Zlatan Križan *Editor*

Sleep, Personality, and Social Behavior

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Preface

Every book is a product of hard work and happenstance, and this volume is no different. Sleeping is a fundamental organismic process, providing a relief from our waking hours that define most of our life. Daily cycles in energy, consciousness, and enthusiasm color every aspect of human functioning, which is why they deserve center stage in science of human behavior. Thus, understanding sleep is an essential component of understanding what it means to be awake, so a full account of human psychology must address this primordial rhythm in sleep-wake states. Although many may agree with this claim, many domains of psychology and behavioral science are still relatively ignorant about the nature of sleep, its importance for how people function while awake, and the challenges sleep is undergoing in the modern technological age. That sleep is important for learning and physical health is broadly accepted, but the fact that sleep-wake processes wiggle their way into virtually every aspect of human behavior is less appreciated. In fact, how we sleep may be a core aspect of our personal constitution.

As a personality-social psychologist who focuses on sleep-wake processes, I was shocked at the paucity of scholarly work on the intersection of sleep, social processes, and personality. Humans are social beings that love, play, work, and fight, activities that define both individual lives and entire cultural eras. Is sleep relevant to these perennial aspects of human interaction? If so how? What about daily circadian variation in physiology and emotion? This volume is the first to tackle these questions directly, pulling on wide swath of interdisciplinary research to oust the social and personal side of sleep and circadian processes. Contributions in this volume from experts spanning psychology, psychiatry, neuroscience, organizational behavior, and behavioral medicine all underscore that social processes are integral to understanding sleep and that any full account of human behavior needs to accommodate sleep-wake and circadian processes. Moreover, sleep is a constitutional characteristic of individuals, speaking to nature of their lives and character. The chapters in this volume stress both the potential of this nascent field and highlight urgent needs to harness behavioral science in service of understanding what role sleep does, could, and should play in our lives together.

Many people deserve thanks for helping this effort come to conclusion. The love and support of my family provided the constant fuel to complete this ambitious project, as well as patience for my rants regarding its progress. This volume ultimately exists because of numerous and dedicated contributors who have invested time to form this book. Many other scholars have also provided input to this volume or words of encouragement while it was being formed, including Susan Cross, Carolyn Cutrona, Tica Hall, Heidi Kane, Richard Smith, Antonio Terracciano, and many others. Finally, this book will only reach the readers due to the efforts from the Springer Nature editorial staff. I owe much gratitude to Ms. Morgan Ryan, who saw the potential of this topic and approached me at a psychology convention about preparing a volume on it during May of 2016. Thanks also go to Ms. Sofia Geck who oversaw the final submission. As always, it takes a village.

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About the Author

Zlatan Križan (transliterated Krizan) was born in the port city of Rijeka, Croatia (then Socialist Federal Republic of Yugoslavia), on June 29, 1979. His father Božidar (b. 1946) was a university professor of mechanical engineering and a musician, while his mother Jadranka (1949–2018) was a language teacher and an entrepreneur. He attended the High School of Chemical Technology in Rijeka from 1993 to 1996, moving to the United States as an exchange student to complete high school in Tulsa, Oklahoma. He eventually earned a Bachelor of Arts in Psychology with Honors, graduating *Magna Cum Laude* in 2001 and then earning a Ph.D. in Personality and Social Psychology in 2007 from the University of Iowa.

After earning his doctorate degree, Zlatan Križan was hired as an assistant professor of Psychology at Iowa State University in 2007. He was promoted to an associate professor with tenure in 2013 and to professor in 2018. He has developed the first sleep laboratory at Iowa State University and was also a visiting scholar at the University of Minnesota in 2015. He has authored more than 40 peer-reviewed articles, edited 2 professional volumes, and authored more than 10 chapters. He has also been invited to lecture at over 15 universities and has participated in more than 50 conference presentations. His research has been supported by the *National Science Foundation* and the *Federal Bureau of Investigation*. His publications have appeared in *Psychological Bulletin*, *Psychological Science*, *Journal of Experimental Psychology*, *Journal of Personality and Social Psychology*, and *Personality and Social Psychology Review*. He is an elected fellow of the Association for Psychological Science and Society for Personality and Social Psychology (since 2018). He currently serves as an associate editor for *Personality and Social Psychology Bulletin* and *Journal of Research in Personality*. He has also reviewed for more than 30 scientific journals and governmental science foundations in Israel, Poland, and Canada. He lives in Ames, Iowa, with his wife and two children.

Part I
Introduction

Sleep and Social Processes

Amie M. Gordon, Wendy Berry Mendes, and Aric A. Prather

Sleep problems are increasingly being recognized as a public health epidemic. Over 69% of US adults get less sleep than they need (Sleep in America Poll, 2014), and poor sleep is related to negative physical and mental health outcomes (for recent reviews, see Barnes & Drake, 2015; Buysse, 2014). Historically, sleep research has separated sleep from the social context in which it occurs and sleep has been largely neglected in social psychological research. However, researchers are increasingly recognizing the importance of considering the bidirectional links between sleep and social processes (Gordon, Mendes, & Prather, 2017). This work provides important evidence that how well we sleep affects how we interact with the social world. Similarly, how we interact with those around us affects how well we sleep. In Fig. 1, we present a conceptual model of these bidirectional links. In the following chapter, we summarize this research by providing illustrative examples of how sleep is linked to a variety of social processes from relationship conflicts to discrimination. We also suggest areas of future research, including the need to identify mechanisms and moderators.

