2016

Aggressiveness and sleep: People with quick tempers and less anger control have objectively worse sleep quality

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by

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A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Psychology

Program of Study Committee:
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Iowa State University

Ames, Iowa

2016

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ACKNOWLEDGEMENTS

For all of the visible and invisible support, guidance, care, and patience, I would like to thank Dr. Zlatan Krizan, Dr. Alison Phillips, Dr. Christian Meissner, my friends, my family, and my coffee. Whether it is by introducing me to Daft Punk, engaging in (so far) fruitless jolly co-operation, pretending to care about disc golf, going for random Somerset walks, or simply keeping me awake, all you make me enjoy the chaotic world of graduate school.

ABSTRACT

Adults and children who report frequent expression of anger and aggression also report sleep disruption. Although these findings suggest an important relationship, it is unknown whether this link extends to real sleep behavior, what aspects of sleep and angry and aggressive tendencies play the most important role, and whether stress and constraint contribute to their connection. To address these questions, the current study used a large scale dataset from the Biomarker Project of the Midlife in the United States Longitudinal Study of Health and Well-Being (MIDUS II) to investigate these relations with respect to both objectively (actigraphy) and subjectively (daily diary) measured sleep. Results indicated that individuals who are quick to anger and with poor anger control had worse *objectively* measured sleep onset latency, sleep efficiency, and sleep fragmentation. Stress and constraint did not contribute to these relations. In addition, all of individuals' anger tendencies related to *subjectively* measured indices of sleep quality; however, these relations were largely accounted for by stress and constraint. The links between these anger tendencies and sleep illuminate the larger growing body of evidence showing that sleep disruption influences aggression and aggressive tendencies.

CHAPTER 1: INTRODUCTION

A single act of aggression can cause emotional and physical trauma to its victims as well as carry large monetary costs to society For instance, a single act of murder can cost $17 million in public resources (DeLisi, et al., 2010). Importantly, some individuals' are prone to anger and provocation across situations and are more likely to aggress as a result (Bettencourt, et al., 2006; Buss & Perry, 1991; Huesmann, et al., 1984). These individuals are more likely than their less anger-prone peers to engage in costly aggressive behavior, such as physically attacking someone who angered them. Given the cost of such behavior, identifying factors which influence dispositions towards anger and aggression is imperative. One relatively neglected factor that may play a key role in expression and development of angry and aggressive propensities is sleep; more angry and aggressive individuals often report having sleep which is disturbed in terms of quality, quantity, or compromised by a clinical sleep disorders (Kamphuis, et al., 2014; Gregory, et al., 2004; Rauer & El-Sheikh, 2012).

While anger and aggressiveness often co-occur with sleep disruption, the existence of this relation has yet to be established using objective measurements of sleep (which avoid self-report biases pervasive in typically used subjective sleep reports). Moreover, if real sleep behavior does relate to angry and aggressive inclinations, it is critical to investigate which aspects of sleep behavior (e.g., insufficient sleep, number of awakenings during sleep, daytime dysfunction) and anger and aggressiveness (e.g. aggressive impulses, anger control, anger expression) actually drive this relationship. Finally, the roles of stress and constraint as potential contributing factors to this relation have yet to be fully assessed.

Overview

To tackle these challenges, the aim of this study is to establish a link between sleep and aggressiveness by using a large and diverse dataset (MIDUS II) by examining connections between objective sleep behavior and individual's dispositions towards anger, while also considering individual differences in stress and constraint. In the following sections, I first introduce and describe aggressiveness and sleep, as well as present evidence suggesting that they are linked by feelings of anger and disrupted cognition. Second, I provide a conceptual rationale for their link and acknowledge potential biases and contributing factors to this link. Finally, I conduct and discuss analyses which avoid these biases and examine the proposed contributing factors to obtain a clearer examination of the relationship between sleep disruption and aggressiveness.

Sleep and Aggression

What is aggression? An act of aggression is defined as any behavior that is intended to harm an individual, assuming that the targeted individual is motivated to avoid the harm (DeWall, Anderson, & Bushman, 2011). Aggression is a complex behavior that can involve many different dimensions, such as the extent of angry emotions, the amount of forethought given to the behavior, and the ultimate goal of the act. Here, I focus on individual differences (i.e. anger propensities) which influence *reactive (or hostile) aggression*, namely aggressive acts that are characterized by impulsive angry reactions to perceived provocations and behaviors which have the immediate goal of harming another individual. An important central construct in reactive aggression is anger, which has been referred to as the "bridge" that connects perceptions of provocations to actual acts of aggression (Buss & Perry, 1991). Anger as a central component of reactive aggression has critical implications for why sleep and aggressiveness often co-occur given increased feelings of anger may be one of the effects of sleep disruption (Kahn, Sheppes, & Sadeh, 2013).

When does reactive aggression occur? For a single instance of a potentially aggression-provoking event, characteristics of the situation (e.g. insults, overcrowding) and person variables (e.g. personality, beliefs) combine to influence an individual's cognition, emotions such as anger, and arousal levels (Anderson & Carnagey, 2004; Wilkowski & Robinson, 2010). From this present internal state, an automatic behavioral impulse arises (e.g., an urge to yell), but may be regulated for a more controlled response (e.g., leaving the room) if enough situational or cognitive resources are available. In addition, each potentially aggressive instance serves as a learning trial which can influence individual's aggressiveness by providing positive or negative feedback about aggression for an individual (Warburton & Anderson, 2015). This feedback is incorporated into aggression-related knowledge structures which further inhibit or disinhibit future aggressive behavior by altering beliefs and attitudes about aggression, increasing perceptions and expectations of aggression, and altering emotional sensitivity to provocation and aggression (Anderson & Dill, 2000; Anderson & Warburton, 2015; Bushman, 2002).

Importantly, individuals' aggressive propensities are influenced by an underlying propensity to become angry (Bettencourt, et al., 2006; Buss & Perry, 1992). This propensity to be become angry can be further examined in terms of frequency, intensity, and duration of anger (Spielberger, 1996). These anger dispositions influence general aggressiveness as individuals who have angry dispositions are more likely to perceive provocation and insufficiently regulate provocation rumination, angry affect, and expression of anger (Wilkinson & Robinson, 2010). Given that sleep problems are often reported along with anger, identifying the role of sleep in anger propensities may provide an important route for examining why sleep may be linked to aggressiveness. However, before examining this potential role, it is first necessary to examine the functions of sleep and the consequences of its disruption.

What is sleep? Sleep is a reversible state of perceptual disengagement from the environment that progresses through alternating cycles of Non-Rapid-Eye-Movement (NREM) sleep and Rapid-Eye-Movement (REM) sleep. The internal pressure to sleep follows a circadian (i.e., daily) rhythm driven by the suprachiasmatic nuclei of the hypothalamus, a brain region largely responsible for the body's circadian rhythms such as body temperature, psychomotor vigilance, and positive affect (Van Dongen & Dinges, 2000). While science is still trying to unravel the mysteries of how and why we sleep, research has shown that it is a crucial regenerative biological mechanism that removes neurochemical waste from the brain, modulates energy conservation, and facilitates physiological rest and restoration as well as encoding and integration of recently learned information and emotions (Xie et al., 2013; Walker, 2010). At a very basic level, sleep works to maintain optimum physiological and emotional functioning.

Research that has sought to illuminate the psychological functions of sleep has often focused on physiological and behavioral deficits under the conditions of sleep disruption. Sleep disruption is often operationalized as *total* sleep deprivation where participants are deprived of sleep for 24 or more hours. However, because total sleep deprivation is relatively uncommon in most populations, it is imperative to study more common forms of sleep disruption such as *partial* sleep deprivation or chronic sleep restriction (losing some sleep on one or more nights, respectively). In these cases, individuals obtain some sleep in a 24 hour period, but their sleep is disturbed in terms of amount (e.g. only four hours of sleep) or quality (e.g. repeated awakenings during the night; fitful sleep). While sleep amount typically reflects the number of hours spent sleeping, sleep quality is composed of multiple components, such as *sleep efficiency* (total time in bed/ total time asleep), *sleep onset latency* (time it takes to fall asleep), and *sleep fragmentation* (number of awakenings during sleep, Buysee, Reynolds, Monk, Berman, & Kupfer, 1989; Cole, Kripke, Gruen, Mullaney, & Gillan, 1992; Kushida, et al., 2001). Sleep efficiency is a composite index of sleep quality as it incorporates both sleep onset latency and sleep fragmentation in its measurement.

Unfortunately, chronic sleep restriction seems to be prevalent in the U.S. population as 30% of American adults report getting less than 6 hours of sleep a night; much less than the National Sleep Foundation's recommendation of 7-9 hours of sleep a night. Furthermore, the number of individuals with insufficient sleep has been increasing over the past two decades (Luckhaupt, Tak, & Calvert, 2010). This trend is particularly concerning given that disrupted sleep over time creates a "sleep debt" which increasingly impairs psychological functioning (i.e. cognition, emotion, performance) until it is paid-off by sleeping (Van Dongen & Dinges, 2003).

