behavioral). But just how and the extent to which it disrupts interpersonal functioning in close relationships is unclear. The objective of the present research was to investigate whether sleep loss negatively affects close, romantic relationships, and if so, through what mechanisms and in what specific ways.

Self and Relationships

The self is one's identity or sense of "who I am" (James, 1890). It is a multifaceted, organized, and elaborate construct in memory (Conway, 2005; Symons & Johnson, 1997). Being the vehicle by which social interactions occur, the self is influenced by and exerts influence on the surrounding social environment (Banaji & Prentice, 1994; Markus & Wurf, 1987). Interactions with close, significant others such as family, friends, and romantic partners, help to foster and maintain one's sense of self (Aron, Ketay, Riela, & Aron, 2007; Berscheid, 1994; Hinde, Finkenauer, & Auhagen, 2001). Three influential theories explaining the development and maintenance of close relationships and their impact on the self are self-expansion, interdependence, and attachment.

Aron and Aron's self-expansion model (Aron & Aron, 1986; Aron, Aron, & Norman, 2001) proposes that individuals are motivated to expand the self in the sense that they seek to enhance their self-efficacy. Close relationships provide one such avenue. During the development of a close relationship, the self can incorporate the other's resources (e.g., knowledge, material goods), perspectives (e.g., seeing the world from the other's point of view), and identities (e.g., the other's unique characteristics). Thus, what my partner knows, to some extent I know; what my partner sees and feels, to some extent I see and feel; who my partner is, to some extent I am as well. After a close relationship is formed, further opportunities for self-expansion are provided by the growth of each individual as well as the dyad's joint participation in novel and challenging activities (Aron, Norman, Aron, McKenna, & Heyman, 2000).

The aforementioned incorporation of a close other has been referred to as inclusion of other in the self, feeling close, and most simply, closeness (Aron, Aron, & Smollan, 1992; Aron, Aron, Tudor, & Nelson, 1991; Aron, Mashek, & Aron, 2004). It represents an overlap and extension of the mental models of the self and a close other. For example, when people rate themselves and their partner on a variety of trait adjectives and are later asked which adjectives are true for the self, reaction time is slower for mismatched traits (traits that were true of one but not the other) as compared with matched traits (Aron et al., 1991; Aron & Fraley, 1999; Smith, Coats, & Walling, 1999). This occurs because if something is true of me but not of my partner, then in a sense it is also not true of me because my partner is part of who I am. Pairs of romantic partners and friends tend to report similar levels of closeness or have scores that are positively correlated (Carson, Carson, Gil, & Baucom, 2004; Deci, LaGuardia, Moller, Scheiner, & Ryan, 2006; Simpson, Orina, & Ickes, 2003). In addition, higher levels of self-reported closeness are associated with greater relationship quality (Carson et al., 2004), satisfaction (Medvene, Teal, &

Slavich, 2000), commitment (Agnew, Van Lange, Rusbult, & Langston, 1998), and subjective well-being (Deci et al., 2006).

Interdependence theory suggests that social interactions can be understood by considering the current motives and prior behaviors of the individuals in a given situation (Kelley & Thibaut, 1978; Rusbult & Van Lange, 2003). When two strangers interact, each is only concerned with their own motives and outcomes. But as close relationships develop, individuals become concerned with, or invested in, their partner's outcomes as well as the joint outcomes of the dyad (Rusbult & Van Lange, 2003). For example, a partner's outcome could be enjoying a day off and a joint outcome could be enjoying a vacation together.

However, relationships are not perfect because people are not perfect. Accommodation is essential to relationships; that is, the promotion of constructive behavior by inhibiting one's tendencies to respond to destructive behavior in kind (Rusbult, Verette, Whitney, Slovik, & Lipkus, 1991; Yovetich, 1997; Yovetich & Rusbult, 1994). Here is an example situation: Joe comes home late and yells at Kate for not turning on the outside light. Kate could respond with a destructive response ("I wouldn't have to turn it on if you came home on time") or a constructive response ("Sorry honey, I didn't know you would be home late. Did you have a bad day at work?"). The latter response illustrates accommodation and represents the transformation of motivation from being self-focused to being both self- and other-focused, to understanding that both partners have needs to be fulfilled (Yovetich & Rusbult, 1994). Transformation of motivation is necessary for maintaining a relationship over an extended period of time, meaning its long-term outcome (Rusbult, Martz, & Agnew, 1998; Yovetich & Rusbult, 1994).

Finally, according to attachment theory, the formation of social bonds is part of our survival instinct; it begins in infancy with our caregivers, people we look to for a "safe haven from fears" and a "secure base for exploration" (Ainsworth, Blehar, Waters, & Wall, 1978; Bowlby, 1969, 1973, 1980). Patterns of interaction between parent and child lay the foundation for our mental models of self and others. These mental models develop from childhood to adulthood and are then used as a template for later attachment figures including romantic partners (Bowlby, 1969; Hazan & Shaver, 1987).

Conceptualizations of adult attachment have varied from a three-category typology (secure, anxious/ambivalent, avoidant; Ainsworth et al., 1978; Hazan & Shaver, 1987) to a four-category typology (secure, preoccupied, dismissing, fearful; Bartholomew & Horowitz, 1991; Griffin & Bartholomew, 1994), and most recently to a two-dimension typology (anxiety and avoidance; Brennan, Clark, & Shaver, 1998; Fraley, Waller, & Brennan, 2000). The basic idea behind each of these is that people see themselves as worthy or unworthy of support, protection, and love, and see their attachment figures as being accessible and responsive to these needs or not. Individuals with adaptive mental models view themselves and others in a positive manner, form relationships easily, and are comfortable trusting others; such individuals have been termed "secures" and score low on the anxiety and avoidance dimensions (Hazan & Shaver, 1987; Fraley et al., 2000). Individuals with maladaptive mental models may view themselves or others in a negative manner, have fears of being abandoned, or have fears of being intimate with others; such individuals have been termed "insecures" and score high on the anxiety and/or avoidance dimensions (Hazan & Shaver, 1987; Fraley et al., 2000). Therefore, the type of attachment style one develops is a major individual difference in how close relationships are perceived and experienced (for a review, see Shaver & Mikulincer, 2006).

Experiences of Stress

Stress can be broadly defined as any internal or external stimulus causing physiological and/or psychological arousal or tension (Caplan, 1981; Seyle, 1976; Spaniol & Jung, 1987). The stress process begins with identification of a stressor and appraisal of the stressor as threatening or non-threatening. If the stressor does not pose a threat, the process ceases. If the stressor poses a threat, however, a person's internal alarm is activated and coping behaviors are utilized to terminate the threat. When coping responses are effective, the threat is terminated (e.g., via reappraisal of the stressor as non-threatening or removal of the stressor in its entirety) and the stress process stops. When coping responses are ineffective, a person continues to resist the stressor and exhaustion may ensue.

Social and health psychologists have classified stressors as being hassles, uplifts, or major life events (Holmes & Rahe, 1967; Kanner, Coyne, Schaefer, & Lazarus, 1981; Quick, Quick, & Gavin, 2000). Hassles are minor negative events or situations that occur on a routine basis, such as being overloaded at work. Uplifts are the opposite of hassles; these are minor positive events or situations that occur on a routine basis, such as going to the movies. Major life events, which can be positive or negative, are those that drastically change our perceptions, expectations, and experiences in everyday life over a discrete period of time; common examples are marriage and divorce. Lazarus and Folkman (1984), among others, suggest that hassles influence one's functioning more so than major life events or uplifts because of their frequency (which accumulated over time may make them more intense than major life events) and their negative valence (which outweighs the positive valence of uplifts).

How do stressors, particularly hassles, undermine functioning? Mental resources are finite and stress diminishes mental resources (Kahneman, 1973; Norman & Bobrow, 1975). Under conditions of stress, an individual must prioritize one's actions to achieve the most optimal state possible. This is accomplished by directing resources such as attention and effort toward situations or tasks perceived to be primary and away from situations or tasks perceived to be secondary (Hockey & Hamilton, 1983; Kahneman, 1973). Thus, when an individual is faced with a hassle, the first priority is to reduce the stress associated with that hassle. But the reprioritization of goals also makes secondary tasks, or other areas of functioning, more prone to deterioration. For example, work on ego depletion by Baumeister, Bratslavsky, Muraven, and Tice (1998) suggests that when individuals exert self-control and force themselves to do something they would rather avoid, performance on subsequent tasks suffers (e.g., less persistence, more frustration).

Much research has shown that hassles have a negative effect on affective, psychological, and interpersonal functioning. Daily diary studies indicate that experiences of hassles result in poorer mood (Bolger, DeLongis, Kessler, & Schilling, 1989; van Eck, Nicolson, & Berkhof, 1998). Hassles external and internal to relationships have also been implicated in feelings about one's romantic relationship and partner, including decreased quality (Neff & Karney, 2004), satisfaction (Bodenmann, Ledermann, & Bradbury, 2007), and closeness (Lavee & Ben-Ari, 2007). Moreover, interactions within relationships suffer; romantic partners withdraw, engage in angry behaviors, or start arguments when hassles are experienced earlier in the day (Bolger, DeLongis, Kessler, & Wethington, 1989; Ilies et al., 2007; Schulz, Cowan, Cowan, & Brennan, 2004). It may be that the decrements seen in interpersonal functioning are due to prioritization—the well-being of the self is categorized as primary (e.g., to address negative affect) while relationships are categorized as secondary.

Sleep Loss as a Stressor

The relationship between stress and sleep is bidirectional—sometimes stress affects sleep and sometimes sleep, or more accurately the lack of sleep, can be a cause of stress (Rosch, 1996). Annual surveys by the National Sleep Foundation conducted in the United States have shown that sleep loss is routinely experienced by 44% of adults (2008), 45% of adolescents (2006), and 16-36% of children (2004). But what does it mean to lose sleep? Sleep loss can be total, partial, or fragmented; it can be acute or chronic; it can occur naturally or be experimentally manipulated (Moorcroft, 2003). Total sleep loss or deprivation refers to one night without sleep or 24 hours of continual wakefulness. Partial sleep loss refers to less than 5-6 hours of sleep in a given night. Sleep fragmentation refers to sleep that is disrupted (e.g., by awakenings during the night). Regardless of the type, sleep loss produces a myriad of affective, behavioral, cognitive, and physiological deficits (for a review, see Moorcroft, 2003; Pilcher & Huffcutt, 1996).

Sleep loss commonly results in increased sleepiness and fatigue, decreased vigor, as well as increased tension and confusion (Carskadon & Dement, 1981; Dinges et al., 1997; Pilcher & Huffcutt, 1996). These outcomes reduce the mental resources that can be applied to tasks and situations. For instance, lapses in attention, slower reaction time, and reduced accuracy (Dinges, 1992; Gillberg, Kecklund, & Akerstedt, 1994), as well impairments on working memory tasks (Lim & Dinges, 2010; Turner, Drummond, Salamat, & Brown, 2007) and complex cognitive tasks involving reasoning and decision making (Blagrove, Alexander, & Horne, 1985; Harrison & Horne, 1999), have been documented following sleep loss. In addition, sleep loss changes effort in terms of preferring less effortful tasks and engaging in less effortful behaviors (Engle-Friedman et al., 2003; Engle-Friedman, Riela, & Strothers, 2008; Hockey, Wastell, & Sauer, 1998; Pilcher & Walters, 1997; Webster, Richter, & Kruglanski, 1996).