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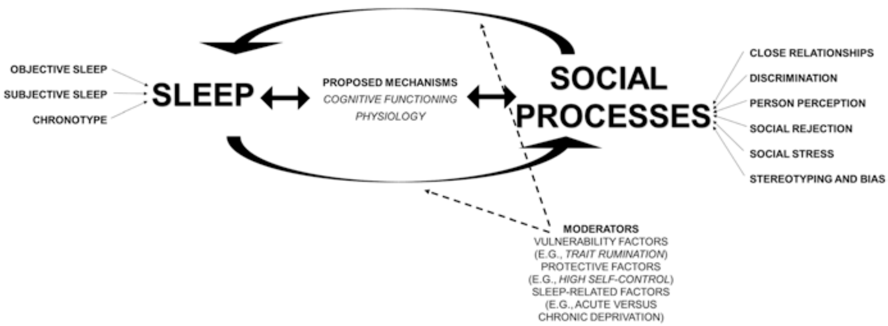

Fig. 1 Conceptual model depicting the bidirectional links between sleep and social processes, as well as potential mechanisms and moderators

Evidence of Bidirectional Links Between Sleep and Social Processes

Evidence is mounting that sleep (or the lack thereof) plays a role in nearly every social process. Below we outline the current research in three key areas: (1) close relationships, (2) aggression, anger, and social stress, and (3) person perception and discrimination.

Close Relationships Romantic partners often share beds, making sleep integral to the relationship experience. Whether sharing a bed improves or impedes sleep quality is an open question. Some work shows that partners negatively influence each other's sleep, with people exhibiting more movement during the night when they are bed-sharing relative to when they are alone (Pankhurst & Horne, 1994). However, those couples also report better subjective sleep and other research indicates that cohabitating couples report more sleep problems when one partner is traveling (Diamond, Hicks, & Otter-Henderson, 2008). In line with these subjective experiences, a pilot study in which young, satisfied couples slept in a laboratory for several nights found that co-sleeping led to greater sleep efficiency, more slow wave sleep, and more REM sleep, compared to when sleeping alone (Drews et al., 2017). Couples with more concordant sleep, both in terms of overall sleep-wake patterns, and in terms of matched minutes awake throughout the night, are more satisfied with their relationships and experience less marital conflict (Gunn, Buysse, Hasler, Begley, & Troxel, 2015; Larson, Russell Crane, & Smith, 1991). Given these potential effects of co-sleeping, researchers have increasingly recognized the need to consider the dyadic nature of sleep (for reviews and a comprehensive model linking sleep to relationship functioning, see Troxel, Robles, Hall, & Buysse, 2007; Troxel, 2010; see also Rogojanski, Carney, & Monson, 2013).

Quality of sleep also plays a role in how partners interact outside of the bedroom. People who tend to sleep better report being generally more satisfied with their marriages (Strawbridge, Shema, & Roberts, 2004). In daily life, people report sleeping better when they feel close and connected with their romantic partners (Kane, Slatcher, Reynolds, Repetti, & Robles, 2014; Selcuk, Stanton, Slatcher, & Ong, 2017). Sleep is related to negative interpersonal processes as well. Individuals report sleeping worse after experiencing romantic conflict (Hicks & Diamond, 2011). Looking at the other direction, poor sleep is associated with greater conflict the following day (Gordon & Chen, 2014). Sleep may also play a role in the nature and resolution of romantic conflict—in one laboratory study, sleeping poorly the prior night was associated with less empathic accuracy, a lower ratio of positive to negative affect (self- and observer-rated), and less conflict resolution (Gordon & Chen, 2014).

Lack of close relationships can impact sleep as well. Sleep has been linked to loneliness, with lonelier individuals exhibiting worse sleep efficiency, fragmentation, and daytime fatigue (Cacioppo et al., 2002; Hawkley, Preacher, & Cacioppo, 2010; Kurina et al., 2011). In the opposite direction, researchers have found that when people sleep worse, they report feeling lonelier the following day. In this vein, depriving people of sleep leads to behaviors associated with social withdrawal, such as maintaining greater physical distance from others (Ben Simon & Walker, 2018).

People seem to be affected not just by their own poor sleep but by the sleep of those around them as well—people experience deficits in empathic accuracy whether they *or* their partners are poorly rested (Gordon & Chen, 2014) and people tend to be less satisfied with their relationships if their partner typically sleeps poorly (Maranges & McNulty, 2016; Strawbridge, et al., 2004). Moreover, people who view a video of a sleep-deprived individual (compared to when they are well-rested) not only rate the sleep-deprived person as lonelier, they actually report feeling lonelier themselves (Ben Simon & Walker, 2018). In related research using a similar paradigm, people reported feeling less inclined to socialize with targets in photos if the target was sleep-deprived (Sundelin, Lekander, Sorjonen, & Axelsson, 2017). These contagion effects highlight the social nature of sleep, particularly within close relationships (for review see Gunn and Eberhardt, Chap. 9, this volume).

Aggression, Anger, and Social Stress Sleep is related to negative social behaviors outside of close relationships as well. Krizan and Hisler (2018) found a causal effect of sleep on anger. After two nights of partial sleep deprivation (compared to two nights of normal sleep), participants showed amplified angry responses in the lab. Although this task was non-social, anger is often an interpersonal emotion with social consequences. For example, research suggests that sleep problems may perpetuate reactive aggression and violence (e.g., Kamphuis, Meerlo, Koolhaas, & Lancel, 2012).