Does sleep disruption predict anger and aggressiveness? Given that sleep disruption impairs psychological functioning, it is reasonable to expect that poor sleep may be associated with undesirable consequences such as feeling angry and behaving aggressively. Existing evidence supports a robust correlational link between sleep disruption and higher anger as well as aggressiveness. For example, studies evaluating sleep problems in children find that sleep-disordered breathing (e.g. habitual snoring, sleep apnea) and daytime sleepiness relate to concurrently assessed parent-rated and teacher-rated aggressive behavior, angry temperament and hostility, and conduct problems (Chervin, Dillon, Archbold, & Ruzicka, 2003; Gregory, Eley, O'Connor, & Plomin, 2004; Reid, Hong, & Wade, 2009). Similar research found that sleep-disordered breathing by itself did *not* predict aggressive behavior, angry temperament, and bullying behavior, but that *daytime sleepiness* did (even after controlling for age, gender, socioeconomic status, and snoring; O'Brien, et al., 2011). This suggests that actual daytime sleepiness, which is an effect of poor sleep more proximal to the enactment of behavior, and not specific physiological sleep problems, may be most relevant to aggression. In line with this interpretation, parents' reports of less sleep and more tiredness in their children (relative to peers) was predictive of aggressive behavior and conduct problems in the same children several years later (Gregory, Eley, O'Connor, & Plomin, 2004; Gregory, Van der Ende, Willis, & Verhulst, 2008; Tochigi, et al., 2012).

The link between poor sleep and angry and aggressive dispositions is not unique to children, however, as adults who report worse sleep quality often report more self-rated hostility, anger, and tendencies to engage in aggressive outbursts (Pilcher, Ginter, & Sadowsky, 1997; Schubert, 1977; Shin et al., 2005). In addition, in cases of intimate partner violence, self-reported sleep problems predicted future self-reports of aggression toward partners, and in one study abused women reported more partner irritability after a night of poor sleep as well as more intense abuse after a night in which their male partner had less sleep (Hoshino, Pasqualini, D'Oliveira, da Silva, Modesto, & Silveira, 2009; Rauer & El-Sheikh, 2012). Finally, the link between sleep and aggressiveness also appears in individuals who have a history of behaving aggressively (e.g. inmates, psychiatric patients). Within both violent offenders and psychiatric populations, worse sleep quality correlates with both aggressiveness and angriness (Ireland & Culpin, 2006: Kamphuis, Dijk, Spreen, & Lancel, 2014). Based on this evidence in children, adults, and clinical populations, it appears that tendencies to become angry as well as engage in aggression are often comorbid with sleep difficulties.

Although self-reported evidence across children, adults, and clinical populations corroborates to suggest that those who have sleep difficulties are more likely to be angry and aggression-prone, much of the link is based on self-reports and targeted empirical work exploring the dynamics between anger and aggressiveness and sleep is lacking. Nevertheless, current theoretical understandings of sleep and angry and aggressive propensities suggests sleep and these dispositions are tightly intertwined.

Why Should Sleep be Causally Associated with Anger and Aggressiveness?

Sleep disruption as fuel for anger and aggressiveness. Sleep disruption can lead to psychological impairments in emotional functioning, attentional vigilance, and executive functioning; these impairments may then create a potential to react angrily and aggressively by increasing angry affect, limiting attention and information that can be used to understand one's situation, and impairing regulation of emotions and behavior. These impairments over time may build tendencies to feel anger and react aggressively.

Disrupted emotional functioning. Studies assessing sleep disruption's effect on emotion generally find that less sleep tends to increase negative emotions while simultaneously blunting positive emotions (Pilcher & Huffcutt, 1996; Zohar, Tzischinsky, Epstein, & Lavie, 2005). Critically, participants report increases in tension and anger after having inadequate sleep, both emotions that drive aggressive reactions (Dinges, et al., 1997; Ford & Wentz, 1984; Anderson & Carnegey, 2004). Self-reports of anger and tension converge with fMRI scans showing increased reactivity in brain's limbic system (i.e. amygdala) during presentation of negative or threatening stimuli, as well as a lack of decreased reactivity when re-presented to the same negative stimuli following sleep (Yoo, et al., 2007; Van der helm, et al., 2011; Sterpenich, et al., 2007).

In addition to increased anger and general negative emotional reactivity, sleep deprived individuals also have an impaired ability to down-regulate these emotions (Gruber & Cassoff, 2014). Impaired emotion regulation may occur because the ability to regulate emotions is heavily associated with activity in the medial prefrontal cortex and its functional connectivity to the amygdala (Davidson, 2002). Both activity in the medial prefrontal cortex as well as the medial prefrontal cortex's functional connection to the amygdala are weakened following sleep deprivation (Yoo, et al., 2007; Killgore, 2013). Thus, sleep disruption may impair emotional functioning by amplifying emotional reactions to negative stimuli while simultaneously degrading the ability to regulate these emotions. These intensified emotions and impaired ability to regulate them may promote anger and aggressiveness by increasing angry reactions and subsequent anger expression (Barlett & Anderson, 2014; Krizan & Herlache, 2015).

Decreased attention and vigilance. Besides disturbed emotional functioning, an individual's ability to consciously direct and sustain their attention on a particular stimulus (i.e. *effortful* attention) is also impaired by sleep restriction (Goel, Rao, Durmer, & Dinges, 2009). This reduced attention may prevent an individual from recruiting relevant social information in making behavioral choices, such as whether to react aggressively to a provocation or whether to perceive a provocation as such. As sleep disruption mounts, brief lapses in attention and effort may result as homeostatic pressure to sleep build (Lim & Dinges, 2008; Priest et al., 2001). Lapses in attention and fluctuation in the ability to control it support the wake-state instability hypothesis which points to attentional deficits as a source of both the overall decrements and the increasing variability in cognitive performance the longer an individual goes without sleep. Moreover, insufficient sleep saps motivation, which may be particularly problematic for forms of attention that require effort to consciously control and direct (Baranski, Cian, Esquievie, Pigeau, & Raphel, 1998; Kessler et al., 2011). In sum, sleep disruption may lead to an "attentional myopia" in which ability and motivation to control effortful attention is impaired.

This attentional myopia is akin to alcohol myopia wherein attention becomes limited to the most salient cues and prevents processing of all available information (Ward & Mann, 2000; Steele & Josephs, 1990). In other words, an individual will "see the tree, but miss the forest altogether" (Steele & Josephs, 1990). This focus on the most salient cues may confine a sleep restricted individual's attention on a potential provocation instead of the larger social and environmental context which may clarify whether the provocation was meant to be provoking and whether aggression is appropriate (Krizan & Herlache, 2015). This confined attention to provocation may facilitate further elaboration and rumination on the provocation, ultimately amplifying feelings of anger (Kavanaugh, Adrade, & May, 2005; Wilkowski & Robinson, 2010).

Impaired executive functioning. Finally, these decreases in attentional processing dovetail with impairments in executive functioning (i.e., inhibition, working memory, and set shifting) which rely on the limited attentional resources (Kaplan & Berman, 2010). Importantly, sleep disruption degrades executive functioning even with consumption of psychostimulants like caffeine which protect arousal and vigilance (Killgore, et al., 2009). Impaired executive functioning in those who are sleep deprived can lead to poor decision making and impulsive, inappropriate, or antisocial behaviors (Harrison & Horne, 2000, Horne, 1993; Christian & Ellis, 2011). For instance, sleep deprived students engage in more theft than non-sleep deprived students, and nurses who were partially restricted from sleep reported engaging in more workplace deviance (e.g., "saying something hurtful to someone at work"; Christian & Ellis, 2011).

Overall, compromised executive functioning may act to increase aggression by stunting regulation of angry emotions and inhibition of aggressive behavior (Krizan & Herlache, 2015). First, impaired executive functioning and attention may prevent relevant information, such as social context, from being integrated into working memory and used in decision making, leading to poor behavioral decisions (Bechara & Martin, 2004; Barlett & Anderson, 2011). Second, decreased executive functioning may lead to aggressiveness through disinhibition and impaired regulation of angry affect (Hofmann, Schmeichel, & Baddeley, 2012). Because inhibitory control is used to prevent impulsive and immediately gratifying behavior, decreased inhibition may result in a failure to stop an initial angry and aggressive reaction to a provoking event, such as a sleep deprived parent who stubs his or her toe on a chair may fail to inhibit angrily cursing out the chair in front of his or her child (Banich, 2009). This line of reasoning informs recent theorizing that impaired executive functioning via decreased prefrontal cortex functioning may be a key mediator of the sleep-aggression relation due to the loss of control over behavioral impulses and angry affect that ensues from sleep disruption (Kamphuis, Meerlo, Koohaas, & Lancel, 2012).

In sum, the increased angry affect and reactivity, attentional myopia, and impaired executive functioning due to sleep disruption may lead to a reduced ability to control angry affect and comprehend the full social and environmental context within which a perceived provocation occurs. Ambiguous stimuli may also be more readily perceived as provocations due to higher levels of state anger, coupled with worse emotional control and higher sensitivity to negative and threatening stimuli following insufficient sleep. It seems that under conditions of sleep disruption an individual may be more likely to perceive provocation, become angry, and fail to control this anger, which may ultimately lead to aggression. Over time, this may increase angry and aggressive dispositions.