Though the effects of sleep loss on individual functioning are well documented, research on sleep loss and interpersonal functioning has been limited. In an early study of chronic sleep restriction, there was an anecdote of one couple reporting antagonism towards the partner as a function of their fatigued state (Friedmann et al., 1977). Another study found that under conditions of 55 hours of sleep deprivation, participants exhibited more frustrated responses to hypothetical interpersonal situations involving ambiguous characters as compared with baseline scores (Kahn-Greene, Lipizzi, Conrad, Kamimori, & Killgore, 2006). A recent review of the literature identified only 21 studies on sleep and relationships, 12 of which focused on the directional effect of sleep deficits on relationships (Troxel, Robles, Hall, & Buysse, 2007). The findings were mixed in terms of whether or not sleep deficits negatively affected relationships, but many of the studies had limitations such as using a retrospective design, lacking adequate controls, or being primarily descriptive (Troxel et al., 2007). Nonetheless, two of those studies are worth mentioning. One of them, which involved treatment for obstructive sleep apnea, found that patients and partners in the treatment group reported better health, greater marital satisfaction, and fewer marital conflicts compared with the control group (McFadyen, Espie, McArdle, Douglas, & Engleman, 2001). The other was a large correlational study of older couples which found that partners were negatively impacted by each other's sleep difficulties (e.g., long sleep latency, nighttime awakenings) in terms of poorer well-being, decreased social involvement, and decreased satisfaction with the relationship (Strawbridge, Shema, & Roberts, 2004).

Investigating the effects of sleep loss as a stressor on close relationships is important for a few reasons. Sleep is a major part of life—we spend one-third of our lives sleeping. The

incidence of sleep loss in the general population is quite common in that people of all ages experience it and for some it occurs on a routine basis. Sleep loss is a stressor that can be examined longitudinally or manipulated with a high degree of control. But most importantly, even short-term sleep loss impairs functioning in multiple domains simultaneously; few other stressors are as pervasive.

The Present Research

Based on the aforementioned work, a general model of sleep and relationships was formulated to suggest that (a) sleep loss would temporarily disrupt mental models of self and other via affective and cognitive variables, and (b) disrupted mental models would lead to poorer interpersonal behaviors. The rationale for this was as follows. First, we have internal mental models of ourselves and close others; these models are intertwined (Aron & Aron, 1986). If the mental model of the self is disrupted, then logically, mental models of close others should also be disrupted. Second, individual functioning can deteriorate under conditions of stress. Sleep loss is a powerful stressor that impairs an individual's functioning in multiple domains simultaneously. This multi-prong attack to functioning may disrupt the mental model of the self. Third, there is some support for the notion that both stress in general, and sleep loss in particular, negatively affect close relationships in terms of relationship perceptions and behaviors. This may be an indication that the mental model of the close other is also disrupted. Because the self-expansion, interdependence, and attachment theoretical views elaborate different mechanisms involved in the formation and maintenance of close relationships and our mental models relevant to close others, each may be sensitive to different aspects of the sleep loss experience.

From the self-expansion perspective (Aron et al., 2001), mental models are partner-specific in that different models are created for different others based on how those others provide opportunities for self-expansion. We expand the self through the incorporation of close others' resources, perspectives, and identities. Under conditions of sleep loss, affect and effort deteriorate. Given that self-expansion is only desired when such expansion is not stressful or when the self is not experiencing an inordinate amount of stress (Aron & Aron, 1986), it may be that closeness to the partner is seen as aversive and that the motivation to expand the self requires too much effort when sleep is lost.

From the interdependence perspective (Rusbult et al., 1998), mental models are partner-specific in that different models are created for different others based on our interactions with those others. People in close relationships are invested in each other's outcomes; there is a transformation of motivation from being focused solely on the self to being focused on both the self and the other in order to support the long-term maintenance of the relationship. When a person experiences a stressor such as sleep loss, it is likely that attention, effort, and working memory are directed towards the short-term interests of the self and the need to deal with the immediate situation. The partner may become secondary to the self, and the temporal distance of long-term relationship outcomes may make such outcomes seem less important.

From the attachment perspective (Brennan et al., 1998; Shaver & Mikulincer, 2006), mental models are akin to stable personality traits in that they develop from an early age and designate specific patterns of interaction with others. There are individual differences in that some people have secure attachments and adaptive mental models while others have insecure attachments and maladaptive mental models (from the point of view of adult relationship quality). People with maladaptive mental models have an inherent bias towards negativity and

therefore should be more susceptible to the stress of sleep loss than people with adaptive mental models.

The current study was a sleep deprivation experiment investigating how one night without sleep would affect both individual and interpersonal functioning. It followed the general protocol described by Engle-Friedman and colleagues (2003). Part 1 was the pretest session which included eligibility screening for the latter part of the study. Part 2 included the key manipulation (normal sleep or sleep deprivation) and the posttest session. The hypotheses were as follows:

1. The deprived group should experience deficits in sleepiness, mood, attention, effort, and working memory as compared with the normal group.
2. The deprived group should experience deficits in self-reported and behavioral sociability as compared with the normal group.
3. The relationship between sleep loss and closeness should be mediated by affect (sleepiness and mood), effort, and self-expansion motivation.
4. The relationship between sleep loss and interdependence should be mediated by attention, effort, and working memory.
5. The relationship between sleep loss and state mental models (closeness and interdependence) should be moderated by the trait mental models (anxious and avoidant attachment).

Method

Participants

Participants were recruited through the Psychology Department subject pool at SUNY Stony Brook and by flyers posted throughout the university's campus. Compensation for Part 1 of the study was one research credit (subject pool) or $5 (other participants). Compensation for Part 2 of the study was three research credits (subject pool) or $20 (other participants). In addition, participants who completed the study were entered into a raffle for $100 (normal group) or $200 (deprived group).

Individuals who were between the ages of 18 and 30, had been in a committed romantic relationship for at least 1 year, and did not have children, were eligible to participate in Part 1. This was done to ensure that participants were old enough to participate, had established mental models of their partners, that those mental models were not influenced by the presence of children, and more generally, to reduce additional sources of variance.

Individuals who met the next set of requirements, as determined by the sleep history and health screening questionnaire (adapted from Engle-Friedman et al., 2003; see Appendices A and B), were eligible to participate in Part 2: no current sleep problems, no history of seizures, no hospitalizations within the past six months, no current medical problems, no current mental health problems (including moderate-severe depression), and no current substance dependence/abuse. In addition, individuals who were assigned to the deprived group were only allowed to participate if they had no work/school commitments and could arrange for an escort home after the posttest session.

Part 1 was completed by 284 individuals, 147 of whom were eligible to participate in the remainder of the study. Eligible and ineligible participants did not differ significantly with regard to any demographic variable (gender, age, sexual orientation, relationship type, relationship length, cohabitation type, cohabitation length). Of those who were eligible, 60 individuals dropped out (17 normal, 43 deprived). An additional 32 individuals did not comply with sleep group instructions (19 normal, 13 deprived; see Appendix C). Therefore, 55 individuals successfully completed the entire study. Individuals who dropped out or were noncompliant did not differ significantly from individuals who finished the study in terms of gender, age, sexual orientation, relationship type, and relationship length. However, the groups did differ in terms of cohabitation type, χ^2 (1, N = 147) = 8.31, p = .004, and cohabitation length, t (145) = -2.66, p = .009. Fewer dropped/noncompliant individuals lived with their partners as compared with those who finished the study (2% vs. 14%), and they lived with their partners for a shorter length of time (Ms = .33 months vs. 2.87 months, respectively). Among dropped/noncompliant individuals, those assigned to the normal group did not differ significantly from those assigned to the deprived group with regard to any demographic variable.

The final sample included 55 participants, with 24 in the normal group and 31 in the deprived group. There were 21 men and 34 women, whose mean age was 19.75 years (SD = 1.47). Most participants had a heterosexual orientation (93%), were in dating relationships (95%), and were not cohabiting with their partners (86%). Average relationship length was 24.25 months (SD = 14.20) and average cohabitation length was 2.87 months (SD = 8.90). There were no significant differences between the sleep groups in terms of demographics.

Procedure

Pretest session. Participants were told the general purpose of the study (namely, to investigate the effects of sleep loss on personal and social functioning), given an overview of the protocol, and provided signed informed consent. None of the participants were aware of the study's hypotheses. They completed questionnaires regarding their demographics, sleep and health, attachment, self-expansion motivation, closeness, interdependence, and sociability. Eligible participants were randomly assigned to one of two sleep conditions—normal (no sleep deprivation) or deprived (sleep deprivation)—and given instructions regarding their assignments (see Appendix C).

Manipulation. Both the normal and deprived groups were instructed to refrain from using caffeine, nicotine, alcohol, and non-prescription drugs after 7:00 p.m. on the night prior to the posttest session. The normal group was instructed to sleep at home, going to bed by 11:30 p.m. and waking up by 8:30 a.m. The deprived group was kept awake overnight in the Interpersonal Relationships Lab in the Psychology Department, starting at 9:00 p.m. on the night prior to the posttest session. A maximum of four participants were scheduled for each overnight; they were monitored by the study coordinator and two to four research assistants. Computers, movies, non-caffeinated beverages, and snacks were provided. None of the participants withdrew their participation during the overnights.

Posttest session. The posttest started at 9:00 a.m. on the day following the sleep manipulation. Sessions were always held on a Friday, Saturday, or Sunday morning. Participants completed questionnaires about their mood, attachment, self-expansion motivation, closeness, interdependence, and sociability. Then, a variety of counterbalanced computer tasks were administered to implicitly assess attention, effort, working memory, closeness, and interdependence. (Please note that some information needed to be collected in advance of the implicit closeness task; this information was obtained from participants during the pretest session, as described below in the Behavioral Measures section.) After the computer tasks were completed, participants were asked to sit on a couch in the laboratory (as part of an implicit sociability measure) to complete questionnaires regarding their previous night's sleep (the sleep diary) and current sleepiness. At the end of the session, participants in the normal group were allowed to leave immediately; participants in the deprived group, however, were not. These latter participants were requested to nap, were required to "pass" a mental state exam assessing awareness, and their escort accompanying them home must have arrived at the laboratory before they were allowed to leave.

Self-Report Measures

Demographics. Demographics included participants' gender, age, sexual orientation, relationship status (e.g., dating, engaged, married), relationship length, cohabitation status (cohabiting or not), cohabitation length, and parental status (parent or not).

Sleep history and health screening. The sleep history and health screening questionnaire (SHHSQ; adapted from Engle-Friedman et al., 2003; see Appendices A and B) inquired about participants' sleep history (26 items), physical/mental health (12 items), and substance usage (20 items). The sleep history section focused on typical sleep behaviors such as total sleep time, sleep latency (time taken to fall asleep), awakenings, time awake at night, and participants' feelings about their sleep. The physical/mental health section focused on past and present medical issues (e.g., major illnesses, medications) and mental health issues (e.g., counseling, psychiatric hospitalization). The substance usage section focused on caffeine, nicotine, and

alcohol consumption as well as recreational drug use. In addition, the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) was administered with the SHHSQ to assess depression. The BDI contains 21 items, each of which has four responses ranging from (0) least depressive statement to (3) most depressive statement. An example item is sadness: "(0) I do not feel sad, (1) I feel sad, (2) I am sad all the time and I can't snap out of it, and (3) I am so sad or unhappy that I can't stand it." Responses were summed to form a composite measure (α = .79); scores of 16 or higher indicated moderate to severe depression.