Sleep is also associated with other types of social stressors, such as rejection. In a within-person field experiment, we found that people took significantly longer to go to bed and slept less after experiencing social rejection just before bedtime compared to a control night where they watched a neutral film. This was particularly true for people high in trait rumination (Gordon, Del Rosario, Flores, Mendes, & Prather, 2019). We also found some evidence for the reverse direction—suggesting sleep modulates how people deal with social stressors. In one study, people who had sleep worse the night prior to the rejection task had greater physiological reactivity (i.e., greater increase in heart rate relative to baseline) during and up to an hour after the rejection task. Relatedly, researchers have shown that sleep deprivation and poorer global sleep quality result in greater physiological responses (i.e., blood pressure reactivity and systemic inflammation) to a stressful social-evaluative task (Prather, Puterman, Epel, & Dhabhar, 2014). In other work, compared with a control group, sleep-deprived participants had greater amygdala activation and reduced activity in the prefrontal cortex when observing emotional faces (Yoo, Gujar, Hu, Jolesz, & Walker, 2007). Poor sleep also strengthens links between amygdala activation in response to emotional stimuli and more general reports of perceived stress (Prather, Bogden, & Hariri, 2013). Together, these studies highlight the possibility that sleep disruption and negative social behaviors, such as anger, aggression, and rejection, mutually amplify each other.

Person Perception and Discrimination Sleep plays a role in how we perceive others. Individuals shown pictures of strangers are less accurate at identifying anger and happiness after sleep deprivation compared to when they are well-rested (Van der Helm, Gujar, & Walker, 2010). Other work shows that people perceive leaders as less charismatic if they've slept poorly (Barnes, Guarana, Nauman, & Kong, 2016). Sleep also affects heuristic tendencies, leading to more stereotyping and bias. For example, people who are more alert in the morning engage in more social stereotyping at night than in the morning whereas the opposite is true for those more alert in the evening (Bodenhausen, 1990). Sleepier people are more likely to engage in racial stereotyping, including rating a job candidate as less qualified if the candidate has a Black-sounding name as opposed to a White-sounding name (Ghumman & Barnes, 2013). This effect of sleep on stereotyping seems particularly pronounced among individuals with strong implicit racial biases.

Sleep has also been linked to discrimination (for a review, see Slopen, Lewis, & Williams, 2016). Although these studies are primarily cross-sectional, there is strong evidence that people who experience more discrimination in their daily lives exhibit worse self-reported sleep, and some studies have shown that discrimination is associated with disturbed sleep, as measured by objective EEG recording (Beatty et al., 2011; Lewis et al., 2013). Some research has suggested that loneliness, stress, and rumination may be pathways through which discrimination disrupts sleep (Hoggard & Hill, 2018; Majeno, Tsai, Huynh, McCreath, & Fuligni, 2018). For decades researchers have worked to understand social bias and prejudice, uncover processes related to differential empathy towards ingroup over outgroup members and understand how discrimination gets under the skin. These studies suggest that lack of sleep may be a neglected factor in the literature.

From relationship conflict to discrimination, the growing research in this area highlights the breadth of ties between sleep and social processes—when people sleep poorly they are more susceptible to social stressors such as rejection and relationship conflict, have more difficulty judging other people's expressions, and are quicker to rely on stereotypes. Moreover, there is evidence that these negative social experiences portend poorer sleep, creating the possibility of a vicious downward cycle not just for poor sleepers but for those who interact with them. This is an emerging literature and many questions remain about the bidirectional links between sleep and social processes.

Future Directions

Mechanisms and Moderators Although the research on sleep and social processes is burgeoning, the focus has been primarily on establishing main effects. To move this literature forward, rigorous research is need to uncover the mechanisms likely underlying these links. Some researchers have peered "under the skin" to identify potential pathways through which sleep and social processes may impact each other: executive functioning—particularly self-regulatory capacity and attentional focus—and physiologic arousal.

Poor sleep is robustly linked to impaired executive functioning (Durmer & Dinges, 2005). One consequences of this is impaired *self-regulation.* Poor sleepers have more difficulty overriding initial impulses (Krizan & Hisler, 2016; for review see Hisler and Križan, Chap. 7, this volume) and depend more on automatic processing, such as relying on implicit racial biases (Ghumman & Barnes, 2013). Reduced self-regulation may also be one reason why people are more reactive to social stressors, such as rejection, after sleeping poorly. In work by Mauss and colleagues, poor sleepers engaged in less cognitive reappraisal to regulate their emotions after a stressful experience (Mauss, Troy, & LeBourgeois, 2013).

Reduced self-regulation may also be one reason why social processes affect sleep. Self-regulation is required in order to get adequate sleep. People have to turn off their screens, leave the bar, or quit their work in order to go to bed. Smart phones appear to be one reason that adolescents are getting less sleep than they previously did (Kroese, Evers, Adriaanse, & de Ridder, 2016; Twenge, Krizan, & Hisler, 2017). Moreover, some social experiences—such as arguing with a spouse or being the victim of discrimination—may be depleting, making it more difficult to engage in the self-regulatory behaviors necessary to get a good night of sleep.

Attention is another aspect of executive functioning that may help explain the links between sleep and social processes (Lim & Dinges, 2008, 2010). In order to pick up on subtle social cues, such as a person's emotional expression, people must be able to sustain attention and re-direct it when appropriate (Whitney, Hinson, Satterfield, Grant, Horn, & Van Dongen, 2017). Reduced attention might also explain why poor sleepers rely more on heuristics and stereotypes during social interactions rather than gathering, integrating, and updating held beliefs with new information.