Anger and aggressiveness as fuel for sleep disruption. While poor sleep may predispose an individual to feel anger and be aggressive, anger and aggressiveness may also chronically disrupt sleep. As outlined below, a feelings of anger and acts of aggression may impair sleep through both cognitive (i.e. rumination, worry) and physiological arousal (i.e. stress responses).

Cognitive arousal. Upon being provoked or engaging in conflict, individuals often angrily ruminate about the event, which can serve to maintain angry affect, aggressive cognitions, and physiological arousal (Pedersen, Denson, Goss, Vasquez, Kelley, & Miller, 2011; Wilkowski & Robinson, 2010). This continued state of ruminative aggressive thinking can then interfere with sleep (Thomsen, Mehlsen, Christensen, & Zachariae 2003). In this vein, cognitive arousal has been associated with poor sleep quality and insomnia (Harvey, Tang, & Browning, 2005; Pillai, Steenburg, Ciesla, Roth, & Drake, 2014; Drake, Richardson, Roehrs, Scofield, & Roth, 2004).

In addition, reacting aggressively and inflicting damage can generate stronger worry about its consequences (e.g., legal sanctions, retaliation; Caprara, Manzi, & Perugini, 1992). This worry may further disrupt sleep by fueling post-aggression rumination and inducing physiological stress responses (Key, Campbell, Bacon, & Gerin, 2008; Akerstedt, Kecklund, & Axelsson, 2007).

Physiological arousal. Being aggressive can be physiologically arousing due mental (e.g., stress), bodily (e.g., pain), and emotional (e.g. anger) effects of aggressive encounters. In addition, aggressiveness can be mentally arousing by inducing worry and rumination. Worry and rumination may often be accompanied by the activation of the Hypothalamic-Pituitary-Adrenal system, subsequently resulting in increased heart rate, breathing, and blood pressure (Demaree & Harrison, 1997; Lundberg, 2005). These amplified sympathetic responses directly opposes the "slowing down" that occurs while sleeping and may delay or interfere with sleep (Wolk, Gami, Garcia-Touchard, & Somers, 2005). Thus, anger and aggressiveness may also correspond with poor sleep because anger and aggressiveness can induce cognitive and physiological arousal which prevents sleep through mental restlessness and increased activation of the sympathetic nervous system.

Contributing Factors to Sleep and Aggressiveness: Stress and Constraint

Although anger and aggressiveness and sleep may directly influence each other, it is possible other extraneous factors account for the relationship between them. Two key factors that have been implicated in this link are stress and constraint.

Stress. Stress may be an important contributing variable as stress has been linked to both aggression and insufficient sleep. Animal models show that chronic activation of the stress systems degrade the neurons in the amygdala and prefrontal cortex, brain regions which are critical for emotion regulation and executive functioning (McEwen, 2006). These regions are imperative to regulating negative emotions such as anger and behaviors such as aggression. Thus, one way in which chronic stress may lead to aggression is by degrading functioning in brain areas involved in regulating aggressive urges. Stressful events themselves may also lead to frustration and aggression as means for overcoming obstacles, as implicated in the frustration-aggression hypothesis (Dollard, Doob, Miller, Mowrer, & Sears, 1939). In this vein, chronic early life stressors are risk factors for developing aggressive tendencies (Veenma, 2009).

Similarly, stress may lead to insufficient sleep. A longitudinal analysis across 42 days found that stress ratings throughout the day as well as worries at bedtime significantly predicted worse sleep quality ratings for that night (Akerstadt, et al., 2012). Moreover, cross-sectional studies have linked stress in the form of high work demands and adverse work conditions to insomnia and short sleep durations (Akerstadt, et al., 2002; Utsigi, et al., 2005; Linton, 2004). Thus, it seems that individual differences in stress reactivity or chronic exposure to stressors can lead to variation in anger and aggressiveness and sleep and may account for the observed relationship between anger and aggressiveness and sleep.

Impulsivity vs. Constraint. Impulsivity is the tendency to act on immediate urges without consideration of negative consequences or in spite of them (DeYoung, 2010). Impulsivity involves multiple aspects of personality, but is most heavily linked to the conscientiousness domain in the form of lower self-control, persistence, and organization (Whiteside & Lynam, 2001). As a result, impulsivity can be conceptualized as the lack of *constraint* (or self-control, Depue & Collins, 1999; Zelinski & Larsen, 1999). Intuitively, this makes sense as behaving impulsively necessitates the existence of an impulse that was not sufficiently constrained, otherwise, with appropriate control, there would be no impulsive behavior (De Young, 2010). Such sufficient constraint may be needed when provoked, as perceived provocation may lead to an impulse to react aggressively. In this vein, self-reports of lower constraint (or higher impulsivity) are often related to higher reports of anger and aggression and those who are less constrained are more likely to react aggressively to provocation (Bettencourt, et al, 2006; Latzman, Vaidya, Clark, & Watson, 2011; Lynam & Miller, 2004; Wingrove & Bond, 1998). Of interest to the current study are findings that low constraint and aggressive behavior often both present in individuals with sleep problems (Kamphuis, et al., 2014). It is likely that lower constraint and higher anger and aggressiveness partially stem from the disruptive effects of insufficient sleep on executive functioning (Anderson & Platten, 2011; Harrison & Horne, 2000). To obtain a more clear understanding of the relation between angry and aggressive dispositions and sleep, it is thus critical to examine the potential contributing role of constraint.

However, while tendencies to feel angry and react aggressively often go hand in hand with sleep disruption, stress, and constraint, sleep is often measured through self-reported introspection of sleep which can be subject to biases and limitations. These biases as well as the limitations of relying on introspection may obscure the true nature of how anger, aggressiveness, and sleep relate, as well as if stress and constraint contribute to their relation.

Enhancing Validity of Sleep Measurement

Self-report biases in sleep. Self-reports of sleep are often biased by individuals' neuroticism or circadian phase. Individuals high in neuroticism are more likely to report negative symptoms, such as sleep loss, as well as to *over*-report such symptoms, than those low in neuroticism (Cohen, Doyle, Skoner, Fireman, Gwaltney, & Newson, 1995; Fernandez-Mendoza, et al., 2011). This misperception of sleep likely contributes to highly neurotic individuals reporting more feelings of tiredness, difficulty waking up in the morning, and worse mood in the morning than those low in neuroticism (Gau, 2000). It is unclear however, whether the misperceived sleep duration leads neurotic individuals to report increased feelings of tiredness and worse morning mood, or if more tiredness and worse morning mood leads them to perceive sleeping less than they actually did.

In addition to neuroticism, timing of self-reports can also bias the subjective sleep quality reports. The closer in time a self-report of sleep quality is to the peak of an individual's circadian phase (i.e. when the suprachiasmatic nucleus' signal for arousal is the most intense), the better quality of sleep people tend to report (Akerstedt, Humes, Minors, & Waterhouse, 1994). For instance, if the peak of an individual's circadian phase occurs at 1 pm, they are likely to report better quality of last night's sleep at that time than if he or she reports at 5 pm. Failure to assess and control for these individual differences may obscure the relationship between anger and aggressiveness and sleep by contaminating assessment of sleep with exogenous variables.

The limitations of using introspection to assess sleep. Even more problematically, self-reports of sleep rely on an individuals' knowledge of their sleep. For example, the Pittsburgh Sleep Quality Index is often used to measure sleep quality and sleep length (e.g., Rauer & El-Sheikh, 2012; Kamphuis, Dijk, Spreen, & Lancel, 2013; Pilcher, Ginter, & Sadowsky, 1996). When compared with objective polysomnographic and actigraphic sleep data, however, this measure shows limited convergent validity (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989; Grander, Kripke, Yoon, & Younstedt, 2006). The poor convergent validity likely reflects the fact that sleep disturbances and sleep length are each measured with only one or two questions regarding sleep over the past month, while actigraphy and polysomnography use moment-to-moment measurements of sleep-wake variables over a sample of days to quantify sleep quality and quantity. In essence, self-reports rely on a participant's conscious memory of (often non-conscious) sleep states that vary considerably over a period of time to create a best guess of their recent sleep patterns, while objective measurements use real-time physiological measurements to best estimate sleep characteristics in a specific window of time.

Moreover, because self-reports of sleep lack the sophisticated technology used in objective assessment of sleep, they are often also limited in their power to assess fine grained characteristics of sleep quality and quantity. For instance, a self-report item such as "How many hours of actual sleep do you get at night?" does not take into account how long an individual was in bed and trying unsuccessfully to sleep nor how many times an individual's sleep was fragmented by periods of wakefulness. Such a question would equate an individual who slept continually for six hours to an individual who slept for six total hours, but was in bed for eight hours and woke up for four thirty minute periods. These two individuals are not interchangeable because the former individual had better sleep than the latter individual as sleep quality seems to best reflect sleep continuity (Akerstadt, Hume, Minors, and Waterhouse, 1994). Thus, finer grained measures of sleep may reveal specific aspects of sleep that are especially important for aggressiveness.

Illuminating the relationship between sleep and aggressiveness. Fine grain analyses of sleep can be economically achieved through the use of actigraphy. At minimum, actigraphs use accelerometry to detect and record second-to-second body movement, whereas more advanced actigraphs also use skin conductance, body temperature, and body position. Utilizing these measurements, an actigraph is able to estimate sleep-wake state based on the premise that particular values of these measurements are indicative of sleep while other values indicate wakefulness (Ancoli-Israel, et al., 2003).