Attachment. Attachment was assessed using the Experiences in Close Relationships Questionnaire—Revised (ECR-R; Fraley et al., 2000). The ECR-R contains 36 items answered on a continuum ranging from (1) strongly disagree to (7) strongly agree. There are two subscales: anxiety and avoidance. An example anxiety item is "My desire to be very close sometimes scares people away." An example avoidance item is "I am nervous when partners get too close to me." Responses were reversed as necessary and then averaged to form composite measures for each subscale; higher scores indicated greater anxious and avoidant attachment. Cronbach's alphas at Time 1 and Time 2, respectively, were .89 and .94 for anxious attachment, and .92 and .95 for avoidant attachment.

Self-expansion motivation. Self-expansion motivation was assessed using a modified version of the Self-Expansion Questionnaire (SEQ; Lewandowski & Aron, 2002) specific to romantic partners. The SEQ contains 14 items answered on a continuum ranging from (1) not at all to (7) extremely. An example item is "How much does a romantic partner provide a source of exciting experiences?" Responses were reversed as necessary and then averaged to form a composite measure; higher scores indicated greater self-expansion motivation. Cronbach's alphas at Time 1 and Time 2, respectively, were .92 and .93.

Closeness. Closeness was assessed using the Inclusion of Other in the Self Scale (IOS; Aron et al., 1992) and the Subjective Closeness Inventory (SCI; Berscheid, Snyder, & Omoto, 1989). For the IOS, participants were presented with Venn diagrams displaying seven pairs of overlapping circles representing the self and the other, and selected the pair of circles that best described their current relationship with their romantic partner. For the SCI, participants were asked how close they are to their romantic partners relative to their previous relationships, as well as other people's relationships, on a continuum ranging from (1) not at all close to (7) extremely close. Following procedures used in previous studies (e.g., Aron, Melinat, Aron, Vallone, & Bator, 1997), the IOS and SCI questions were averaged to form a composite measure; higher scores indicated greater closeness. Cronbach's alphas at Time 1 and Time 2, respectively, were .82 and .87.

Interdependence. Interdependence was assessed using the Investment Model Scale (IMS; Rusbult et al., 1998). The IMS contains 22 items answered on a continuum ranging from (1) not at all to (7) completely. There are four subscales: commitment, satisfaction, quality of alternatives, and investment size. Example items from each of the subscales, respectively, are "I want our relationship to last for a very long time," "My relationship is close to ideal," "If I weren't dating my partner, I would do fine—I would find another appealing," and "Many aspects of my life have become linked to my partner." Responses were reversed as necessary and then averaged to form composite measures for each subscale; higher scores indicated greater amounts of each construct. Cronbach's alphas at Time 1 and Time 2, respectively, were .95 and .95 for commitment, .94 and .93 for satisfaction, .76 and .78 for quality of alternatives, and .87 and .89 for investment size. Given that the subscales were highly intercorrelated (see Table 1), they were

combined to form an overall measure of interdependence for analysis. Cronbach's alphas at Time 1 and Time 2, respectively, were .95 and .95.

Sociability. Sociability was assessed using the Brief Sociability Scale (BSS; Cheek & Buss, 1981). The BSS contains 5 items answered on a continuum ranging from (1) not at all to (7) extremely. An example item is "I like to be with people." Responses were reversed as necessary and then averaged to form a composite measure; higher scores indicated greater sociability. Cronbach's alphas at Time 1 and Time 2, respectively, were .81 and .88.

Sleep diary. The sleep diary (adapted from Engle-Friedman et al., 2003; see Appendix D), administered during Part 2 of the study, contains 12 questions focusing on previous night's sleep (e.g., total sleep time, sleep latency, number of awakenings) and other items addressing compliance to sleep group instructions (e.g., caffeine, nicotine, and alcohol consumption).

Sleepiness. Sleepiness was assessed using a feeling refreshed question (RFQ; Engle-Friedman et al., 2003), the Stanford Sleepiness Scale (SSS; Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973), and the Affect Grid (AG; Russell, Weiss, & Mendelsohn, 1989) during Part 2 of the study. For the RFQ, participants were asked "How rested and refreshed do you feel right now?" and could choose from (1) extremely exhausted to (7) extremely refreshed. For the SSS, participants were presented with seven statements ranging from (1) most alert statement to (7) most sleepy statement, and were asked to choose the statement that best represented their current state of alertness, awareness, and sleepiness. For the AG, participants were presented with a square-grid containing 81 boxes and asked to rate their present state by placing a checkmark in one of the boxes. An arousal score was calculated by counting (bottom to top) what square was checked on the vertical dimension; scores could range from (1) sleepiness to (9) high arousal. Given that the items used different continuums, responses were reversed as necessary, and then summed to form a composite measure; higher scores indicated greater sleepiness. Cronbach's alpha was .94.

Mood. Mood was assessed using the Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1971) during Part 2 of the study. The POMS contains 65 items that were responded to on a continuum ranging from (1) not at all to (7) extremely. There are six subscales: tension, confusion, anger, fatigue, vigor, and depression. Example words from the six subscales, respectively, are "nervous," "confused," "annoyed," "sluggish," "active," and "hopeless." Participants were supplied with a list of synonyms for each mood word. Responses were reversed as necessary and then averaged to form composite measures for each subscale; higher scores indicated greater amounts of each construct. Cronbach's alphas were .88 for tension, .84 for confusion, .94 for anger, .91 for fatigue, .93 for vigor, and .94 for depression. Given that most of the subscales were highly intercorrelated (see Table 2), they were combined to form an overall measure of negative mood for analysis. Cronbach's alpha was .97.

Behavioral Measures

Attention. Attention was assessed using a simple reaction time task similar to that reported by Engle-Friedman et al. (2003). Participants were instructed to press the spacebar as soon as they saw a 0.5-inch white square on the black computer screen. The square appeared in random locations on the screen for 500ms with an inter-trial interval varying from 1000ms to 3000ms. This task had 100 trials. Reaction time was the focal measure.

Effort. Effort was assessed using a variation of Engle-Friedman et al.'s (2003) Math Effort Task. Participants were presented with mathematical (addition) problems to be completed mentally. Before each addition problem, participants were instructed to choose a level of

difficulty ranging from (1) least difficult to (5) most difficult. Randomly generated numbers determined each difficulty level: Level 1 included numbers 0 to 2, Level 2 included numbers 3 to 6, Level 3 included numbers 7 to 10, Level 4 included numbers 11 to 15, and Level 5 included numbers 16 to 20. For each problem, four numbers were presented sequentially. Each number was displayed for 500ms seconds with an inter-stimulus interval of 1000ms. After the last number had been presented, participants were prompted to type in their answer. They proceeded to the following trial after a response had been made or 20000ms had elapsed. This task had 40 trials. Difficulty level was the focal measure, though reaction time and accuracy were also recorded.

Working memory. Working memory was assessed using a variation of the N-back working memory task (Gevins & Cutillo, 1993; Owen, McMillan, Laird, & Bullmore, 2005). A series of shapes were presented sequentially on the computer screen. The following shapes were used: circle, cross, diamond, downward arrow, empty set (meaning, a circle with a bisecting line), heart, hexagon, hourglass, square, star, triangle, and upward arrow. For the 1-back portion of the task, participants determined whether the current shape being viewed was the same as the shape shown one picture beforehand. For the 2-back portion of the task, participants determined whether the current shape being viewed was the same as the shape shown two pictures beforehand. They were asked to respond "yes" or "no" by pressing designated computer keys. There were 50 trials (25 for the 1-back portion, 25 for the 2-back portion). The order of shapes was randomized. Each shape was displayed for 500ms seconds with an inter-trial interval of 3000ms. Accuracy was the focal measure, though reaction time was also recorded.

Closeness. Closeness was assessed using Aron et al.'s (1991; Aron & Fraley, 1999) "me-not me" task, closely following the details of their procedure. At the pretest session, participants rated themselves and their romantic partner on 90 trait adjectives (e.g., serious, friendly) using a continuum ranging from (1) unlike to (7) extremely like. Those traits originally rated 1-3 for both self and partner or rated 4-7 for both self and partner were considered "matches" while traits originally rated 1-3 for self and 4-7 for partner (or vice versa) were considered "mismatches." Then, at the posttest session, participants were presented with each trait and asked to determine whether the trait is true or is not true of the self ("me" or "not me") by pressing designated computer keys. There were 90 trials. The order of traits was randomized. Each trait was displayed until the participant chose a response or 3000ms had elapsed. The inter-trial interval was 1000ms. Reaction time and accuracy were assessed. The "matches" scores were subtracted from the "mismatches" scores; these difference scores were the focal measures.

Interdependence. Interdependence was assessed using a variation of Yovetich's (1997; Yovetich & Rusbult, 1994) accommodation task. Participants were presented with hypothetical scenarios where their romantic partner engaged in a constructive behavior or a destructive behavior. They were asked to respond to each scenario by choosing a constructive response or a destructive response using designated computer keys. An example constructive scenario, with constructive and destructive responses, respectively, is as follows:

Your partner gives you some very flattering compliments on your appearance.

a. Thank my partner for the compliments and feel good about myself.
b. Suggest that my partner had an ulterior motive for the compliments.

An example destructive scenario, with constructive and destructive responses, respectively, is as follows:

Your partner promises to return some books to the library for you, forgets, and then says that he/she has better things to do than run your errands.

a. Apologize for even asking at all since I knew how busy he/she was.
b. Tell my partner that I thought he/she was incredibly rude and thoughtless.

There were 10 constructive scenarios and 10 destructive scenarios. Each scenario was presented twice using different constructive and destructive responses, for a total of 40 trials. The order of scenarios was randomized and the order of constructive/destructive responses was counterbalanced. Each scenario was displayed until the participant chose a response or 30000ms had elapsed. The inter-trial interval was 1000ms. Percentage of destructive responses was the focal measure, though reaction time was also recorded.

Sociability. Sociability was assessed using covert behavioral observation. Each participant was directed by one research assistant to sit on a striped couch in the main room of the laboratory. Another research assistant was already stationed on the couch, sitting 15cm from one end, pretending to work on a laptop. (Note that the seated research assistant was always female.) While the participant completed two short questionnaires, both research assistants assessed the distance between the participant and seated research assistant by counting the number of stripes (each of which was 6cm). Inter-rater reliability was high (ICC = .99), so the ratings were averaged. Distance was the focal measure; higher scores indicated lower sociability.

Mental state. Mental state was assessed using the Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975), which was given in interview format by the study coordinator. The MMSE contains 11 tasks assessing various facets of awareness such as attention, recall, and language. Points were awarded based on participants' success in completing the tasks. An example task is to spell "world" backwards. Total scores ranged from 0 to 30; scores of 23 or less indicated impaired functioning.

Results

Data Cleaning and Screening

Prior to any statistical tests, the data were cleaned and screened (Tabachnick & Fidell, 2001). Cleaning involved a review of means, standard deviations, minimum values, and maximum values, as well as checks for missing data and erroneous data entries. Screening involved the following steps.

1. The sleep diary data were checked for compliance with sleep group instructions.
2. The sleep history data were checked for pre-existing group differences.
3. Reliabilities for the self-report measures and sociability observation were computed.
4. Outliers were deleted from the behavioral measures' reaction time data.
5. Normality was assessed for all self-report and behavioral measures of interest.