The autonomic nervous system made up of the sympathetic (SNS) and parasympathetic nervous systems (PNS) activates during social and affective experiences (Mendes, 2016), and can directly affect the ability to fall and stay asleep. PNS activation is imperative for sleep onset and uninterrupted sleep; thus, any experience that alters the PNS might quicken or delay sleep onset. For example, social experiences such as interpersonal conflict or social rejection, particularly right before bed, might increase SNS and/or decrease PNS, possibly delaying sleep onset and decreasing sleep quality.

Biological systems, such as the autonomic nervous system, may also be a pathway through which sleep impacts social processes. Poor sleep may lead to physiological dysregulation. Indeed, couples with higher sleep-wake concordance have lower systolic blood pressure both during sleep and while awake (Gunn et al., 2017). Tying it together, we know from other research that physiological reactivity and flexibility are linked to processes such as accurately identifying emotional stimuli and responding to social cues (Muhtadie, Koslov, Akinola, & Mendes, 2015). Thus, it is likely that physiological arousal plays an important role in the recursive nature between sleep and social processes.

Here we suggest executive functioning and physiologic arousal as two potential pathways linking sleep and social processes. However, little work has rigorously examined these links, and more work is clearly needed to help elucidate these neurological and physiological mechanisms, as well as robustly test other potential mechanisms (e.g., rumination, stress). In addition, uncovering moderators will help pinpoint when and for whom sleep is linked with social processes. In our work on social rejection, we found that trait ruminators were most susceptible to the negative effects of social rejection on sleep (Gordon et al., 2019). In work by Hisler and colleagues (2018), they found that individuals with higher chronic stress were particularly susceptible to the effects of short sleep on daily stress. We anticipate that there are other individual differences which make people particularly vulnerable to the negative effects of poor sleep. On the flipside, there may be individual differences that help protect people from such negative effects. These might be sleep-based (e.g., having low sleep needs, acute versus partial sleep deprivation), personality-based (e.g., being good at regulating emotions, see Duggan and Križan, Chap. 12, this volume), or context-based (e.g., being highly motivated to pay attention). The literature also points to another moderator that needs to be attended to—the distinction between subjective and objective measures of sleep. Work on sleep has consistently shown different effects depending on whether the sleep is subjectively or objectively measured. Moreover, studies in which people are given false feedback about their sleep show that in these situations subjective sleep feedback influences perceptions of alertness, but not objective measures of attention (Gavriloff et al., 2018). Thus, careful attention should be paid to when these two aspects of sleep provide consistent versus divergent results.

Leveraging Technology to Collect Big Data We are on the cusp of a technological revolution in which wearable devices may produce cheap but also reliable sleep measurement. This technology paves the way for "big data" on sleep that can be collected on a large scale and cross-culturally. Examining the links between sleep and social processes in different cultures will reveal important information about the inherent nature of these links, as well as the extent to which they are context-based or universal. This new technology also provides the opportunity for exciting work measuring sleep contagion via social network analyses (e.g., Mednick, Christakis, & Fowler, 2010). Given the evidence that people are affected by the sleep of those around them, with global data on sleep patterns matched to social interactions via social media, we will have the ability to plot the spread of poor sleep across social networks.

Manipulating Sleep: Sleep Deprivation and Sleep Extension One reason that social psychologists may have neglected sleep previously is the difficulty in successfully manipulating it. The majority of studies examining the links between sleep and social processes use a correlational approach. Future work is needed that carefully manipulates sleep to examine its causal effects. Sleep deprivation is one important avenue for testing these effects; however, given the increasing number of people who suffer from chronic insufficient sleep (i.e., less than 7 hours per night), another approach to assessing the causal effects of sleep is sleep extension—increasing the number of hours participants sleep either through naps or an earlier bed time. Ideally, work will directly compare these two approaches to identify whether they produce similar results in opposite directions, or if, perhaps, deprivation and extension have unique effects.

Capturing Complex Social Behavior Just as more work is needed to carefully measure and manipulate sleep, we also need research which moves away from self-reports of social behavior to methods that capture complex social processes as they unfold without the requirement of conscious self-assessment. Social psychologists have created rigorous methods to induce meaningful social situations in the lab, from inducing discrimination, to forming new friendships, to capturing relationship conflict. As this body of research moves forward, we will need to focus on marrying the gold-standard measures of sleep and sleep-deprivation from sleep science with the best-validated in-lab tasks used by social psychologists. Given the potential effects of sleep contagion, examining meaningful social interactions between two or more individuals (some of whom are sleep deprived) will allow us to test interesting and important questions about how sleep spreads and affects those who interact with poor sleepers.

Sleep as a Control Variable For the researchers who are not primarily interested in sleep, we would urge the measurement and accounting of sleep differences in studies. Individual differences in sleep may be adding unnecessary noise to social experiments. For example, people of different chronotypes differ in their response to social stimuli—from stereotyping to reports of trustworthiness and altruism—depending on the time of day the study is conducted (Bodenhausen et al., 1990; Dickinson & McElroy, 2017) and insomnia is associated with error in survey responding, reducing reliability (Barber, Barnes, & Carlson, 2013). We argue that like other basic demographics, such as gender, race, and age, sleep should become a background variable collected and accounted for during studies of social processes.