Using recordings of sleep-wake state throughout a day allows for the accurate generation of multiple indices of sleep quality, such as sleep efficiency, sleep onset latency, and sleep fragmentation, in addition to sleep amount. These more nuanced measurements capture critical aspects of sleep that self-reports miss, allowing for a more decisive analysis of the sleep-aggressiveness relationship. For instance, ruminative processes associated with perceiving provocations or acting aggressively may lead to longer sleep onset latency, but may not disturb sleep once the conscious awareness of the rumination dissipates and sleep is initiated. Additionally, sleep fragmentation may exhibit a more robust association with aggressiveness than does sleep onset latency. This is possible because Rapid Eye Movement (REM) sleep is associated with de-potentiating emotional experiences and decreasing emotionality, while awakenings during the night disrupt the sleep cycle needed to invoke proper REM sleep. (Van der Helm, et al., 2011). Thus, particular sleep quality indices that imply specific disruptions in REM sleep may be especially predicative of angry impulses which are often elicited by reactions to provocations. Sleep fragmentation may also be more important than other sleep quality indices because it is an indicator of consolidated sleep, and consolidated sleep seems to best represent subjective sleep quality. However, it is unknown whether sleep fragmentation itself is more important to hostile aggressiveness than subjectively perceived sleep quality (Akerstadt, Hume, Minors, and Waterhouse, 1994).

Summary

Overall, anger, aggressiveness, and sleep covary, but the understanding of this relationship is far from clear. First, due to the intrusiveness and financial costs of measuring sleep objectively (e.g., using polysomnography), past research has mainly used subjective reports of sleep which are prone to reporting biases (e.g., complaining) and are limited by individuals' introspective knowledge of sleep. Second, due to a lack of accuracy in sleep assessment, self-reports of sleep are not able to precisely capture the different ways sleep may be disturbed (e.g. amount of sleep, fragmentation of sleep, restfulness of sleep) and it is unclear if specific characteristics of sleep are particularly important for anger-fueled aggression. Finally, it is unclear whether this relationship is due merely to the presence of other factors such as stress and low levels of constraint (which often contribute to both sleep problems and inter-personal conflicts). Addressing these issues will provide more pointed evidence of whether aggressiveness and sleep are actually associated as well as the nature of the association.

Purpose

To address these issues, data from the Biomarker Project sample from the MIDUS II (Midlife in the US) study were used to examine the relation between sleep and angry tendencies (Ryff, Seeman, & Weinstein, 2013). MIDUS is a nationwide survey of adults which aimed to evaluate the long term consequences of behavioral and psychological factors on health. A subsample of the Biomarker project participants completed a weeklong daily diary of sleep quality and quantity during a week in which they simultaneously wore an actigraph to objectively measure sleep. Additionally, the Biomarker Project sample includes a wide range of psychological measurements which include behavioral tendencies regarding feeling anger, anger expression, trait constraint, and perceived stress (Buysee, Reynolds, Monk, Berman, & Kupfer, 1989; Cohen, Kamarck, & Mermelstein, 1983; Gross & John, 2003; Spielberger, 1996). Importantly, this dataset does not lend itself to direct assessment of the relation between aggressiveness and sleep, but does lend itself to the assessment of multiple aspects of anger propensities and sleep, such as the dispositions to quickly become angry.

Because participants provided both subjective (daily diary) and objective (actigraphy) measurements of sleep, these data allow for testing the hypotheses that both *objective* and *subjective* sleep measurements will link to anger propensities. Additionally, the multiple indices of anger propensities allow for exploration of what anger propensities link to objective sleep. Given the central role of executive control in models of aggression and anger expression (e.g. General Aggression Model, Integrative Cognitive Model of Trait Anger) and the likely bi-direction relation between sleep and executive control, disposition towards controlling anger is hypothesized to relate to both objectively- and subjectively-recorded sleep. It is unknown, however, if other anger propensities will also relate to sleep. These analyses will serve to establish whether anger tendencies are linked to actual sleep patterns and will illuminate what aspects of anger and sleep are the most important to this relationship. Finally, stress and constraint will be explored as contributing variables to any relations between anger propensities and sleep.

CHAPTER 2: METHODS

Participants

From 1995-1996, MIDUS II recruited 7,108 Midwestern adults ranging from 25 to 75 to examine behavioral and psychosocial factors in age related differences in physical and mental health. Of these initial 7,108 participants, the Biomarker project sample included 1,255 participants who completed additional physiological measurements at a clinic sometime from 2004 to 2006. Additional actigraphic assessments of sleep occurred only at the University of Wisconsin site where 440 participants received an actigraph and wore it for one week after completing questionnaires and other physiological measurements. As key analyses involve evaluating how participant's angriness relates to objective (actigraphic) and subjective (daily diary) sleep measures, only data from participants who completed both actigraphic and daily diary measures of sleep used in analysis of data (*N*= 436). The mean age of participants was 56.91 years (*SD*=11.49 years; Range= 35-85 years) and 60.3 percent of the participants identified as female.

Key Measures

Anger propensities. Individual's tendencies toward becoming angry and expressing anger will be measured through the State Trait Anger Expression Inventory (Spielberger, 1996). The State Trait Anger Expression Inventory items included in the Biomarker project are used to create two distinct scales: the *Trait Anger Inventory* and the *Anger Expression Inventory* (State Anger Inventory items were not included in the Biomarker project; Forgays, Forgays, & Spielberger, 1997). Example items are abbreviated to protect copyright (Spielberger, 1996).

Trait Anger Inventory. The Trait Anger Inventory consists of fifteen items asking participants how they generally feel from 1 ("Almost never") to 4 ("Almost always"). Scores on this inventory are used to generate an overall trait anger score, as well as to assess two subdimensions of trait anger, namely the tendency to become angered quickly and easily (Angry temperament) and the tendency to react angrily to inter-personal provocations and frustrations (Angry reaction). Thus, the Trait Anger Inventory allows for assessment of, in general, how *likely* are participants to feel emotions of anger, become quickly angered, and to react angrily to perceived provocation.

1. *Trait anger total* (Fifteen items such as, "Feel angry"; α= .83).
2. *Angry temperament* (Four items such as, "Quick tempered."; α= .83).
3. *Angry reaction* (Four items such as, "Furious when criticized by others."; α= .74).

Anger Expression Inventory. The Anger Expression Inventory contains twenty items which are used to measure three distinct ways in which people may handle their feelings of anger: the degree to which individuals hold in and internalize angry feelings (Anger-In), the degree to which individuals express and externalize feelings of anger (Anger-Out), and the degree to which individuals attempt to control and dissolve anger (Anger-Control). Notably, this scale asks participants, in general, how they behave "*when angry or furious*" and thus assesses what participants generally *do* with their anger as opposed to *how likely* they are to feel angry in general. All items are assessed on a scale from 1 ("Almost never") to 4 ("Almost always").

1. *Anger-In* (Eight items such as, "Boil inside, don't show it."; α= .83).
2. *Anger-Out* (Eight items such as, "Say nasty things."; α= .77).
3. *Anger-Control* (Four items such as, "Keep my cool."; α= .83).

Sleep indices.

*Actigraphic assessment of sleep***.** Participants wore the Mini Mitter Actiwatch-64 wrist monitor continuously for seven days starting on the Tuesday after receiving the Actiwatch and ending on the next Tuesday morning. The Actiwatch was worn on the non-dominant wrist and used accelerometry to evaluate sleep-wake state at every 30 seconds epoch. Data from the actigraph was used to generate weekly averages of:

1. *Sleep amount* (total time asleep in minutes).
2. *Sleep quality*
    a. *Sleep onset latency* (minutes categorized as "resting" before falling asleep).
    b. *Sleep efficiency* (total time spent sleeping divided by total time spent in bed).
    c. *Sleep fragmentation* (total number of times awakened while trying to sleep).

Daily sleep diary. The daily sleep diary was completed during the same seven day interval as the Actiwatch assessment of sleep. Before bed, participants reported their daytime fatigue and each morning participants reported the time they went to bed, the time they woke up for the day, their subjective sleep quality, the time it took to fall asleep, and the number of awakenings during the night. Daily diary data was used to generate weekly averages of:

1. *Sleep amount* (the difference in minutes between reported time in which participants went to bed and woke up the next day minus sleep onset latency and minus sleep fragmentation).
2. *Sleep quality*
    a. *Sleep onset latency* ("How long did it take you to get to sleep last night?" in minutes).
    b. *Sleep efficiency* (total sleep amount divided by the difference in minutes between time reported in which participants went to bed and got out of bed the next day).
    c. *Sleep fragmentation* (number of reported awakenings during sleep).

d. *Subjective sleep quality* (the average of four items assessing the prior night's quality and depth of sleep and feelings of being alert and well-rested in the morning; higher scores represent better quality; α= .93).