As mentioned in the Method section, the sleep diary data were reviewed to determine compliance with sleep group instructions. Noncompliance occurred in terms of going to sleep or waking up later than specified, taking a nap, using prohibited items (including sleep medication), or sleeping less than 8 hours. Given that the objective of the normal sleep condition was to experience a night of "good" sleep (Moorcroft, 2003), those individuals whose sleep quality was poor were also considered to be noncompliant, and thus excluded from all analyses. Poor sleep quality, based on criteria approximating those delineated in the sleep literature (Buysse, Ancoli-Israel, Edinger, Lichstein, & Morin, 2006; Lichstein, Durrence, Taylor, Bush, & Riedel, 2003; Moorcroft, 2003), were as follows: sleep latency ≥ 30min, awakenings ≥ 3, time awake at night ≥ 30min, and total sleep time ≥ 10hrs. Therefore, the data analyses discussed herein were based on the 55 individuals who completed the study. The averaged sleep diary data for the final set of participants in the normal group included a sleep latency of 11.88 minutes (SD = 7.15), 0.46 awakenings (SD = 0.72), 1.46 minutes (SD = 3.58) spent awake at night, and a total sleep time of 8.55 hours (SD = 0.41).

The sleep history data were examined for pre-existing differences between the normal and deprived groups using independent *t*-tests. Statistics are provided in Table 3. The groups were not significantly different in terms of weekday sleep latency, awakenings, time awake at night, and total sleep time; weekend sleep latency, awakenings, and time awake at night; as well as optimal sleep time and the number of nights per month with no sleep or less sleep than needed. However, the normal group reported sleeping about an hour longer on average than the deprived group did on weekends.

As reported throughout the Method section, internal consistency was assessed for applicable measures. Cronbach's alphas for the self-report measures ranged from .76 (for quality of alternatives at pretest) to .97 (for negative mood at posttest). The intra-class correlation coefficient for the observation of sociability at posttest was .99. All of these statistics exceeded the .70 standard (Cohen, 2008; Field, 2005), thus demonstrating adequate reliability.

The behavioral reaction time (RT) data were screened for outliers. RTs shorter than 200ms (Uleman, Hon, Roman, & Moskowitz, 1996; Whelan, 2008) were omitted for the attention, effort, working memory, and closeness tasks; RTs shorter than 1000ms were omitted for the interdependence task which required participants to read scenarios. RTs longer than three standard deviations (Bargh & Chartrand, 2000; Uleman et al., 1996) were omitted for all computer tasks. The number of excluded trials (namely, those that were missing, based on short RTs, or based on long RTs) was recorded, and did not differ significantly between the sleep groups for any measure.

Normality was assessed using the Kolmogorov-Smirov one-sample *Z*-test; variables whose significance levels exceeded .05 were determined to have non-normal distributions (Field, 2005). Most of the measures were normal, with one exception. Attention reaction time was positively skewed ($Z = 1.40$, $p = .039$); the distribution was corrected by applying a log transformation (Tabachnick & Fidell, 2001). A follow-up test showed that the transformed measure was normal ($Z = 1.16$, $p = ns$). Given that the significance of results in every analysis were the same regardless of whether the original or transformed variable was used, the statistics reported herein are based on the original variable.

Basic Sleep Group Differences

It was predicted that the deprived group would experience deficits in sleepiness, mood, attention, effort, and working memory as compared with the normal group (Hypothesis #1). It was also predicted that the deprived group would experience deficits in self-reported and behavioral sociability as compared with the normal group (Hypothesis #2).

For the affective self-report measures (administered only at posttest), sleep group differences were assessed using independent *t*-tests. Statistics are provided in Table 4. As predicted, the deprived group was significantly sleepier and had a more negative mood as compared with the normal group.

For the interpersonal self-report measures, sleep group differences were assessed using analyses of covariance (ANCOVAs); pretest scores served as covariates and posttest scores were the dependent variables. Statistics are provided in Table 5. As predicted, the deprived group reported marginally lower sociability as compared with the normal group. (Had this predicted result been interpreted as a one-tailed *t*-test, it would be significant at the .05 level.) Contrary to expectations, the deprived group reported marginally greater self-expansion motivation as compared with the normal group. Group differences did not approach significance in terms of anxious attachment, avoidant attachment, closeness, or interdependence.

For the behavioral measures (administered only at posttest), sleep group differences were assessed using independent *t*-tests. Statistics are provided in Table 4. The groups did not differ significantly in terms of the attention, effort, working memory, closeness, or interdependence task variables. However, opposite to predictions, the deprived group was significantly more sociable as compared with the normal group. (Given that sitting close to a female research assistant may have a different meaning for men than it does for women, a two-way ANOVA was computed to test for a sleep group × gender interaction; the interaction was not significant, $F(1,51) = .01$, $p = ns$.)

Hypothesis #1 was partially supported; predicted differences in sleepiness and mood were obtained, but significant differences in attention, effort, and working memory were not. Hypothesis #2 was also partially supported; self-reported sociability was indeed lower for the deprived group, as predicted, whereas behavioral sociability was higher for the deprived group, contrary to expectations.

Sleep Group Analyses with Covariates

Additional ANCOVAs were computed to assess whether the basic sleep group differences would change when controlling for gender and/or relationship length. Gender was a covariate in all analyses whereas relationship length was only included in those analyses focused on romantic relationships (namely, the attachment, self-expansion motivation, closeness, and interdependence self-report measures, as well as the closeness and interdependence behavioral

tasks). A log transformation was applied to relationship length to correct for skewness, as is customary in relationship research, even when data are not skewed, because of the decreased relative importance of absolute length over time (e.g., Aron et al., 1992; Aron & Fraley, 1999). Given that a key assumption of ANCOVA is homogeneity of regression (HOR; Tabachnick & Fidell, 2001), sleep group × gender, sleep group × relationship length, gender × relationship length, and sleep group × gender × relationship length interactions were tested for significance prior to computing the ANCOVAs. (Possible interactions were also of potential importance.) The HOR assumption was met for all analyses with one exception (accuracy during the behavioral closeness task; discussed below).

Statistics for the ANCOVAs are provided in Tables 4 and 5. Significant sleep group differences were found for sleepiness, negative mood, and behavioral sociability. Marginally significant sleep group differences were found for self-expansion motivation and self-reported sociability. Group differences did not approach significance for the remaining measures. These results are consistent with those that were presented for the basic analyses.

Accuracy during the behavioral closeness task was further investigated. The main effects (sleep group, gender, relationship length) and gender × relationship length interaction were not significant (Fs < 3.00, ps > .10). There was a significant sleep group × gender interaction, F (1,46) = 4.74, p = .035, as well as a marginal sleep group × relationship length interaction, F (1,46) = 3.28, p = .076. Most importantly, though, there was a significant sleep group × gender × relationship length three-way interaction, F (1,46) = 5.49, p = .023, displayed in Figure 1. (Note that when using non-transformed relationship length, the three-way interaction was marginally significant, F (1,46) = 3.87, p = .055.) Accuracy difference scores reflect the extent to which the accuracy of mismatches was greater or lesser than the accuracy of matches, with larger absolute values indicating greater discrepancies. Within the normal group, relationship length and accuracy difference scores were not significantly correlated for men (r = -.11, p = *ns*) or women (r = -.01, p = *ns*). Within the deprived group, though, relationship length and accuracy difference scores were significantly correlated for both men (r = .79, p = .001) and women (r = -.52, p = .028), but in opposite directions. Under conditions of sleep loss, as length increased, mismatches increased for men (indicating more self-other confusion, presumably resulting from greater self-other overlap), but decreased for women (indicating less self-other confusion/overlap).

Mediation Analyses

Tests of mediation show whether the relationship between a cause and an effect diminishes with the introduction of a third variable. It was predicted that the relationship between sleep loss and closeness would be mediated by affect (sleepiness and mood), effort, and self-expansion motivation (Hypothesis #3). It was also predicted that the relationship between sleep loss and interdependence would be mediated by attention, effort, and working memory (Hypothesis #4).

Baron and Kenny (1986) outlined a few standard conditions for mediation, one of which was that the IV should significantly predict the DV. In the present study, this condition was not met for any of the focal measures. Sleep group was not significantly correlated with any of the closeness or interdependence variables (rs < .16, ps > .25). Furthermore, no offsetting patterns of the mediators were expected (a relatively rare circumstance in which one might find mediation even if the IV does not significantly predict the DV; Shrout & Bolger, 2002). Thus, there does not appear to be any evidence for mediation, and Hypotheses #3 and #4 were not supported.

Moderation Analyses

Tests of moderation show whether the relationship between a cause and an effect changes in the presence of a third variable. It was predicted that the relationship between sleep loss and state mental models—closeness and interdependence—would be moderated by the trait mental models—anxious and avoidant attachment (Hypothesis #5).

To test for moderation (Tabachnick & Fidell, 2001), IV × Moderator interaction terms were computed (based on centered main effects), and then the centered main effects, two-way interaction terms, and three-way interaction term were entered hierarchically into the regression equation. Moderation occurs when an interaction block is significant along with one or more coefficients for specific interaction terms. Posttest scores were used for all variables. (Results of the analyses with and without pretest scores as covariates were generally the same in terms of significance, so the statistics presented here are based on the simpler analyses without covariates.) As shown in Table 6, significant (or near significant) interactions were found for only the two behavioral interdependence measures.

The block of two-way interaction effects was significant for percentage of destructive responses. There was a significant sleep group × anxious attachment interaction (see Figure 2), which appears to be a function of equivalent and additive main effects (Wahlsten, 1991). Within the normal group, anxiety and destructiveness were not significantly correlated ($r = .29$, $p = ns$). Within the deprived group, anxiety and destructiveness were marginally correlated ($r = .31$, $p = .095$); the trend was that destructiveness increased along with anxiety. There was also a significant sleep group × avoidant attachment interaction (see Figure 3). Within the normal group, avoidance and destructiveness were significantly correlated ($r = .60$, $p = .002$); as avoidance increased, destructiveness increased. Within the deprived group, avoidance and destructiveness were not significantly correlated ($r = .02$, $p = ns$). The block of two-way interaction effects was marginal for reaction time. The sleep group × anxious attachment interaction was significant (see Figure 4). Within the normal group, anxiety and reaction time were not significantly correlated ($r = -.06$, $p = ns$). Within the deprived group, though, anxiety and reaction time were significantly correlated ($r = .38$, $p = .040$); as anxiety increased, reaction time increased, meaning that participants spent more time considering whether to choose a constructive or destructive response. Thus, Hypothesis #5 was partially supported in that anxious and avoidant attachment moderated the relationship between sleep loss and interdependence, but did not moderate the relationship between sleep loss and closeness.

Discussion

Integrating theories and methods from the areas of close relationships (e.g., Aron & Aron, 1986; Rusbult et al., 1998; Shaver & Mikulincer, 2006), stress (e.g., Hockey & Hamilton, 1983; Lazarus & Folkman, 1984), and sleep loss (e.g., Engle-Friedman, et al. 2003; Pilcher & Huffcutt, 1996; Troxel et al., 2007), the present experiment proposed and investigated a general model of sleep and relationships. It was suggested that mental models of the self and close others (e.g., romantic partners) would be temporarily disrupted by sleep deprivation and its effects on affective and cognitive constructs, which in turn would increase the likelihood of poor interpersonal behaviors. Several aspects of this model were tested with a variety of self-report and behavioral measures after participants experienced either a night of normal sleep in their own homes or a night of sleep deprivation in the laboratory.

Individual Functioning

The experience of sleep deprivation, compared with a night of normal sleep, led to greater self-reported sleepiness and negative mood, as anticipated. Sleep group accounted for approximately 65% of the variance in sleepiness and 31% of the variance in negative mood. (Results were the same whether or not gender was included as a covariate, and no significant interactions with gender were obtained.) These effects were stronger than those reported by Engle-Friedman et al. (2003), whose sample size and protocol were comparable to the present experiment; in that study, sleep deprivation accounted for approximately 10% of the variance in sleepiness and 22% of the variance in negative mood. However, in Pilcher and Huffcutt's (1996) meta-analysis, sleep deprivation accounted for approximately 71% of the variance in mood. Therefore, it appears that effect size estimates for affective variables can vary widely.