Conclusion

The research on sleep and social processes increasingly shows that our nights invade our days, and our days invade our nights. When people sleep poorly, they are less satisfied with their romantic relationships, more aggressive, and engage in more stereotyping, to name a few social consequences. Conversely, social experiences impact sleep. Social rejection disrupts sleep while social connection enhances sleep quality. This is a small but growing body of work, and as this literature develops, there are many areas ripe for exploration, from uncovering mechanisms and moderators to leveraging new technology to identify global patterns in sleep.

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Part II
Circadian Rhythms

Daily Rhythmicity in Social Activity

Joshua Tutek, Heather E. Gunn, and Brant P. Hasler

Human life is structured around day-to-day social experiences, such as cohabitation with family members, interaction with friends, and occupational roles. These activities govern and provide a context for the occurrence of daily pursuits that include performing work, consuming food and drink, recreating, accessing technology and media, feeling positive emotions, and initiating sleep and waking. *Daily social rhythmicity* (DSR) may be defined as periodicity in the timing of behaviors that are linked to social engagement and recur on a 24-hour schedule (Monk, Flaherty, Frank, Hoskinson, & Kupfer, 1990). Investigators have long proposed that DSR is closely tied to circadian rhythms in underlying physiological activity, such that propensities for social engagement may be driven by the biological circadian clock (Watson, 2000), while social routines also recursively feed back onto the clock to regulate its action (Aschoff et al., 1971). Given this strong, cyclic association with bodily functioning, DSR is proposed to have far-reaching implications for social and health outcomes (Ehlers, Frank, & Kupfer, 1988; Monk et al., 1990).

This chapter gives an overview of extant literature providing evidence for DSR, as well as its associations with sleep and other health outcomes. We begin with a brief history of the theoretical conceptualization of DSR and its hypothesized influence over biological timing. We then describe evidence for rhythmicity in several phenomena linked to social activity: self-reported and observed behaviors of everyday living, activation of affective systems that drive engagement and reward-seeking, animal reproduction and group coordination, and close familial relationships. Next, we note health correlates of disrupted DSR and psychotherapeutic approaches for correcting disruption. Finally, we address several persisting gaps in knowledge of social rhythms and potential directions for future research.

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Early Conceptualization of Social Rhythmicity

Prior to the 1980s, DSR was actually believed to be the primary agent regulating biological rhythms in humans (Wever, Polášek, & Wildgruber, 1983). In a seminal study, Aschoff et al. (1971) continuously monitored adult male dyads in a controlled chamber for 4 days on an artificial light-dark schedule, followed by another 4 days in constant darkness. They found that during the darkness trial, participants sustained properly timed oscillations in core body temperature, a reliable marker of the endogenous circadian pacemaker (Kräuchi, 2002). The study concluded that social cues such as knowledge of clock time, living routine, and interpersonal communication are sufficient conditions for entraining bodily processes even in the absence of periodic light exposure. However, subsequent investigations concluded that light is the dominant environmental signal for synchronizing the body's circadian timing, which is regulated by a "central clock" in the suprachiasmatic nucleus of the hypothalamus, to that of the outside world (Czeisler et al., 1986; Lewy, Wehr, Goodwin, Newsome, & Markey, 1980; Reppert & Weaver, 2001). Accordingly, the literature has largely shifted its emphasis to examinations of physiological entrainment via the natural forces of light and darkness.

Nevertheless, interest persists in how social schedules may serve as important adjunctive cues, perhaps by shaping exposure to stimuli that impact the circadian clock directly such as light exposure, physical exercise, food consumption, or sleep-wake times (Carney, Edinger, Meyer, Lindman, & Istre, 2006; Haynes, Ancoli-Israel, & McQuaid, 2005; Mistlberger & Skene, 2004; Moss, Carney, Haynes, & Harris, 2015). This perspective was first encapsulated by social zeitgeber theory, which proposes that day-to-day social routines act as "zeitgebers" – time cues that structure the 24-hour period and thereby regulate the flow of endogenous circadian rhythms (Ehlers et al., 1988; Grandin, Alloy, & Abramson, 2006). The theory further suggests that maintaining consistency in social routines is essential for anchoring the timing of important behavioral and physiological processes. Major life events can trigger changes in the usual occurrence of social zeitgebers, which destabilize the internal circadian pacemaker and disrupt rhythmicity. Disruption of rhythmicity leads to somatic symptoms such as compromised sleep schedules, which in turn elicit affective symptoms that may culminate in depressive or manic episodes in vulnerable individuals (Ehlers et al., 1988).

Evidence for Daily Rhythms in Socially Significant Activities

Self-Reported Routines Based on the principles of social zeitgeber theory, and on observations that psychotherapy often seeks to promote regularity in relationships and activities, Monk et al. (1990) sought to create a tool for establishing a normative range of rhythmicity in socially-significant behavioral routines among humans. The resulting *social rhythm metric* (SRM) is a self-report diary prompting respondents to specify the clock times of 15 events that often transpire on a daily basis: getting out of bed, first contact with another person, having a morning beverage, having breakfast, going outside for the first time, starting work, having lunch, taking a nap, having dinner, exercising, having a snack, watching evening TV news, watching another TV program, returning home, going to bed, and two self-identified idiosyncratic activities (Monk, Kupfer, Frank, & Ritenour, 1991). Variability in the daily timing of these activities over a seven-day period produces a unitary score of overall regularity. A 5-item version of the SRM that focuses on bed- and wake-times, first interpersonal contact, starting work, and having dinner yields comparable results (Monk, Frank, Potts, & Kupfer, 2002).