Contributing Factors

Constraint. Constraint (or low impulsivity) was assessed through three items (e.g. "I like to stop and think things over before I do them"; α=.65) from the control facet of the constraint scale from the Multidimensional Personality Questionnaire (Krueger, 2000). Participants indicated the extent to which a statement was true of themselves from 1 ("False") to 4 ("Very true"). The control facet reflects the tendencies to be cautious and engage in premeditated thought and is the facet of constraint which most closely related to aggressive reactions (Latzman, et al., 2011). The constraint scale was administered during the MIDUS II original assessments *and not* during the Biomarker project (on average, two years prior to the Biomarker project; see Figure 1 for general timeline of data collection). Although the assessment of constraint was temporally displaced from the Biomarker project, personality traits usually show sufficient relative stability overtime with test-retest coefficients ranging from .6-.8 (McCrae & Costa, 1994; Small, Hertzog, Hultsch, & Dixon, 2003). Specific assessments of the stability of constraint over time reflect these findings (Messer & Brodzinsky, 1981; Olson, Schilling, & Bates, 1999). Nevertheless, the temporal separation suggests conservative tests of the role of constraint.

Stress. Stress was evaluated using the Perceived Stress Scale (Cohen & Williamson, 1988). The Perceived Stress Scale contains ten items assessing how often participants experienced a variety of stressful situations and feelings in the past month (e.g. "been upset because of something that happened unexpectedly") from 0 ("Never") to 5 ("Very often" α=.87).

Control Variables

Participants reported age and gender at time of Biomarker project assessment, which will be used as control variables in all analyses. Circadian phase will be assessed by calculating the mid-point of sleep using morning rise times and night bed times on the weekends from the daily diary. Using mid-point of sleep on weekends has been validated as a measurement of circadian phase as it represents an anchor point for melatonin onset associated with modulating the circadian rhythm of sleep (Roenneberg, Wirz-Justice, & Merrow, 2003; Terman, Terman, Lo, & Cooper, 2001). Circadian phase will be used as a control variable for daily diary sleep outcomes to control for time-of-day effects in self-report of sleep.

Missing data

Missing data occurred in less than 2% of the Biomarker measures used for analyses. Given the exceptionally low rates of missing data, these cases were excluded pairwise in all analyses. Participant's level of constraint was measured during original MIDUS II dataset and exhibited high levels of missing data (29%). Both due to the extent of missingness (125 missing cases) and temporal displacement of the constraint data, data will be excluded pairwise as imputation of 125 cases of data that would have been observed two years prior to the Biomarker dataset would be statistically unsound. Logistic regression was used to examine whether missingness on constraint related to anger propensities, sleep indices, and stress. In general, missingness on constraint was predicted by higher Angry reaction scores, worse actigraphic sleep quality indices, and higher stress. Given the high level of missingness on constraint and the fact that missingness was related to key variables of interest, caution is advised when interpreting findings regarding constraint.

CHAPTER 3: RESULTS

Relations Among Anger Propensities and Sleep Measures.

Before investigating the relationships between anger propensities and sleep measures, convergence among measures of anger propensities and among sleep measures were first examined through bivariate correlations. Table 1 includes means and standard deviations for all key measures.

Correlations among actigraphic and daily diary measures of sleep. Convergence between actigraphic and daily diary measures of sleep replicated past findings in which estimates of duration of total sleep time showed a high level of convergence (r = 0.61, p < 0.001), with estimates of sleep onset latency (r = 0.29, p<0.001) and sleep fragmentation (r = 0.19, p<0.001) showing lower levels of convergence. Surprisingly, actigraphic and daily diary sleep efficiency showed even less of a relation (r= 0.13, p=0.007) than suggested by past research (Keklund & Akerstadt, 1996; O'Donoghue, Fox, Heneghan, & Hurley, 2009). It seems that individuals had a somewhat accurate sense of their actual total sleep time and how long it took them to fall asleep. However, inaccuracies, when combined with little insight into fragmentation, were substantive enough to result in the composite index of sleep efficiency being largely unrelated to people's subjective sense of sleep efficiency.

Correlations among anger propensities. In general, dimensions of Anger Expression (i.e. Anger-In, Anger-Out, Anger-Control) were largely distinct from each other (all |r's| < .25; See table 3). Unsurprisingly, Anger-In and Anger-Out correlated moderately with the Trait Anger Inventory and its components (Angry temperament and Angry reaction) as individuals who were more likely to become angry were also more likely to have internalized or externalized that anger (all r's < .31). However, while related, the Anger Expression and Trait Anger inventories still seem to capture some unique aspects of feeling angry and acting out on that anger (all |*r*'s| < .59). Angry temperament and Angry reaction were weakly related to one another ($r < .28$). A final notable point is that Anger-Control exhibited a relatively weak relation to all other measures (all |*r*'s| < .25).

Relations Between Anger Propensities and Actigraphic Sleep Indices.

To first examine if anger propensities related to objective (actigraphic) measures of sleep amount and sleep quality, bivariate correlations were calculated between all measures of anger and sleep amount and sleep quality (See table 4).

No measures of anger significantly related to sleep amount (all *p*'s > .1), although they trended in expected directions of more anger relating to less sleep. While anger did not significantly relate to sleep amount (over the week of assessment), it did relate to indices of sleep quality. Specifically, the tendencies to try to become quickly angered (Angry temperament) and control and dissolve feelings of anger (Anger-Control) significantly and consistently related to indices of sleep quality. Higher Angry temperament were associated with higher sleep onset latency ($r = .10$, $p = 0.04$) and lower sleep efficiency ($r = -.13$, $p = 0.009$). Additionally, higher Anger-Control was associated with shorter sleep onset latency ($r = -.11$, $p = .03$), higher sleep efficiency ($r = .14$, $p = 0.003$), and less sleep fragmentation ($r = -.12$, $p = .01$).

Because Angry temperament and Anger-Control were correlated, partial correlations between Angry temperament and sleep quality while controlling for Anger-Control (and between Anger-Control and sleep quality while controlling for Angry temperament) were used to examine the extent to which these measures of anger propensities were independently related to sleep quality. When controlling for Anger-Control, higher Angry temperament was no longer significantly associated with higher sleep onset latency ($r = .07$, $p = .12$), but was still significantly associated with worse sleep efficiency (*r* = -.09, *p* = .05). When controlling for Angry temperament, higher Anger-Control became only marginally correlated with lower sleep onset latency (*r* = -.09, *p* = .08), but was still significantly correlated with better sleep efficiency (*r* = .12, *p* = .02) and less sleep fragmentation (*r* = -.12, *p* = .02). Overall, while the magnitudes of the correlations decreased, Angry temperament and Anger-Control had somewhat independent relations to indices of sleep quality and thus represent distinct dimensions of aggressiveness with relevance to objective sleep quality.

Because these two measures of anger showed a relatively unique relation to these indices of sleep quality, hierarchical regressions were next used to examine whether these relations were maintained after controlling for gender, age, stress, and constraint. Additionally, although the data did not exhibit a significant degree of temporal precedence to allow for formal mediational analyses on the role of stress and constraint, controlling for the stress and constraint variables still allowed for examination of whether these variables contributed to the link between anger and sleep in some way. For example, if controlling for stress substantially reduces the association between anger and sleep, then stress may either be a potential confounding variable *or* a mediating variable.

Regression of Angry temperament and Anger-Control on Actigraphic Sleep Quality. To examine whether Angry temperament and Anger-Control were still associated with indices of sleep quality after controlling for gender, age, stress, and constraint, hierarchical regressions were used in which sleep quality indices were predicted from gender and age in step one, stress and constraint in step two, and Angry temperament or Anger-Control in step three (See table 5).

Regressing Angry temperament on sleep quality indices. After controlling for gender, age, stress, and constraint, higher Angry temperament was no longer associated with higher sleep onset latency (*B* = 2.90; 95% CI = -3.51, 9.30) nor lower sleep efficiency (*B* = -.86; 95% CI = -3.30, 1.58). Once again, neither stress nor constraint were significantly associated with the indices of sleep quality after controlling for gender and age (all 95% confidence intervals included 0).

Regressing Anger-Control on correlated sleep quality indices. After controlling for gender, age, stress, and constraint, higher Anger-Control was still associated with lower actigraphic sleep onset latency (*B* = -5.02; 95% CI = -9.59, -.45) and higher sleep efficiency (*B* =1.93; 95% CI = .20, 3.67). While the 95% confidence interval included 0, higher Anger-Control also tended to predict lower sleep fragmentation (*B* = -1.70; 95% CI = -3.91, .51; *p*= .10). Interestingly, after controlling for gender and age, neither stress nor constraint significantly predicted sleep onset latency, sleep efficiency, or sleep fragmentation (all 95% confidence intervals included 0). One caveat to this was that constraint marginally predicted actigraphic sleep fragmentation (*B* = -2.86; 95% CI = -.31, 6.03; *p* = .08). Thus, in general, Anger-Control maintained a significant association with actigraphic indices of sleep quality after controlling for gender, age, stress, and constraint. As a result, neither stress nor constraint received support as a variable that could account for these relationships.