Sleep group differences were not obtained for the attention, effort, and working memory behavioral tasks. Sleep group accounted for less than 2% of the variance in each measure. (Results were the same whether or not gender was included as a covariate, and no significant interactions with gender were obtained.) The lack of significant differences for the cognitive tasks are inconsistent with past research which has reported deficits in these domains following total sleep deprivation (e.g., Dinges, 1992; Engle-Friedman et al., 2003; Gillberg et al., 1994). These effects were much weaker than those reported in the literature. Engle-Friedman et al. (2003) found that sleep deprivation accounted for approximately 41% of the variance in attention and 8% of the variance in effort. In a recent meta-analysis by Lim and Dinges (2010) focused on cognition, sleep deprivation accounted for approximately 50% of the variance in attention and 25% of the variance in working memory.

It is unlikely that the deprivation manipulation used in the present study was ineffective considering that it closely followed Engle-Friedman et al.'s (2003) protocol (for example, by constantly monitoring participants during the overnights). Instead, the null findings could be due to the particular sample, whose sleep history data indicated that partial/total sleep loss was being experienced on a routine basis (about 10 times per month).

Sleep loss-related deficits in affect are stronger, and appear more rapidly, than do deficits in psychomotor and cognitive performance (Pilcher & Huffcutt, 1996). But it takes longer for performance to return to baseline levels as compared with affect (Axelsson et al., 2008; Belenky et al., 2003). If participants in the normal group had recently experienced sleep loss, then they might have still been in a recovery phase. In such a scenario, the normal group's performance on the attention, effort, and working memory tasks would be unrepresentative of baseline levels.

Sleep loss-related deficits in affect and performance are also greater when sleep loss occurs rapidly (e.g., 0 hours sleep for one night) than when sleep loss occurs slowly (e.g., 6 hours sleep for four consecutive nights), possibly because slow accumulation allows one to adapt to the circumstances (Drake et al., 2001). If participants in the deprived group had recently experienced sleep loss, then the night of deprivation in the laboratory would have simply been an addition to a growing sleep debt they were getting accustomed to. In such a scenario, the deprived group's performance on the attention, effort, and working memory tasks would be unrepresentative of acute total sleep deprivation.

General Interpersonal Functioning

Self-reported sociability was marginally lower for the deprived group compared with the normal group. (Results were the same whether or not gender was included as a covariate, and no significant interactions with gender were obtained.) Though the predicted difference was not statistically significant, its effect size was moderate, with about 7% of the variance in sociability being accounted for by sleep group. This finding is consistent with related research that found a consistent decline in optimism-sociability over the course of a 10-day sleep restriction protocol (Haack & Mullington, 2005).

Behavioral sociability was implicitly measured by observing the distance between a research assistant, seated on a couch in the laboratory, and where participants chose to sit on the couch (to complete printed questionnaires). Sitting further away was considered to be an indicator of decreased sociability. Contrary to predictions, sociability was significantly higher for the deprived group compared with the normal group, with about 14% of the variance being accounted for. (Results were the same whether or not gender was included as a covariate, and no significant interactions with gender were obtained.) The simplest explanation for this result is exposure (Zajonc, 1968)—the deprived group interacted with research assistants to a greater extent than the normal group did because of the overnight sleep deprivation sessions. A plausible alternative, though, is that deprived participants were unconsciously seeking social support as a buffer against the stress of being sleep deprived (DeVries, Glasper, & Detillion, 2003; Uchino, Cacioppo, & Kiecolt-Glaser, 1996).

Relationship Functioning

Determining the effects of sleep loss on relationship functioning was of paramount importance. The constructs examined in the present experiment were anxious and avoidant attachment (trait mental models of self and other), closeness and interdependence (state mental models of self and other), as well as self-expansion motivation (an effort variable relevant to closeness). Explicit self-report scales were used for all constructs; additional, implicit behavioral tasks were used for closeness and interdependence.

The sleep groups did not significantly differ in self-reported anxious or avoidant attachment. This was anticipated because attachment style is relatively stable over the lifespan (Shaver & Mikulincer, 2006). However, the sleep groups also did not demonstrate significant differences in self-reported closeness or interdependence. Moreover, the marginal difference found for self-expansion motivation (deprived > normal) was inconsistent with the hypothesized model. Results were the same whether or not gender and relationship length were included as covariates, and no significant interactions with either variable were obtained. All analyses had controlled for pretest scores. Because necessary conditions for mediation were not met (e.g., lack of basic sleep group differences in closeness and interdependence), analyses testing the indirect

effects of sleep loss were not appropriate. Self-reported anxious and avoidant attachment did not moderate the effects of sleep loss on self-reported closeness or interdependence.

Sleep group accounted for 1% or less of the variance in self-reported attachment, closeness, and interdependence, but did account for about 5% of the variance in self-expansion motivation. Aron and Aron (1986) speculated that self-expansion, the process by which one seeks to enhance self-efficacy, would not be sought when the self was extremely stressed. In the present experiment, it seems that the sleep deprivation manipulation was not stressful enough to deter self-expansion motivation. Indeed, the opposite appears to have occurred. The deprived participants may have been motivated to perceive and/or seek support from their partners to increase their efficacy for combating the sleepiness and negative mood engendered by the sleep deprivation experience. Cohen (2004) commented that social support and social integration influence physical health to the extent that they can, respectively, buffer sources of stress or enhance psychological well-being and immune function regardless of amount of stress. Anecdotally, some participants maintained contact with their partners via cell phone and instant messaging during the overnight sessions, which may account for the lack of significant group differences in self-reported closeness and interdependence.

With regard to the implicit behavioral tasks, basic sleep group differences in closeness (accuracy and reaction time) and interdependence (destructiveness and reaction time) were not obtained, and therefore mediation analyses were not appropriate. Nonetheless, significant (and interesting!) moderation effects were found, as discussed next.

Behavioral closeness was implicitly measured by asking participants to determine whether or not traits were true of the self while also taking into account whether or not those traits were true for the partner (Aron et al., 1991; Aron & Fraley, 1999). Relationship length and gender moderated the effect of sleep loss on closeness accuracy. Under conditions of normal sleep, relationship length and accuracy were not significantly correlated for men or women. But under conditions of sleep loss, as relationship length increased, mismatches increased for men (indicating more self-other confusion/overlap), but decreased for women (indicating less self-other confusion/overlap). This finding is consistent with related research in the social/health literature suggesting that women benefit more from same-gender relationships while men benefit more from supportive cross-gender relationships (House, Landis, & Umberson, 1988), and that marriage serves more of a protective function for men than for women because of the emotional support provided (Ross, Mirowsky, & Goldsteen, 1990).

Behavioral interdependence was implicitly measured by asking participants to respond to hypothetical scenarios (where their romantic partner engaged in a constructive or destructive behavior) by choosing a constructive or destructive response (Yovetich, 1997; Yovetich & Rusbult, 1994). Anxious attachment moderated the effect of sleep loss on both interdependence reaction time and destructiveness, such that the deprived group spent more time considering whether to choose a constructive or destructive response, and tended to choose destructive responses more often than constructive responses, as compared with the normal group. Considering that anxious attachment reflects ambivalence as well as insecurity (Hazan & Shaver, 1987), it is unsurprising that both destructiveness and reaction time were affected. Avoidant attachment moderated the effect of sleep loss on interdependence destructiveness only, such that the normal group chose destructive responses more often than constructive responses, as compared with the deprived group. Insecurely attached individuals have been shown to use more destructive responses (e.g., exit and neglect strategies) than securely attached individuals (Gaines et al., 1997), so the difference in response choice for the normal group is unsurprising. However,

it is unclear why such a difference was not obtained for the deprived group. Avoidant individuals have been shown to benefit emotionally from particular types of social support when experiencing stress (Mikulincer & Florian, 1997), so it may be that support received during the overnight (e.g., from the research assistants and partners) could have alleviated some of the stress of sleep deprivation, thus curtailing the impulse to respond destructively.

Limitations and Future Directions

Most of the hypotheses were only partially supported (e.g., mixed results for sleep-related scales and tasks) or not supported at all (e.g., mediation of closeness and interdependence). Some results obtained were also in the opposite direction than that predicted (e.g., self-expansion motivation). Aside from the need for replication and addressing the limitations described below, other future directions include testing the explanations provided for unexpected findings, as well as varying the amount of sleep deprivation imposed.

The sample size used in the current experiment was smaller than warranted for the type of statistical tests conducted, which curtailed power (Cohen, 1988). Of those participants who passed the eligibility screening during Part 1, only 37% completed Part 2 of the study. Not only were the subject mortality and noncompliance rates exorbitant, but they also differed by condition (with greater mortality in the deprived group and greater noncompliance in the normal group). Therefore, the results may have been biased by using a small convenience sample of undergraduate students as well as differential self-selection. In addition, as noted earlier in the discussion, the sample's sleep history is problematic given that it may have unduly influenced the efficacy of the experimental manipulation.

With regard to procedure, the experimental manipulation could have been better controlled. Compliance with sleep group instructions was assessed using self-report. Had objective measures been used (such as actigraphy, to assess sleep time in the normal group), perhaps noncompliance would have been lower. Also, during the overnight, participants were permitted to interact with one another and the research assistants. Likewise, because it had not been strictly prohibited in advance, some participants maintained contact with their partners and friends via phone and Internet. These uncontrolled interactions may have unduly influenced the results obtained for the self-reported relationship measures.

The measures used in the present experiment were more than sufficient for hypothesis-testing. All of the self-report scales demonstrated adequate inter-item reliability, the observations of sociability were highly consistent, and the other behavioral tasks had been used in previous research. But, only part of the proposed sleep-relationships theoretical model could be explored because observation of partners' interactions was not included in the study's design. Thus, measures of dyadic behavior should be included in future research.

Conclusion

Are close relationships hindered by sleep loss? The present research illustrated that the effects of sleep loss on general interpersonal functioning and romantic relationship functioning are complex. Sociability, closeness, and interdependence showed some deterioration as a function of the sleep deprivation experience. But instead of being a mediator, sleep condition emerged as a significant moderator of closeness and interdependence when considering gender, relationship length, and attachment. Nonetheless, it is apparent that getting an adequate amount of sleep is not only important for one's health but also the vitality of one's interpersonal relationships.

Table 1

Correlations between Subscales of the Investment Model Scale

Variables	1	2	3	4	5	6	7	8
1. Time 1 Commitment	-----							
2. Time 1 Satisfaction	.83***	-----						
3. Time 1 Quality of alternatives	-.59***	-.48***	-----					
4. Time 1 Investment size	.65***	.54***	-.41**	-----				
5. Time 2 Commitment	.89***	.78***	-.52***	.56***	-----			
6. Time 2 Satisfaction	.70***	.85***	-.44***	.47***	.81***	-----		
7. Time 2 Quality of alternatives	-.49***	-.39**	.78***	-.29*	-.57***	-.43***	-----	
8. Time 2 Investment size	.69***	.62***	-.35**	.73***	.69***	.64***	-.35**	-----

*$p < .05$. **$p < .01$. ***$p < .001$.