Day-to-day consistency in routines, as measured by the SRM, tends to be robust and normally distributed in the population (Monk et al., 1990). SRM scores also display good test-retest reliability (Monk et al., 1991) and stability throughout the year (van Tienoven et al., 2014), which suggests that behavioral regularity remains relatively consistent over time within subjects and may constitute a stable trait. Additionally, the SRM has demonstrated appropriate correspondence with objective estimates of activity and biological rhythmicity (Monk, Petrie, Hayes, & Kupfer, 1994). Since its conception and initial validation, further studies have administered the SRM in both younger and older adult samples, as well as depressed and anxious clinical populations (Brown et al., 1996; Carney et al., 2006; Monk, Reynolds, Buysse, DeGrazia, & Kupfer, 2003; Monk et al., 1997; Monk et al., 1994; Monk, Reynolds, Machen, & Kupfer, 1992; Moss et al., 2015; Shear et al., 1994; Szuba, Yager, Guze, Allen, & Baxter Jr, 1992). Generally, social rhythmicity is found to be higher among normative than clinical populations, and it increases with age over the lifespan.

Overt Behavior Comparatively few studies have employed observational methods to examine DSR in actual behavior. One investigation sought to determine whether periodicity manifests in affect-laden actions characteristic of social encounters. Participants wore a portable recording device (electronically-activated recorder, or EAR) that continuously collected 30-second audio samples at scheduled intervals throughout the day (Hasler, Mehl, Bootzin, & Vazire, 2008). The investigators coded the frequency of three recorded behaviors associated with positive mood: socializing, laughing, and singing. They also coded instances of arguing or sighing as behavioral indicators of negative mood. Socializing, laughing, and singing displayed a 24-hour diurnal pattern with a peak in the early evening hours and a trough close to conventional wake time, while arguing and sighing did not display a significant 24-hour rhythm. Another study observed daily rhythmicity in initiating social exchanges in a massive multiplayer online game. Across over 100 million encounters between players' avatars in a virtual environment, individuals were most likely to connect with one another in the evening around 8:00 P.M. and 12:00 A.M. and least likely to do so around 8:00 A.M. (Zhang et al., 2015).

Alcohol consumption is another behavior whose habitual occurrence is closely connected to social activity and mood. Research indicates that drinking is expected to facilitate social interactions, perhaps by reducing processing of self-relevant information to increase empathy and identification with others (Brown, Goldman, Inn, & Anderson, 1980; Hull, 1987; Smith, Goldman, Greenbaum, & Christiansen, 1995). Accordingly, consuming alcohol has been found to enhance both individual- and group-level facial and speech behaviors associated with positive mood, reduce those associated with negative mood, and elevate self-reported social bonding (Sayette et al., 2012).

Social rhythms might feature in how drinking is pursued as a ritualized daily event. At least two studies have observed daily rhythmicity in alcohol use. A survey examining alcohol consumption timing across the day and the entire week in the United States population found that self-reported drinking displayed diurnal periodicity each day, peaking between 6:00 and 9:00 P.M. and troughing between 3:00 and 6:00 A.M. (Arfken, 1988). Another study in which cocaine and heroin users monitored their drug activity across the day found that incidents of drug craving, drug use, and drinking displayed a similar rhythm that peaks in the afternoon and evening, and drops in the late night or early morning hours (Preston, Jobes, Phillips, & Epstein, 2016). These findings hint that work schedules and cultural mores may discourage day drinking, while popular customs such as "happy hour" after work encourage drinking in the late afternoon. Conversely, human physiological circadian propensities for positive feeling or rewarding-seeking may contribute to the usual scheduling of work and happy hour at a societal level. We now turn to a discussion of such propensities from a DSR perspective.

Positive Affect and Reward Activation Rhythms in social behaviors may be reflected, and in part driven, by the periodicity of intrinsic systems that generate positive feelings and desire for engagement. Mood is a continuous, pervasive influence on daily life that is conceptualized as two related but independently operating dimensions called positive and negative affect. Positive affect (PA) is proposed to manifest a bio-behavioral mechanism motivating interaction with the environment to pursue rewards and goals. It ranges from enthusiasm, joy, alertness, and determination at the high extreme to lethargy and drowsiness at the low extreme (Watson, 1988). As social connection is perhaps one of the most inherently enjoyable activities that humans can pursue, social activity unsurprisingly displays a robust correlation with self-report measures of PA, as well as activation of neural circuits implicated in reward (Brandstätter, 1983; Clark & Watson, 1988; Isen, 1987; Krach, Paulus, Bodden, & Kircher, 2010; Watson, 1988). Experimental inductions of positive mood also elicit stronger desire for socializing compared to negative or neutral affective stimuli (Whelan & Zelenski, 2012).

Studies consistently find that PA demonstrates a 24-hour pattern closely approximating that of socializing behavior. On average, it peaks sometime between early afternoon and early evening, then begins declining through the late evening to reach a low point in the hours just before typical rise time (Miller et al., 2015; Murray, Allen, & Trinder, 2002; Murray et al., 2009; Watson, 2000). Given that positive mood is believed to reflect an underlying reward-orienting system, its activation pattern likely serves to prime individuals for engaging the external world by steadily increasing throughout daytime hours when the probability of gratification (e.g., social encounters) is highest. Humans are a diurnal species whose prospects for rewarding activity have historically varied according to the availability of sunlight, meaning that an internally based drive to seek out rewards during the day would be evolutionarily adaptive.