In sum, individuals who quickly became angry tended to take longer to fall asleep and have worse sleep quality, but age and gender seemed to account for these tendencies. Individuals who succeed at controlling their anger also tended to fall asleep more quickly, have more efficient sleep, and wake up less during the night according to objective sleep measures. These tendencies held even after controlling for gender, age, stress, and constraint. Overall, neither perceived levels of stress nor individual levels of constraint seemed to contribute to any of the relations between objective sleep and tendencies to become quickly angered or to control anger. A final point of note is that general tendencies to internalize or externalize anger (once angry), did not relate to objective sleep. It seems that quick tempers and suboptimal control of angry impulses are at the core of the relation between aggressiveness and objective sleep.

Relations Between Anger Propensities and Daily Diary Sleep

To examine if anger propensities related to *subjective* (daily diary) measures of sleep amount and sleep quality, bivariate correlations were calculated between all measures of anger propensities and daily diary sleep amount and sleep quality (See table 4).

When evaluating how anger propensities related to measures of daily diary sleep, two trends emerged: Anger-Control related to both sleep amount and indices of sleep quality, whereas all other measures of anger propensities only related to subjective sleep quality. Specifically, higher Anger-Control was associated with lower sleep amount (r = -.13, p = .008), and sleep onset latencies (r = -.14, p = .004), as well as higher sleep efficiency (r = .10, p = .04) and subjective sleep quality (r = .21, $p < .001$). Higher subjective sleep quality was also associated with lower Anger-In (r = -.28, $p < .001$), Anger-Out (r = -.13, p = .006), Trait anger total (r = -.23, $p < .001$), Angry temperament (r = -.17, $p < .001$), and Angry reaction (r = -.12, p = .01).

Regression of anger propensities on daily diary sleep indices. To examine whether anger propensities were still associated with their correlated indices of sleep amount and sleep quality after controlling for gender, age, stress, and constraint, hierarchical regressions consisting of the same steps described earlier were conducted (See tables 6 and 7). To help ease discussion, circadian phase (measured as a the mid-point of sleep on free days) was excluded from the reported and discussed daily diary results as inclusion or exclusion of circadian phase in the hierarchical regression did not change final interpretation of results.

Regressing Anger-Control on correlated sleep indices. After controlling for gender, age, stress, and constraint, higher Anger-Control was still associated with lower daily diary sleep amount (*B* = -.18.28; 95% CI = -31.33, -5.22) and better subjective sleep quality (*B* = .14; 95% CI = .01, .27; See table 6). However, higher Anger-Control was no longer associated with lower sleep onset latency (*B* = -1.94; 95% CI = -4.96, 1.09) and sleep efficiency (*B* = -.16; 95% CI = -1.68, 1.36). Interestingly, stress was only related to subjective sleep quality. Individuals with lower stress reported better subjective sleep quality (*B* = -27; 95% CI = -.38, -.15). While the confidence intervals included 0, constraint was suggested as a possible contributing variable to sleep amount and better subjective sleep quality as higher constraint seemed to be related to lower sleep amount (*B* = -18.63; 95% CI = -37.37, .11; *p* = .05) and better subjective sleep quality (*B* = .17; 95% CI = -.02, .35; *p* = .08)

Regressing measures of anger propensities on subjective sleep quality. After controlling for gender, age, stress, and constraint, only Anger-In was associated with subjective sleep quality (See table 7). Specifically, higher Anger-In was associated with worse subjective sleep quality (*B* = -.17; 95% CI = -.32, -.01). Anger-Out, Total trait anger, Angry temperament, and Angry reaction were no longer associated with subjective sleep quality (all 95% confidence intervals included 0). Across all the anger propensity measures, higher stress was associated with worse subjective sleep quality (95% confidence intervals did not include 0) and higher constraint was potentially linked to better subjective sleep quality (95% confidence intervals include 0, but all p-values were less than .09).

In sum, after accounting for stress and constraint levels, individuals who attempt to control their anger also tended to sleep for shorter amounts as well as perceived their sleep as being more refreshing and restorative. Individuals who tended to hold in their anger and not show it also perceived their sleep as being less refreshing and restorative. Moreover, stress was associated with subjective sleep quality and, with the exceptions of Anger-Control and Anger-In, accounted for the relation between the anger measures and daily diary sleep. Constraint was also suggested as being implicated in the relation between Anger-Control and sleep amount as well as in all relations between anger measures and subjective sleep quality. Overall, anger did not associate with daily diary sleep after accounting for stress and constraint, suggesting that stress and constraint may be confounding or mediating factors in this relation.

CHAPTER 4. DISCUSSION

The current study sought to examine (1) if anger propensities were related to objectively measured sleep, (2) what particular propensities and aspects of sleep may be important for their relation, and (3) if stress and constraint were contributing factors to these relations. Critically, week-long measurements of sleep through both objective actigraphy and subjective daily diary were related to individuals' anger propensities. The link between objectively measured sleep and anger propensities provided a novel finding whereas the link between subjectively measured sleep and anger propensities replicated prior findings. In particular, individuals' propensities towards becoming quickly angered and trying to control feelings of anger were related to *objectively* measured indices of sleep onset latency, sleep efficiency, and sleep fragmentation, but not sleep amount. Stress and constraint *did not* emerge as contributing factors to any of these relations. In terms of *subjectively* measured sleep, individuals' propensities towards controlling feelings of anger were also related to subjectively measured sleep amount, sleep onset latency, sleep efficiency, and subjective sleep quality. Moreover, all anger propensities were associated with subjectively measured sleep quality. However, unlike objectively measured sleep, stress and constraint tended to account for *most or all* of the relation between anger propensities and subjectively measured sleep. It seems that stress and constraint are contributing factors between anger propensities and subjectively measured sleep, but not objectively measured sleep.

Theoretical Implications

Aggressiveness and sleep. The foremost finding was that objectively measured sleep was linked to general tendencies of anger. No study has yet established such a link. Specifically, the tendency to become quickly angered and fail at anger control were associated with worse indices of sleep quality (although this former tendency was largely accounted for by age and gender and should be investigated within these demographics). Both of these predispositions have important implications for whether aggression occurs as individuals who are more easily angered may be more easily provoked into aggressing, and individuals who control their anger may be less likely to act on it (Anderson & Carnegey, 2004). Thus, the findings demonstrate that objectively measured sleep is connected to important cognitive and affective individual differences in feeling and regulating anger, which are important precursors of aggression. The relations to these precursors yield insight into how sleep may influence aggressiveness.

Of notable theoretical importance was the finding that the tendency to control anger was related to multiple indices of objectively and subjectively measured sleep quality. As the tendency to control anger likely reflects an individual's ability to exert regulation over emotions, this finding brings evidence to recent theorizing that suggests impaired regulatory ability as a key factor in the relation of sleep and aggression (Kamphuis, Meerlo, Koohaas, & Lancel, 2012). It may be that individuals who often experience disrupted sleep have trouble controlling feelings of anger and this may lead to aggressive expression of anger. However, the tendency to express anger in aggressive ways (once angry) was not related to sleep. Perhaps this relation is more complex than impaired emotional regulation. This possibility is discussed in greater detail below.

In addition, it is difficult to draw causal directions between sleep and anger propensities, such as the tendency to control anger, due to the essentially cross-sectional nature of the data.

However, some logical deduction regarding the nature of the relation between these angry tendencies and sleep is possible depending on the index of sleep. For instance, both tendencies to become quickly angry and to control anger were related to sleep onset latency. As sleep onset latency represents the number of minutes it takes an individual to fall asleep at night, it seems reasonable to conclude that the number of minutes it takes to fall asleep at night would not have a profound effect on controlling anger and becoming angry. The short period of time right before sleep should not have any more influence on affect and cognition than any other short period of consciousness. Rather, it seems more likely that individuals who tend to control their anger and those who do not become easily angered are more easily able to achieve a state of cognitive calmness needed to fall asleep at night. Those who are tend to control their anger may be able to reappraise and dissipate their anger before sleep to avoid angry rumination while those who are not quick to anger would be less likely to experience distressing angry feelings before bed time. It should also be noted that better anger control may be indicative of higher levels of general self-control which may influence a host of sleep-related factors (e.g. experience less familial conflict; better sleep hygiene; Tangeny, Baumeister, & Boone, 2004; Kraus, De Ridder, Evers, Adriaanse, 2014; Krizan & Hisler, 2014).

Explaining relations between other objective sleep indices and angry temperament and anger control is more speculative, however. For example, the relation between angry temperament, anger control, and sleep efficiency is likely bi-directional. Because sleep efficiency is the amount of time an individual spends sleeping relative to the amount of time he or she is in their bed (and presumably trying to sleep), sleep efficiency encapsulates both pre-sleep behaviors and processes (e.g. sleep onset latency discussed earlier), and sleep behaviors and processes that occur throughout the night (e.g. amount of REM sleep and sleep fragmentation). Some of the processes encapsulated in sleep efficiency may influence an individual's tendency to become quickly angered or to try to control anger, such as sleep fragmentation. This seems likely as fragmentation marks a disruption to the natural progression through the sleep cycle that is needed to achieve REM sleep. Once the sleep cycle is disrupted, individuals have to progress back through the sleep stages to achieve REM (except in cases of severe REM deprivation). Not only has REM sleep been implicated as playing an important role in de-potentiating and integrating emotional experiences, but it has also been linked to increased aggressive behavior in animals (Hicks, Moore, Hayes, Phillips, & Hawkins, 1979; Sloan, 1972). Thus, because sleep fragmentation is a marker of disruption to the sleep cycle's natural progression to REM sleep and REM sleep seems to have particular implications for emotions and aggressive behavior, sleep fragmentation may be especially important for anger and aggressiveness.