Table 2

Correlations between Subscales of the Profile of Mood States

Variables	1	2	3	4	5	6
1. Tension	-----					
2. Confusion	.78***	-----				
3. Anger	.82***	.69***	-----			
4. Fatigue	.65***	.77***	.47***	-----		
5. Vigor	-.43**	-.63***	-.21	-.78***	-----	
6. Depression	.78***	.71***	.88***	.43**	-.15	-----

**$p < .01$. ***$p < .001$.

Table 3

Sleep History Variables by Sleep Group at Pretest

Variables	Normal (n = 24) M	SD	Deprived (n = 31) M	SD	M_{DIFF}	t
Weekdays						
Sleep latency (min)	15.42	7.65	18.27	17.88	-2.86	-0.73
Number of awakenings	0.63	0.84	0.76	1.14	-0.13	-0.48
Time awake at night (min)	6.80	4.89	6.47	6.97	0.33	0.13
Total sleep time (hrs)	7.23	1.29	7.39	0.83	-0.16	-0.55
Weekends						
Sleep latency (min)	14.06	8.80	17.26	19.92	-3.20	-0.60
Number of awakenings	0.28	0.52	0.24	0.47	0.04	0.26
Time awake at night (min)	1.38	3.38	2.96	12.47	-1.58	-0.49
Total sleep time (hrs)	9.63	1.06	8.54	1.54	1.08	2.44*
General						
Optimal sleep time (hrs) [a]	7.56	1.07	7.52	1.35	0.05	0.14
Nights/month of no sleep	1.06	1.22	1.15	1.58	-0.08	-0.21
Nights/month of less sleep	9.02	6.48	8.45	5.65	0.57	0.34

Note. Statistics include means (M), standard deviations (SD), pretest–posttest mean difference scores (M_{DIFF}), and independent t-test values (t).
[a] Optimal sleep time was based on the question "How much sleep per night do you need to feel refreshed the next day?"
*$p < .05$.

Table 4

Affective Self-Report and Behavioral Measures by Sleep Group at Post-test

Variables	Normal (n = 24) M	SD	Deprived (n = 31) M	SD	t	r	F_{CV}	pr_{CV}
Affective Self-Report Measures								
Sleepiness	8.27	3.19	18.72	3.95	-10.13***	-.82	91.31***	-.81
Negative mood	1.97	0.73	2.97	0.75	-4.96***	-.56	23.60***	-.56
Behavioral Measures								
Attention: reaction time (ms)	319.20	60.49	331.35	48.34	-0.83	-.11	0.88	-.13
Effort: difficulty level (#)	2.88	1.11	2.73	1.21	0.45	.06	0.62	.11
Effort: accuracy (%)	91.63	8.87	92.16	7.06	-0.25	-.03	0.07	-.03
Effort: reaction time (ms)	5034.34	2307.41	4651.98	1886.48	0.68	.09	0.60	.10
Working memory: accuracy (%)	89.13	8.88	88.35	7.61	0.35	.05	0.11	.04
Working memory: reaction time (ms)	594.32	180.92	601.20	124.34	-0.17	-.02	0.29	-.08
Closeness: accuracy (%) [a]	-15.30	22.36	-12.16	19.14	-0.56	-.08	0.41	-.09
Closeness: reaction time (ms) [a]	67.60	113.09	66.77	113.66	0.03	.00	0.01	.00
Interdependence: destructiveness (%)	23.50	15.92	17.73	11.55	1.54	.20	1.79	.19
Interdependence: reaction time (ms)	7807.71	2116.91	8049.97	2653.71	-0.36	-.05	0.13	-.05
Sociability: distance (# stripes) [b]	14.21	3.22	11.66	3.75	2.66*	.34	8.74**	.38

Note. Statistics based on the basic analyses include means (M), standard deviations (SD), independent t-test values (t), and effect sizes (r). Statistics based on the advanced analyses (using gender and/or relationship length as covariates) include ANCOVA F-test values (F_{CV}) and effects sizes (pr_{CV}).

[a] For behavioral closeness, mismatch–match difference scores were used.

[b] For behavioral sociability, higher scores indicated greater distance and thus lower sociability.

*p < .05. **p < .01. ***p < .001.

Table 5

Interpersonal Self-Report Measures by Sleep Group at Pretest and Posttest

	Pre-Test				Post-Test									
	Normal (n = 24)		Deprived (n = 31)		Normal (n = 24)			Deprived (n = 31)						
Variables	M	SD	M	SD	M_{ADJ}	M	SD	M_{ADJ}	M	SD	F	pr	F_{CV}	pr_{CV}
Anxious attachment	2.53	1.06	2.30	0.83	2.42	2.55	1.34	2.49	2.38	1.20	0.09	-.04	0.19	-.06
Avoidant attachment	2.25	0.88	2.18	1.00	2.36	2.40	1.04	2.35	2.32	1.16	0.01	.00	0.01	.00
Self-expansion motivation	5.40	0.80	4.90	1.18	5.02	5.25	0.78	5.31	5.13	1.20	3.17^{+}	-.24	2.78^{+}	-.23
Closeness	5.67	1.06	5.59	1.19	5.34	5.38	1.21	5.41	5.38	1.30	0.13	-.04	0.08	-.04
Interdependence	5.18	0.99	5.17	1.25	5.09	5.09	1.11	5.20	5.20	1.20	0.57	-.10	0.50	-.10
Sociability	5.36	1.19	5.26	1.12	5.62	5.67	1.14	5.31	5.28	1.16	3.66^{+}	.26	3.78^{+}	.26

Note. Statistics based on the basic analyses include means (M), standard deviations (SD), adjusted means controlling for pretest scores (M_{ADJ}), ANCOVA F-test values (F) and effects sizes (pr). Statistics based on the advanced analyses (using gender and/or relationship length as covariates) include ANCOVA F-test values (F_{CV}) and effects sizes (pr_{CV}).

$^{+}p < .10$.

Table 6

Tests of Moderation

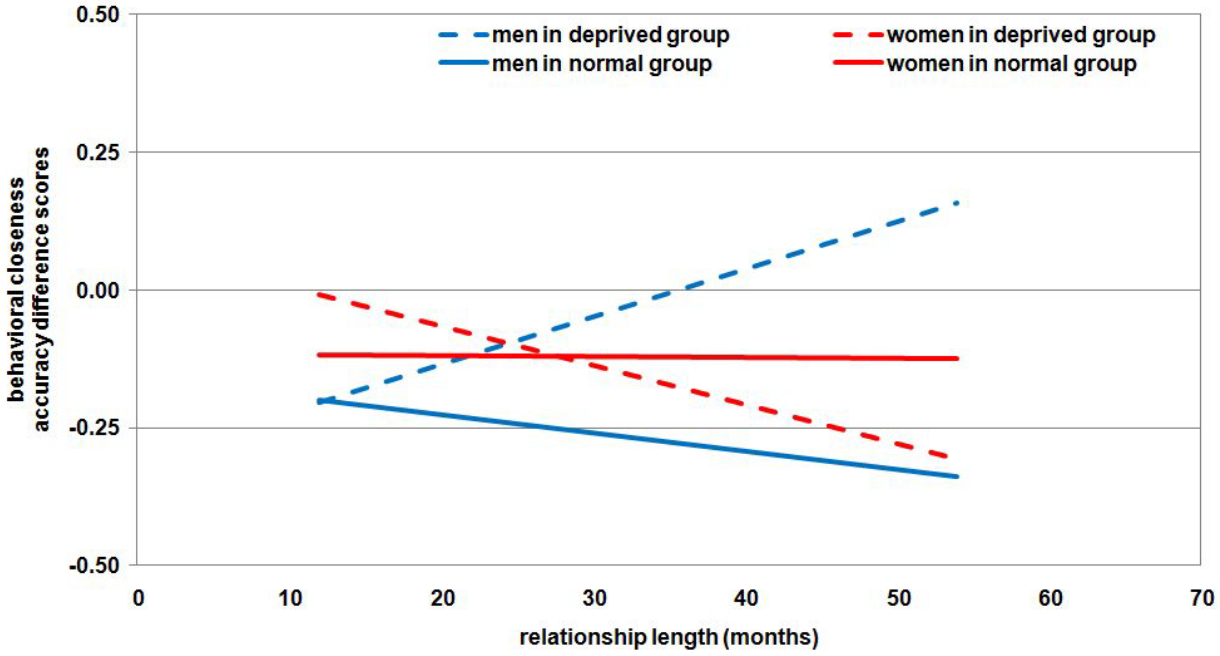
Variables	Two-Way Interaction Block					Three-Way Interaction Block		
	ΔR^2	ΔF	$\beta_{GRP\times ANX}$	$\beta_{GRP\times AVO}$	$\beta_{ANX\times AVO}$	ΔR^2	ΔF	$\beta_{GRP\times ANX\times AVO}$
Self-Report Measures								
Closeness	.05	1.45	.37^{+}	.00	.19	.02	1.67	.26
Interdependence	.03	1.05	-.14	-.14	.06	.00	0.13	.07
Behavioral Measures								
Closeness: accuracy (%) [a]	.04	0.69	-.30	.37	.08	.00	0.04	.06
Closeness: reaction time (ms) [a]	.05	0.77	.25	-.40	.16	.00	0.05	-.06
Interdependence: destructiveness (%)	.19	4.64**	.66**	-.93***	.16	.00	0.19	.10
Interdependence: reaction time (ms)	.12	2.25^{+}	.71*	-.41	.22	.03	1.67	.33

Note. Statistics for each block of interaction effects include increment changes in proportion of variance accounted for (ΔR^2), increment changes in regression *F*-test values (ΔF), and standardized coefficients for the focal predictors (β). Abbreviations: GRP = sleep group (coded as 1=deprived and 0=normal), ANX = anxious attachment, AVO = avoidant attachment.

[a] For behavioral closeness, mismatch–match difference scores were used.

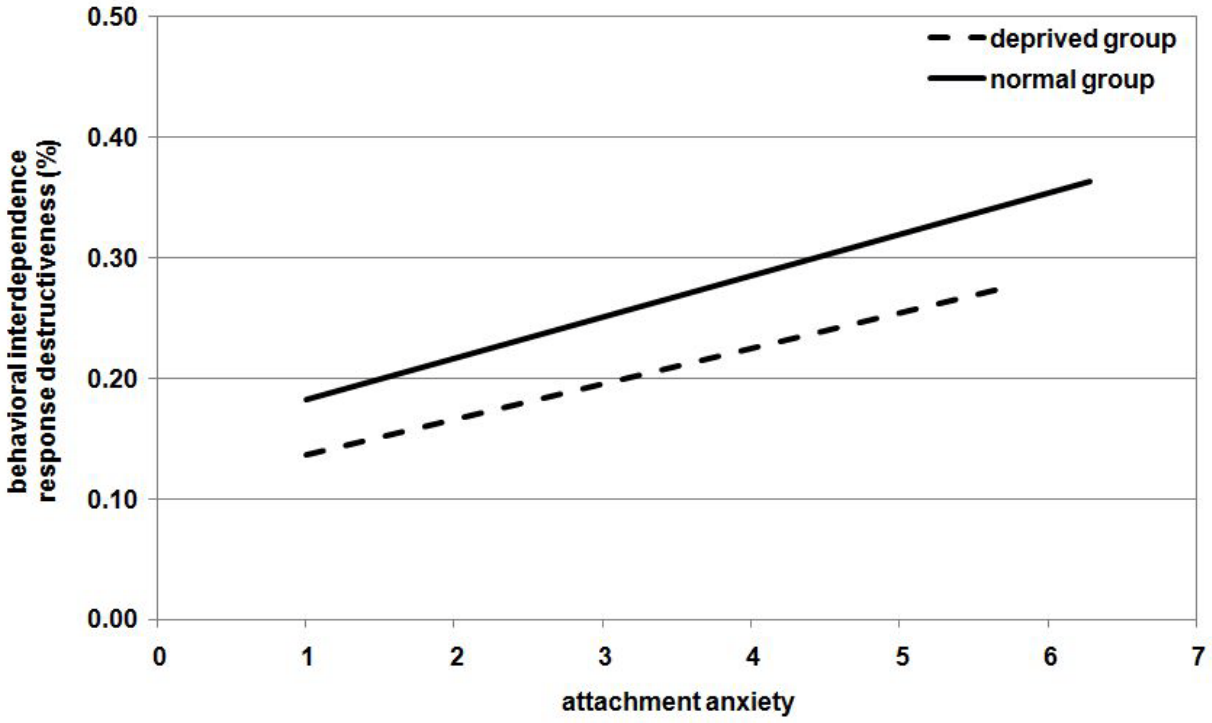
$^{+}p < .10$. $*p < .05$. $**p < .01$.