Notably, rhythms in PA and reward-related processes persist even under strict experimental conditions designed to block the influence of sociocultural factors and other potential confounds. Two studies (Murray et al., 2002; Murray et al., 2009) have employed a *constant routine* procedure, which involves continuously monitoring participants under constant wakefulness, light, heat, humidity, posture, activity, and/or mealtime conditions to "unmask" rhythms driven by the biological clock (Minors & Waterhouse, 1984). Under such conditions, fluctuations in PA over time were found to parallel oscillations in the core body temperature rhythm.

This rhythmicity in mood state is even observed when participants undergo a *forced desynchrony* protocol, which typically prescribes a 20- or 28-hour sleep-wake schedule in order to assess endogenously generated 24-hour periodicity independent of sleep timing (Dijk & Czeisler, 1995). Forced desynchrony studies have reported a sustained 24-hour cycle in PA (Murray et al., 2009) and related mood constructs (Boivin et al., 1997) corresponding to core body temperature fluctuations. Furthermore, Murray et al. (2009) discovered circadian rhythmicity in a validated physiological measure of reward activation: heart rate during a gambling task involving rewards for performance accuracy and speed (Fowles, 1988). Across repeated administrations of the task during the desynchrony protocol, reward activation assessed via heart rate displayed a 24-hour period, again paralleling that of core body temperature (Murray et al., 2009). These findings provide compelling evidence for an intrinsically-driven pattern in daily positive mood, reward activation, and receptivity to stimulation from the external environment. Emerging evidence suggests that daily rhythm effects may extend to other behavioral (Byrne & Murray, 2017) and neural (Hasler, Forbes, & Franzen, 2014) measures of reward activation, although these latter studies have not been conducted in the constant conditions required to demonstrate an endogenous circadian basis. Nevertheless, current findings are sufficient to suggest that rhythms in social predisposition have physiological underpinnings, even as they are also structured around culturally prescribed events (Hasler et al., 2008; Murray et al., 2002).

Two studies have examined daily rhythmicity in the affective tone and psychological states of social media participation. Golder and Macy (2011) analyzed the affective content and timing of messages posted on Twitter, a microblogging website that records public comments from users worldwide. Approximately 509 million messages from 2.4 million individuals around the world were collected and coded for emotional valence. PA in posts displayed a consistent pattern internationally, peeking relatively early in the morning and again around midnight. The similarity in this rhythm across calendar days and distinct cultures suggests that regular daily oscillation in positive mood is a fundamental human experience involving the biological clock. However, the nature of Twitter as a forum for self-presentation warrants cautious interpretation of these findings, as social desirability may motivate individuals to strategically over- or under-represent their emotional states. Preoccupations with social judgment are thus likely to strongly impact the observed oscillations in overt mood. PA amplitude was also significantly higher on weekends compared to weekdays, further hinting that socially relevant factors such as imposed occupational schedules partly drive the results. The daily rhythm in negative affect observed within Twitter messages showed a different pattern, with a low point in the morning and a steady rise throughout the day to a nighttime peek. However, negative affect varied less across the day than PA, consistent with previous findings that it exhibits weaker rhythmicity that is not always detectable (Clark & Watson, 1988; Miller et al., 2015; Murray et al., 2002; Murray et al., 2009; see Peeters, Berkhof, Delespaul, Rottenberg, & Nicolson, 2006 for an exception). Another study (Dzogang, Lightman, & Cristianini, 2018) has since coded psychological states in Twitter messages across the day, observing diurnal rhythms for an extracted factor reflecting analytical thinking and personal drive and achievement (which peaked between 6 and 10 A.M.), and for a factor reflecting existential concerns inversely correlated with positive emotion (which peaked between 3 and 4 A.M.). These studies demonstrate the potential of technological platforms for exploring daily affective expression in social communication outside the traditional limitations of culturally-homogenous samples within a single area.

Animal Social Behavior Although a thorough discussion of evidence for social rhythmicity in the animal literature goes beyond the scope of this review, we offer a few pertinent findings that complement the human literature. The most concrete evidence for rhythms in social behavior in animal models comes from research on reproduction. Indeed, the circadian clock appears to modulate rhythms in mating behavior in a range of species, from fruitflies (Rymer, Bauernfeind, Brown, & Page, 2007; Sakai & Ishida, 2001) and cockroaches (Rymer et al., 2007) to trout (Duston & Bromage, 1986) to hamsters (Eskes, 1984). Circadian modulation also appears to extend to courtship behaviors prior to mating. For example, circadian rhythms in courtship vocalizations of a species of singing fish are dependent on melatonin (Feng & Bass, 2016; Wilczynski & Lutterschmidt, 2016). Notably, as reviewed by Wilczynski and Lutterschmidt (2016), melatonin receptors are also present in brain areas associated with song control in certain songbirds (Fusani & Gahr, 2015).