These same processes encapsulated in sleep efficiency may also be affected by angry temperament or anger control. For instance, the arousal associated with feelings of anger can delay sleep onset or cause restless sleep and sleep fragmentation (Shin, et al., 2005; Ottani, Lorenzi, & Lara, 2011). Moreover, feelings of anger broadly implicate the presence of negative affect which can also disrupt sleep (Kahn, Sheppes, & Sadeh, 2013). Due to sleep efficiency's complex nature, more precise and targeted research is needed to examine its relation to dispositions towards controlling anger and ease of becoming angry.

Anger expression and sleep. While objectively measured sleep is linked to angry temperament and anger control which represent important cognitive and affective precursors of expressing aggression, it begs the question of why objectively measured sleep wasn't related to reports of heightened behavioral expression of anger. Although this may be due to a variety reasons, at two seem especially important. The first is that whereas cognitive and affective dispositions towards anger are certainly linked to ultimate aggressive acts, these dispositions are simply precursors of aggression and aggressive tendencies. Many other factors beyond these cognitive and affective dispositions would determine actual tendencies towards acting on one's anger, such as age (e.g. elderly individuals are less able to successfully carryout physical aggression than their younger peers). Sleep likely has the most direct relations to the cognitive and affective precursors of aggression (such as tendencies to get angry) rather than the end-outcome of aggression itself.

Another factor that may contribute to why sleep was not associated with tendencies for anger expression in the current study is age. The MIDUS II Biomarker sample consists of middle age individuals who are between 35 and 85 years old, and 50% of whom are above the age of 55. While individuals who have higher aggressive tendencies than their peers tend to remain higher than their peers over time, aggressive tendencies as a whole tend to decrease over the lifespan (Bushman & Huesmann, 2010). Moreover, it seems reasonable to assume that the physical ability to act on one's anger as well as the social opportunities to become aggressive decline over time. Thus, using a predominately older sample of adults may restrict the range of angry tendencies that relate to sleep. Moreover, the relation between sleep and actual aggressive acts may be more relevant in children, adolescents, and young adults, for whom angry and aggressive tendencies may be more likely, as well as for at-risk individuals with antisocial propensities (Krizan & Herlache, 2015; Krizan, Herlache, & Gentile, 2016).

Stress, constraint, and sleep. While this is the first study to link dispositions to anger to objective sleep measurement, another notable finding pertains to stress and constraint as contributing factors to this relation. Interestingly, stress and constraint did *not* emerge as potentially contributing factors for the relation between anger and *objective* sleep, but *did* emerge as large contributing factors for the relation between anger propensities and *subjective* sleep. It seems that actual, objectively recorded sleep exhibits a different relation with anger than subjective appraisals of one's sleep as stress and constraint accounted for most of the relation between anger and subjective sleep. This is especially important given that prior research finding a link between angry and aggressive propensities and sleep measured sleep subjectively and did not evaluate the extent to which stress and constraint contributed to this relation. It may be the case that stress and constraint facilitate (i.e. mediate) this relation or may actually account for this relation. Further research examining the specific role of stress and constraint in regards to the relation between anger and aggressiveness and subjective sleep is needed to investigate these possibilities.

However, the present findings to provide some evidence that can be used to reason what the role of stress and constraint may be. One reason that stress and constraint may account for the relation between subjective sleep and anger propensities is common method variance. Stress, constraint, subjective sleep, and anger propensities were all measured through participants' self-reports. Because participants were responding to these scales using the same reporting method, at least part of the overlap across these scales may be due to common influences on participants' self-report. These include idiosyncrasies about how people use rating scales as well as individuals' tendencies to perceive themselves in positive or negative ways (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Specifically, accounting for stress and constraint in the relation between anger and subjective sleep will remove method variance that is also common in measures of constraint, and stress. Note that this common variance does not exist for self-reported anger and objectively measured sleep when accounting for stress and constraint.

Although method overlap may inflate the importance of stress and constraint for the link between anger and sleep, there are compelling reasons to expect these factors to play some role.

For instance, stress may be one confounding factor between anger and sleep. As described earlier, stress can lead to feelings of anger and acts of aggression. In addition, stress has been strongly implicated in poor sleep (Edwards, Baglioni, & Cooper, 1990; Akerstadt, et al., 2012). Thus, chronic stress may simultaneously influence anger and aggressiveness while also influencing the subjective perception of poor sleep (in addition to actually undermining sleep). Finally, stress may also account for the relation between subjective sleep and anger because all three constructs may reflect a central disposition towards negative affectivity, a pervasive factor that can lead to over inflation of relations in domains related to health (Watson & Pennebacker, 1989). Those who have general dispositions towards feeling negative affect may perceive more stress, may actually sleep worse and perceive worse sleep, and may be prone to feel the negative affect of anger.

Other than confounding factors, stress and constraint may also be potential mediators between anger and sleep. However, the finding that stress and constraint did not contribute to the relation between anger and objective sleep suggests otherwise. If truly mediated the relation between angry dispositions and sleep, then the effects of stress and constraint should not be contained to often biased and inaccurate subjective perceptions of sleep. Instead, it seems that something about the subjective nature of the measurements is influencing the relation and not the constructs of stress and constraint themselves.

While the exact role that stress and constraint may play in the relation between anger and subjective sleep cannot be determined from the current findings, they clearly play a large role in relation to subjective perceptions of sleep. Key directions for future research will be to examine the relation among anger, sleep, stress, and constraint in a younger population for whom the relations among these variables may be more sensitive to one another. Additionally, given that this study focuses on broad behavioral tendencies for anger, future research should seek to examine the relation between objective sleep and broad aggressive dispositions and specific instances of aggression (e.g. examining whether actigraphically measures sleep over two weeks relates to number of incidents of aggression). As sleep was consistently related to anger control propensities, this future work should consider the role of anger control in the relation between sleep and aggression

Conclusion

This study provides the first evidence that objectively measured sleep is related to anger propensities, specifically propensities to be quickly angered and to control anger. Stress and constraint were not found to contribute to these relations when using objectively measured sleep (which avoid many of the short comings and biases in self-reports of sleep). Altogether, this study provides strong evidence that angry tendencies are related to sleep and that this relation is not simply due to measurement inaccuracies or other theoretically relevant confounding factors. This study adds to the growing evidence that sleep is intimately connected to people's emotional lives, as poor sleep quality is related to lower tendencies to control of anger and higher susceptibility to become angry. Given that anger is often the bridge that connects provocation to actual acts of aggression, disrupted sleep seems to represent one risk factor for dispositions towards aggression and, ultimately, committing acts of aggression.

APPENDICES

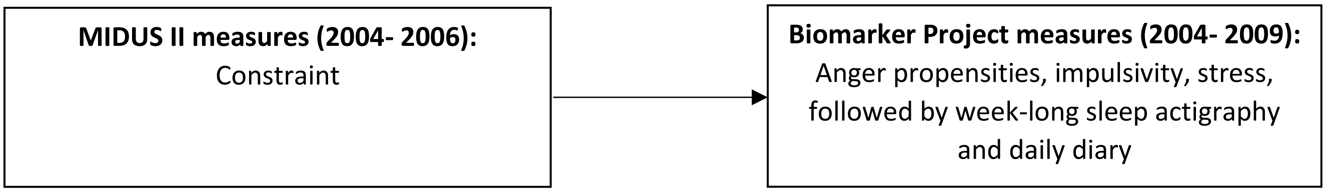

Figure 1. Timeline of data collection

Table 1. *Means and standard deviations of study variables.*

Measure	*M* (SD)
Sleep amount (A)	369.08 (67.68) minutes
Sleep onset latency (A)	31.41 (31.79) minutes
Sleep efficiency (A)	79.27 (31.79) percent
Sleep fragmentation (A)	32.39 (10.08) nightly awakenings
Sleep amount (D)	440.55 (73.71) minutes
Sleep onset latency (D)	21.53 (18.05) minutes
Sleep efficiency (D)	90.58 (8.80) percent
Sleep fragmentation (D)	1.94 (1.34) nightly awakenings
Sleep quality (D)	2.35 (.72)
Anger-In	1.85 (.53)
Anger-Out	1.62 (.42)
Anger-Control	2.47 (.56)
Trait anger total	1.59 (.35)
Angry temperament	1.30 (.44)
Angry reaction	1.93 (.59)
Stress	2.27 (.64)
Constraint	1.81 (.37)
Circadian phase (sleep mid-point)	3:34 am (2.57) hours

Note. (A) = Actigraphic measure, (D) = Daily Diary measure.