Figure 1



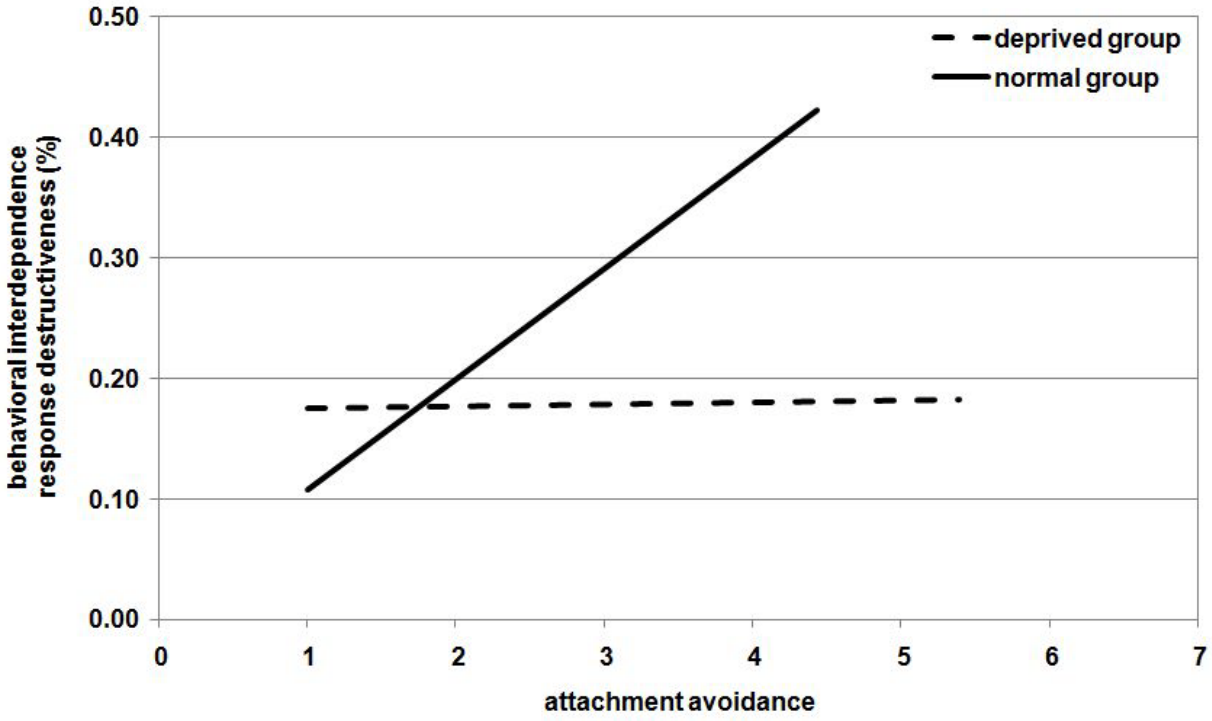
Sleep group × gender × relationship length three-way interaction found for the behavioral closeness task's accuracy difference scores (mismatches–matches). A log function was applied to relationship length (plotted along the *y*-axis). Higher accuracy scores (more positive values along the *x*-axis) indicate greater closeness (inclusion of other in the self; Aron et al., 1991). In the normal group, length and accuracy scores were not significantly correlated for men (r = -.11) or women (r = -.01). But in the deprived group, there was a significant positive correlation for men (r = .79) and a significant negative correlation for women (r = -.52); as relationship length increased, mismatches increased for men but decreased for women.

Figure 2



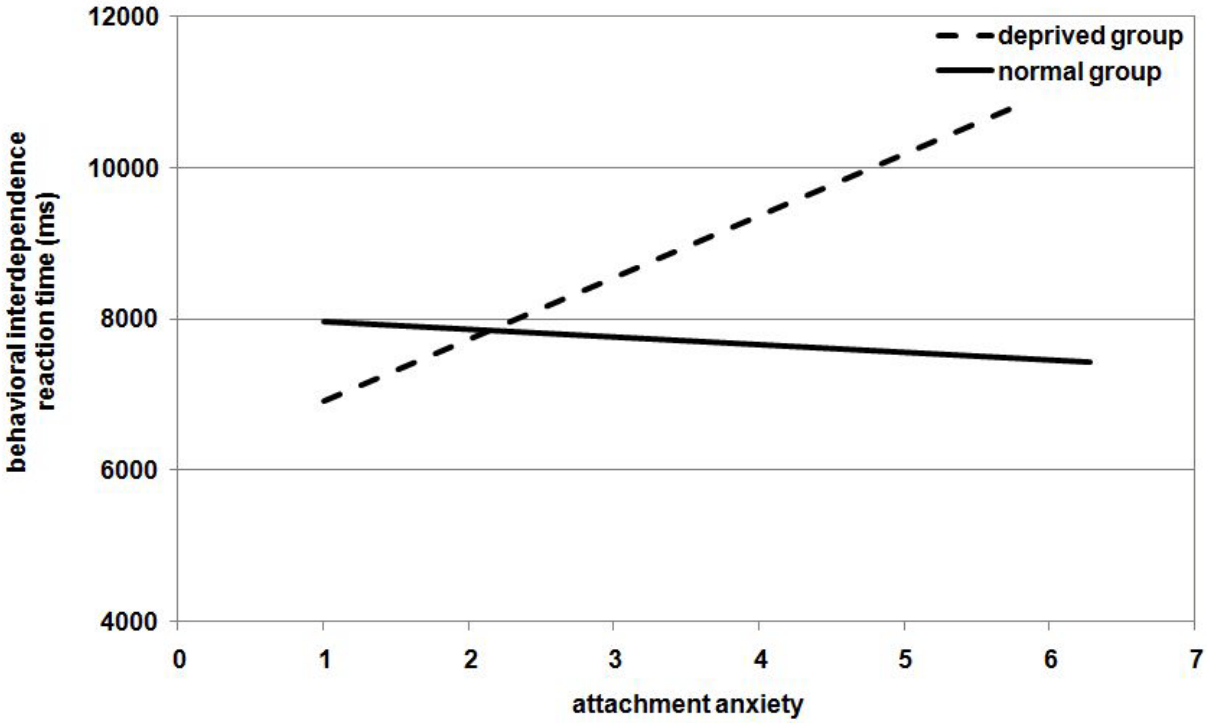
Sleep group × attachment anxiety interaction for the behavioral interdependence task's response destructiveness. Anxiety and destructiveness were not significantly correlated for the normal group (r = .29), and were only marginally correlated for the deprived group (r = .31). In both cases, the trend was such that as attachment anxiety increased, destructiveness increased.

Figure 3



Sleep group × attachment avoidance interaction for the behavioral interdependence task's response destructiveness. Avoidance and destructiveness were significantly correlated for the normal group (r = .60), such that as attachment avoidance increased, destructiveness increased. No significant correlation was found for the deprived group (r = .02).

Figure 4



Sleep group × attachment anxiety interaction for the behavioral interdependence task's reaction time. Anxiety and reaction time were not significantly correlated for the normal group (r = -.06). But there was a significant positive correlation for the deprived group (r = .38); as attachment anxiety increased, reaction time increased.

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Appendix A

Sleep History and Health Screening Questionnaire (SHHSQ)

SLEEP HISTORY (SH)

INSTRUCTIONS: Please answer the following questions regarding your weekday (Sunday night – Thursday night) sleep habits.

1. Do you usually take naps during the day? □ yes □ no
   If YES, how long do you usually nap? _____min

2. What time do you usually go to sleep at night?
   □ before 10pm □ 10pm-11pm □ 11pm-12am
   □ 12am-1am □ 1am-2am □ after 2am
   □ Other (specify): _____

3. How long does it usually take you to fall asleep? _____hrs _____min

4. How many awakenings do you usually experience during a night? _____

5. If you wake up during the night, how much time do you usually spend awake when you prefer to be asleep? _____hrs _____min

6. What time do you usually wake up in the morning?
   □ before 6am □ 6am-7am □ 7am-8am
   □ 8am-9am □ 9am-10am □ after 10am
   □ Other (specify): _____

7. How much sleep, in total, do you usually get per night? _____hrs _____min

8. Are your weekday sleep habits (sleep length, time of going to bed, time of waking up) different from your weekend sleep habits? □ yes □ no
   (If YES, please complete questions 9 – 15.)

INSTRUCTIONS: Please answer the following questions regarding your weekend (Friday night – Saturday night) sleep habits IF you answered YES to Question #8.

9. Do you usually take naps during the day? □ yes □ no
   If YES, how long do you usually nap? _____min

10. What time do you usually go to sleep at night?
    □ before 10pm □ 10pm-11pm □ 11pm-12am
    □ 12am-1am □ 1am-2am □ after 2am
    □ Other (specify): _____

11. How long does it usually take you to fall asleep? _____hrs _____min

12. How many awakenings do you usually experience during a night? _____

13. If you wake up during the night, how much time do you usually spend awake when you prefer to be asleep? _____hrs _____min

14. What time do you usually wake up in the morning?
    - □ before 6am □ 6am-7am □ 7am-8am
    - □ 8am-9am □ 9am-10am □ after 10am
    - □ Other (specify): _____

15. How much sleep, in total, do you usually get per night? _____hrs _____min

INSTRUCTIONS: Please answer the following questions regarding your sleep <u>in general</u>.

16. How many times a month do you have no sleep for an entire night? _____
    What percentage of these nights is due to...
    a. Studying _____%
    b. Employment/Job _____%
    c. Recreation _____%
    d. Inability to fall asleep _____%

17. How many times a month do you have "less" sleep than you need? _____
    What percentage of these nights is due to...
    a. Studying _____%
    b. Employment/Job _____%
    c. Recreation _____%
    d. Inability to fall asleep _____%

18. How much sleep per night do you need to feel refreshed the next day? _____hrs _____min

19. Do you have any problems with your sleep? □ yes □ no
    If yes, please explain: _____
    _____
    _____

20. Do you take drugs to induce sleep? □ yes □ no

21. Are you bothered by difficulty falling asleep? □ yes □ no

22. Are you bothered by frequent awakenings during the night? □ yes □ no

23. Are you bothered by long periods of wakefulness during the night? □ yes □ no

24. Are you bothered by waking up too early? □ yes □ no

25. Do you usually feel tired during the day? □ yes □ no

26. If there are any other aspects of your sleep which you feel are important, please describe them here: _____

_____

_____

PHYSICAL/MENTAL HEALTH (PMH)

1. Are you in good health as far as you know? □ yes □ no
   If no, please explain: _____

   _____

   _____

2. Have you had any of the following major illnesses? (Place a check in the appropriate column.)

ILLNESS	NEVER HAD	HAD BEFORE	NOW HAVE
High blood pressure			
High cholesterol			
Diabetes			
Rheumatic fever			
Asthma			
Chronic bronchitis			
Seizures			
Pneumonia			
Heart trouble			

3. How many times during the PAST YEAR did you have any of the following minor health problems? (Place a check in the appropriate column.)

ILLNESS	NOT AT ALL	SOMEWHAT	CONSTANTLY
Cold			
Flu			
Sinus trouble			
Headaches			
Backaches			
Muscle aches			
Skin rashes			
Allergies			
Stomach problems			

4. How many times during the PAST YEAR were you hospitalized for an illness/accident?
   _____

5. How many times during the PAST YEAR did you go to the doctor for an illness/accident? (Do not include return check-up visits.) _____

6. How many days during the PAST YEAR were you unable to work/go to school due to illness/accident? _____

7. Are you currently taking any kind of medication (e.g., antibiotics, birth control pills, allergy shots, vitamins, etc.)? □ yes □ no
   If YES, please list below the name and amount of all medications you are taking and state how often and why you take each one.

MEDICATION	AMOUNT	HOW OFTEN	REASON

8. Have you ever sought any of the following mental health aids?
   a. Marriage counseling □ yes □ no
   b. Group therapy □ yes □ no
   c. Sensitivity training □ yes □ no
   d. Psychological/psychiatric counseling □ yes □ no
   e. Psychiatric outpatient clinic □ yes □ no
   f. Psychiatric hospitalization □ yes □ no

9. Are you now seeing a psychologist, psychiatrist, or any other type of counselor? □ yes □ no

10. How would you rate your overall health? □ poor □ fair □ average □ good □ excellent

WOMEN ONLY:

11. Are you pregnant? □ yes □ no

12. If no, what was the date of your last period (menstrual cycle)? _____

SUBSTANCE USAGE (SU)

1. Write in the average number of each of these beverages that you drink per day:
   a. Regular coffee/soda _____
   b. Decaf coffee/soda _____
   c. Tea _____

2. Are you a smoker? □ yes □ no

If YES, how many cigarettes do you smoke per day? _____

3. Do you drink alcoholic beverages? □ yes □ no
   If YES, how many alcoholic beverages do you drink on weekdays? _____
   If YES, how many alcoholic beverages do you drink on the weekend? _____

4. Do you smoke marijuana or take any other type of psychotropic drug? □ yes □ no
   If YES, what drug and how often? _____

5. Are you addicted to nicotine, alcohol, or any recreational drug? □ yes □ no

6. Do you feel you are a normal drinker? □ yes □ no

7. Do friends or relatives think you are a normal drinker? □ yes □ no

8. Have you ever lost friends or romantic partners because of your drinking? □ yes □ no

9. Have you ever neglected your obligations, your family, or your work for two or more days in a row because you were drinking? □ yes □ no

10. Have you ever gone to anyone for help about your drinking? □ yes □ no

11. Have you ever been in a hospital because of drinking? □ yes □ no

12. Have you ever been arrested for drunk driving or driving after drinking? □ yes □ no

13. Do you think you have a drug problem? □ yes □ no

14. Does anyone close to you think you are having a problem with drugs? □ yes □ no

15. Have you ever lost friends or romantic partners because of your drug use? □ yes □ no

16. Have you ever neglected your obligations, your family, or your work for two or more days in a row because you were using drugs? □ yes □ no

17. Have you ever gone to anyone for help about your drug use? □ yes □ no

18. Have you ever been hospitalized because of a drug overdose? □ yes □ no

19. Have you used marijuana frequently (2-3/week) during the past month? □ yes □ no

20. Have you ever used LSD or heroin? □ yes □ no

Appendix B

SHHSQ List of Disqualifications

INSTRUCTIONS: If a participant meets ANY of the criteria listed below, then EXCLUDE from Part 2. Please refrain from asking participants about their answers, except in the following cases: (a) SH 19, SH 26, PMH 1, PMH 11, PMH 12, (b) participant did not answer a question, and (c) participant clearly misunderstood a question. When in doubt regarding eligibility, contact the study coordinator.

SLEEP HISTORY (SH)

Q16: Multiply number of times per month by percentage provided in Part D. Convert percent to proportion. Calculation equals 5 or more.

Q17: Multiply number of times per month by percentage provided in Part D. Convert percent to proportion. Calculation equals 10 or more.

Q19: Review explanation. Could person have a sleep disorder? Write explanation in margin of questionnaire. If unsure, contact the study coordinator.

Q20 thru Q25: Answered "yes" for 3 or more items.

Q26: Review explanation. Could person have a sleep disorder? Write explanation in margin of questionnaire. If unsure, contact the study coordinator.

PHYSICAL/MENTAL HEALTH (PMH)

Q1: Review explanation. Could person's physical/mental health be adversely affected by sleep loss? Write explanation in margin of questionnaire. If unsure, contact the study coordinator.

Q2: Marked "had before" for seizures or heart trouble, or "have now" for rheumatic fever, bronchitis, seizures, pneumonia, or heart trouble.

Q3: Marked "constantly" for any category; exception: allergies.

Q4: Number of times equals 1 or more.

Q5: Number of times equals 5 or more.

Q7: Taking medication for heart issue, epilepsy, anxiety, depression, or insomnia. IF taking antibiotics, allow only if medication will be completed before proposed date of post-session.

Q8: Answered "yes" to item E or F.

Q10: Answered "poor."

FOR WOMEN ONLY:

Q11 thru Q12: Read the following paragraph to female participants IF (a) pregnant OR (b) last menstrual cycle was more than 30 days past. Ask male subjects to leave the room before proceeding.

No studies have investigated the effects of total sleep deprivation during and after pregnancy. Longitudinal studies on naturally occurring sleep loss, though, suggest that chronic sleep loss can negatively impact the fetus, newborn child, and mother (e.g., Skouteris, Germano, Wertheim, Paxton, & Milgrom, 2008). Women who are aware of or suspect they are pregnant are strongly discouraged from participating in this study.

SUBSTANCE USAGE (SU)

Q1: Sum of Part A and Part C is 5 or more.

Q2: Answered "yes" and number is 3 or more cigarettes/day.

Q3: Answered "yes" and sum for weekdays and weekends is 10 or more.

Q4: Answered "yes," drug listed as marijuana, and amount is 2 times or more per month. OR answered yes, and listed drug other than marijuana.

Q5: Answered "yes."

Q8 thru Q20: Answered "yes" for 3 or more items.

BECK DEPRESSION INVENTORY (BDI)

Q1 thru Q21: Sum equals 16 or more. (For Q19, if participant is purposely trying to lose weight, then use a score of 0 for that item.)

Q9: This item focuses on suicidal ideation. Exclude if answered "2" or "3" AND alert the study coordinator!

Appendix C

Sleep Group Instructions

You have been randomly assigned to the NORMAL group. Your post-test session is scheduled for: _____.

Day before Post-Test Session

- Wake up by 8:30am.
- Do not take any naps during the day.
- After 7:00pm, do NOT have:
  - Caffeine (e.g., coffee, tea, chocolate)
  - Nicotine (cigarettes)
  - Alcohol
  - Non-prescription drugs
- Go to bed by 11:30pm.

Day of Post-Test Session

- Wake up by 8:30am.
  - Anyone sleeping less than 8 hours will be disqualified from the study and will NOT be allowed to complete the post-test session.
- Do not take a nap after you wake up in the morning.
- Bring your ID in case you need it to enter the campus.
- Arrive promptly at 9:00am at <BUILDING AND ROOM>.
- The assessment session will begin at 9:00am and end by about 12:00pm.

If you need to reach us for any reason, please contact <NAME>
by email at <EMAIL ADDRESS> or by phone at <PHONE NUMBER>

You have been randomly assigned to the DEPRIVED group. Your sleep deprivation session is scheduled for: _____. The post-test session will be completed the following day.

Day before Post-Test Session

During the day:

- Wake up by 8:30am.
- Do not take any naps.
- After 7:00pm, do NOT have:
  - Caffeine (e.g., coffee, tea, chocolate)
  - Nicotine (cigarettes)
  - Alcohol
  - Non-prescription drugs

Arriving at the laboratory:

- Wear comfortable clothing.
- Do NOT drive to the study. Have someone bring you to campus.
- Bring your ID in case you need it to enter the campus.
- Arrive promptly at 9:00pm at <BUILDING AND ROOM>.
- Give <NAME> (the study coordinator) the contact information for your escort home, and in case of an emergency. This information will be returned to you the following day.

Sleep Deprivation Overnight

The following items will be available to you:

- Non-caffeinated beverages
- Snacks
- Movies
- Desktop computers

You are permitted to have:

- iPod, CD player, and/or walkman
- Laptop
- Homework or study materials
- Cell phone
- Video game console
- Prescription medication (if needed)

You are NOT permitted to:

- Leave the building
- Have visitors or guests
- Exercise

Important!

- If you discontinue your participation while staying in the Psychology Department, you will be allowed to do so and provided with a place to sleep. However, for safety purposes, you cannot leave the premises until the following morning.

Day of Post-Test Session

- You will be provided with breakfast at 8:30am.
- The assessment session will begin at 9:00am and end by about 12:00pm.
- You will be asked to sleep following the assessment. You will be allowed to sleep for up to 4 hours in the laboratory. Air mattresses, sheets, blankets, and pillows will be set up to provide you a place to sleep.
- After you have slept (or declined sleep), the study coordinator will give you a simple mental skills test to determine whether you are permitted to leave. This test will be in an interview format and last about 10 minutes.
- After you have "passed" the mental skills test, your escort will be contacted by the study coordinator) to pick you up from the laboratory.
- You will not be able to leave the laboratory until you have passed the mental skills test and your escort has arrived.

Recovering from Sleep Deprivation

Adults usually need 7 to 8 hours of sleep per night. Because of the physiology of sleep, we do not need the exact amount of sleep that has been lost during sleep deprivation, but we do need more sleep than usual. When you have been deprived of sleep for 24 hours, most of your "recovery" occurs within the first 4 hours of sleep, but continues up to approximately 10 to 12 hours.

The following are suggestions for getting your sleep back on track:

1) Sleep at the laboratory for 4 hours. Then sleep at least 6 hours at home that night, going to bed at your normal bedtime.
2) Sleep at the laboratory for 2 hours. Then sleep at least 8 hours at home that night, going to bed earlier than your normal bedtime.
3) If you choose NOT to sleep at the laboratory, follow #1 or #2 as soon as you get home. If you do not, you should go to bed much earlier than your normal bedtime and sleep at least 12 hours.

If you need to reach us for any reason, please contact <NAME>
by email at <EMAIL ADDRESS> or by phone at <PHONE NUMBER>

Appendix D

Sleep Diary

SLEEP DIARY

1. Did you take a nap yesterday? □ yes □ no

2. If you took a nap, how long did you nap for yesterday? _____hrs _____min

3. How many cups of a caffeinated beverage did you drink after 7pm last night (e.g., coffee, tea, Coca-Cola, Snapple)? _____

4. How many cigarettes did you smoke since 7pm last night? _____

5. How many cups of an alcoholic beverage did you drink after 7pm last night (e.g., beer, wine)? _____

6. Did you take any medication to help you sleep last night? □ yes □ no

7. What time did you go to bed last night? _____ am/pm

8. How long did it take you to fall asleep last night? _____hrs _____min

9. How many awakenings did you have last night? _____

10. If you woke up during the night, how much time did you stay awake when you preferred to be asleep? _____hrs _____min

11. What time did you wake up this morning? _____ am/pm

12. How much sleep did you get last night, in total? _____hrs _____min