Table 2. *Correlations among sleep measures and control variables.*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. SA (A)	--													
2. SOL (A)	-37***	--												
3. Eff. (A)	.62***	-.78***	--											
4. Frag. (A)	.19***	.13**	-.33***	--										
5. SA (D)	.61***	.25***	-.10*	.44***	--									
6. SOL (D)	-.06*	.29***	-.28***	.12*	-.10*	--								
7. Eff. (D)	.17***	-.13*	.13*	-.01	.38***	-.61***	--							
8. Frag. (D)	.23***	-.07	.04	.19***	.17**	.11*	-.03	--						
9. Qual. (D)	.05	.10*	-.14**	-..08†	-.05	.39***	-.24***	.27***	.93					
10. Age	.06	.00	.02	-.04	.05	.06	-.03	.18***	-.15**	--				
11. Gender	.20***	-.14**	.20***	-.15**	.06	.08†	-.06	.01	.04	-.09*	--			
12. Stress	-.07	.21***	-.21***	.08	.08†	.15**	-.06	.04	.34***	-.16**	.08	.87		
13. Constraint	.10†	.04	-.01	.08	.12*	.00	-.03	-.08	.11†	-.02	.12*	.04	.65	
14. Cir. phase	-.21***	.16**	-.24***	-.11*	-.04	-.04	.06	.03	.12*	-.12*	-.07	.15**	.11†	--

Note. SA = Sleep amount, SOL = Sleep onset latency, Eff. = Sleep efficiency, Frag. = Sleep fragmentation, Qual. = Subjective sleep quality, Cir. Phase = Circadian phase; (A) = Actigraphic measure, (D) = Daily diary measure; $^{\dagger}p < .1$, *p < .05, **p < .01, ***p < .001.

Table 3. *Correlations among anger propensities and control variables.*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Anger-In	.83									
2. Anger-Out	.22***	.77								
3. Anger-Control	-.10*	-.25***	.68							
4. Trait anger total	.52***	.58***	-.18***	.83						
5. Angry temperament	.34***	.59***	-.25***	.70***	.83					
6. Angry reaction	.39***	.31***	-.06	.80***	.28***	.74				
7. Age	.25***	-.20***	.03	-.12*	-.18***	-.08	--			
8. Gender	-.03	.07	-.10*	.05	.07	-.01	-.09*	--		
9. Stress	.46***	.23***	-.31***	.42***	.32***	.24***	-.16**	.08	.87	
10. Constraint	.08	.07	-.04	.11†	.06	.08	.02	.12*	.04	.65

Note. *p < .05, **p < .01, ***p < .001.

Table 4. *Correlations between anger propensities and daily diary sleep*

	SA(A)	SOL(A)	Eff.(A)	Frag.(A)	SA(D)	SOL(D)	Eff. (D)	Frag.(D)	Qual.(D)
Anger-In	.03	.03	.00	.00	.00	.06	.00	.06	-.28***
Anger-Out	-.08	.01	-.06	-.03	-.04	-.05	-.03	.03	-.13**
Anger-Control	-.04	-.11*	.14**	-.12*	-.13**	-.14**	.10*	-.05	.21***
Trait anger total	-.07	.03	-.07	-.02	-.03	.02	-.02	.00	-.23***
Angry temperament	-.08	.10*	-.13**	.02	.04	-.02	.00	-.01	-.17***
Angry reaction	-.04	-.03	.00	-.03	-.04	-.03	.02	-.04	-.12*

Note. SA = Sleep amount, SOL = Sleep onset latency, Eff. = Sleep efficiency, Frag. = Sleep fragmentation, Qual. = Subjective sleep quality; (A) = Actigraphic measure, (D) = Daily diary measure; *p < .05, **p < .01, ***p < .001.

Table 5. *Regression of Anger-Control and Angry temperament on correlated actigraphic sleep quality indices.*

Measure	Step	Variable	SOL *B* (se)	SOL Adjusted R^2	Efficiency *B* (se)	Efficiency Adjusted R^2	Fragmentation	Fragmentation Adjusted R^2
Anger-Control		Gender	-10.29 (2.46) CI: -15.13, -5.47		-5.53 (.94) CI: 3.66, 7.33		-4.63 (1.18) CI: -6.97, -2.30	
	Step one	Age	.18 (.11) CI: -.02, .39	.05	-.07 (.04) CI: -.15, .01	.10	.01 (.05) CI: -.09, .11	.03
		Stress	.10 (.21) CI: -3.06, 5.13		-.30 (.80) CI: -1.85, 1.26		.46 (1.00) CI: -1.52, 2.44	
	Step two	Constraint	3.61 (3.33) CI: -2.95, 10.17	.06	-.97 (1.27) CI: -3.46, 1.53	.10	2.86 (1.61) CI: -.31, 6.03	.04
	Step three	Anger-Control	-5.02 (2.32) CI: -9.59, -.45	.07	1.93 (.88) CI: .20, 3.67	.11	-1.70 (1.12) CI: -3.91, .51	.05
Angry temperament		Gender	-10.01 (2.47) CI: -14.87, -5.15		5.41 (.94) CI: 3.56, 7.26			
	Step one	Age	.21 (.11) CI: .01, .42	.06	-.16 (.00) CI: -.08, .04	.10		
		Stress	1.77 (2.11) CI: -2.49, 5.82		-.58 (.80) CI: -2.17, 1.00			
	Step two	Constraint	3.66 (3.36) CI: -2.95, 10.26	.07	1.00 (1.28) CI: -3.51, 1.52	.10		
	Step three	Angry temperament	2.90 (3.26) CI: -3.51, 9.30	.07	-.86 (1.24) CI: -3.30, 1.58	.10		

Note. SOL = Sleep onset latency; CI = 95% Confidence interval; Gender was coded as 1 = Male, and 2 = Female.

Table 6. *Regression of Anger-Control on correlated daily diary sleep quality indices.*

Measure	Step	Variable	SA *B* (se)	SA Adjusted R^2	SOL *B* (se)	SOL Adjusted R^2	Efficiency	Efficiency Adjusted R^2
Anger-Control	Step one	Gender	2.01 (7.02) CI: -8.79, 18.81		2.98 (1.63) CI: -.23, 6.18		-1.47 (.82) CI: -3.07, .14	
		Age	.21 (.30) CI: -.38, .79	.01	.23 (.07) CI: .10, .37	.03	-.08 (.04) CI: -.15, -.02	.02
	Step two	Stress	-1.03 (5.95) CI: -12.73, 10.67		2.19 (1.40) CI: -.52, 4.91		-.03 (.69) CI: -1.39, 1.34	
		Constraint	-18.63 (9.52) CI: -37.37, .11	.02	.48 (2.21) CI: -3.87, 4.82	.04	.29 (1.11) CI: -1.90, 2.47	.02
	Step three	Anger-Control	-18.28 (6.64) CI: -31.33, -5.22	.04	-1.94 (1.54) CI: -4.96, 1.09	.04	-.16 (.77) CI: -1.68, 1.36	.01

Measure	Step	Variable	SQ *B* (se)	SQ Adjusted R^2
Angry-Control	Step one	Gender	.03 (.07) CI: -.11, .16	
		Age	.00 (.00) CI: .00, .01	.01
	Step two	Stress	-.27 (.06) CI: -.38, -.15	
		Constraint	.17 (.10) CI: -.02, .35	.09
	Step three	Angry-Control	.14 (.07) CI: .01, .27	.10

Note. SA = Sleep amount; SOL = Sleep onset latency; CI = 95% Confidence interval; Gender was coded as 1 = Male, and 2 = Female.

Table 7. *Subjective sleep quality predicted by anger propensities.*

Measure	Step	Variable	Qual. *B* (se)	Qual. Adjusted R^2
Anger-In	Step one	Gender	.01 (.07) CI: -.13, .15	
		Age	.00 (.00) CI: .00, .01	.01
	Step two	Stress	-.24 (.06) CI: -.37, -.12	
		Constraint	.19 (.10) CI: .00, .38	.09
	Step three	Anger-In	-.17 (.08) CI: -.32, -.01	.10
Total trait anger	Step one	Gender	.02 (.07) CI: -.12, .16	
		Age	.00 (.00) CI: .00, .01	.01
	Step two	Stress	-.27 (.07) CI: -.40, -.14	
		Constraint	.16 (.10) CI: -.03, .35	.09
	Step three	Total trait anger	-.12 (.12) CI:-.35, .12	.09
Angry reaction	Step one	Gender	.02 (.07) CI: -.12, .16	
		Age	.00 (.00) CI: .00, .01	.01
	Step two	Stress	-.30 (.06) CI: -.41, -.18	
		Constraint	.17 (.10) CI: -.02, .36	.09
	Step three	Angry reaction	-.02 (.10) CI:-.20, .17	.09

Measure	Step	Variable	Qual. *B* (se)	Qual. Adjusted R^2
Anger-Out	Step one	Gender	.02 (.07) CI: -.12, .16	
		Age	.00 (.00) CI: .00, .01	.01
	Step two	Stress	-.30 (.06) CI: -.41, -.18	
		Constraint	.17 (.10) CI: -.02, .36	.09
	Step three	Anger-In	-.02 (.10) CI: -.20, .17	.09
Angry temperament	Step one	Gender	.02 (.07) CI: -.12, .16	
		Age	.00 (.00) CI: .00, .01	.01
	Step two	Stress	-.29 (.06) CI: -.41, -.17	
		Constraint	.17 (.10) CI: -.02, .36	.09
	Step three	Angry temperament	-.06 (.09) CI: -.24, .13	.09

Note. Qual. = Sleep quality; CI = 95% Confidence interval; Gender was coded as 1 = Male, and 2 = Female.

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