As with social zeitgebers in humans, social cues appear to substantively influence entrainment of the circadian clock in a number of animal models, including some (but not all) of the mammalian species that have been investigated (Davidson & Menaker, 2003; Favreau, Richard-Yris, Bertin, Houdelier, & Lumineau, 2009; Mistlberger & Skene, 2004). The pervasiveness of social influences on circadian rhythms suggest an adaptive function, spurring speculation that “social influences on circadian timing might function to tightly organize the social group, thereby decreasing the chances of predation and increasing the likelihood of mating” (Davidson & Menaker, 2003). Predictably, some evidence suggests that social factors are particularly relevant in communal animals (Paul, Indic, & Schwartz, 2015). Honeybees, for example, exhibit hive-level circadian rhythms in activity that persist under constant light conditions, with evidence that the circadian rhythms of young bees are entrained by the hive environment (Bloch, Herzog, Levine, & Schwartz, 2013). More recent work indicates that the social entrainment observed in honeybees can actually override the entraining influence of competing light exposure (Fuchikawa, Eban-Rothschild, Nagari, Shemesh, & Bloch, 2016), perhaps not surprising in a species where the cohesiveness of the colony is so critical to survival.

As reviewed by Favreau et al. (2009), social cues can provide putatively adaptive influences, including full entrainment or mutual synchronization, but also can be detrimental, disrupting circadian rhythms and leading to desynchronization. For example, social isolation (relative to grouped housing) led to less stable body temperature rhythms of lower amplitude in rats (Cambras, Castejón, & Díez-Noguera, 2011). However, substantial evidence indicates that these effects occur downstream of the suprachiasmatic nucleus (Meerlo, Sgoifo, & Turek, 2002), and mechanisms by which social cues entrain and/or disturb circadian function remain an area of investigation.

Familial Relationships Among humans, evidence suggests that close relationships shape several components of DSR. Cohabitating family members, particularly partners, tend to have similar or concordant health behaviors (e.g., dietary intake, smoking) through social control (Umberson, 1992), and shared resources such as a similar environment or social network (Meyler, Stimpson, & Peek, 2007; Smith & Zick, 1994). Several investigations have also focused on the implications of familial relationships for sleep-wake patterns. A study of married couples found that wives' sleep duration predicted that of their husbands (though not vice versa), suggesting that wives exert some impact over their partners' sleep pattern (Lee et al., 2018). Parents may influence their children's circadian rhythm by structuring their sleep timing, as adolescents whose parents set their bedtime report experiencing earlier intrinsic preferences for sleep and waking (Randler & Bilger, 2009). Conversely, children strongly influence their mothers' lifestyle and sleep rhythm, even more so than a male spouse (Leonhard & Randler, 2009). Though family members' sleep timing preferences tend to be intercorrelated, these associations can vary during transition periods. During pregnancy, for example, mothers and their partners have similar wake, bed, and meal times, but this association drops after childbirth as mothers become more synchronized with their newborn children (Leonhard & Randler, 2009; see Randler, chapter "Chronotype and Social Behavior", this volume, for review). School-aged children's wake times have also been found to cofluctuate with their mother's wake times, while their fathers' sleep was associated only with their mothers' sleep (Kouros & El-Sheikh, 2017). This suggests that associations between family members' social rhythms are dynamic and bidirectional, and they may act as social zeitgebers for entraining daily behavioral and physiological rhythms.

Synchronized behavioral and circadian rhythms observed in parent-child or romantic bonds may constitute a form of *co-regulation*, reciprocally maintained physiological functioning of individuals in a relationship (Sbarra & Hazan, 2008). The purpose of coregulation in close relationships is to maintain a state of homeostasis. In healthy couples, bedpartners are more concordant in actigraphy-assessed sleep throughout the night than would be expected due to chance (Gunn, Buysse, Hasler, Begley, & Troxel, 2015). Moreover, degree of sleep concordance within couples is linked to relationship characteristics and individual cardiovascular health. For example, low sleep onset concordance is associated with fewer positive and more negative interactions the following day (Hasler & Troxel, 2010). Higher concordance relative to lower concordance is also associated with lower nighttime blood pressure in wives and lower systemic inflammation (an early marker of cardiovascular disease) in husbands and wives (Gunn et al., 2017). Thus, there is evidence of synchrony in components of daily rhythmicity in families, and synchrony, in turn, predicts physiological and interpersonal outcomes.

Implications of Social Rhythmicity for Health and Treatment

Correlates of Social Rhythm Regularity As previously described, social zeitgeber theory hypothesizes that wellbeing is compromised by disruption in social activities that anchor daily behavioral and physiological rhythms (Grandin et al., 2006). In keeping with this, DSR (usually quantified using the SRM) has been associated with sleep and other health outcomes. Investigations in samples ranging from young college students to retirement community-dwelling older adults have observed a correlation between higher SRM-assessed irregularity and poor sleep quality or insomnia status (Carney et al., 2006; Monk et al., 2003; Monk et al., 1994; Moss et al., 2015; Zisberg, Gur-Yaish, & Shochat, 2010). Lower self-rated social rhythmicity similarly predicts depression and bereavement symptoms (Brown et al., 1996; Ehlers et al., 1988; Margraf, Lavallee, Zhang, & Schneider, 2016; Monk et al., 1991; Moss et al., 2015; Prigerson et al., 1994; Szuba et al., 1992; Velten et al., 2014), anxiety and stress (Gorwood, 2012; Margraf et al., 2016; Monk et al., 2010; Shear et al., 1994; Velten et al., 2014), and poorer self-reported overall health and life satisfaction (Margraf et al., 2016; Velten et al., 2014).

Evidence for a link between social rhythm irregularity and long-term physical health consequences comes from an extensive literature on shift workers, who adhere to nighttime occupational schedules for certain days of the week that do not align well with conventional light or social timetables. Over time, such chronic desynchrony between endogenous circadian phase and environmental schedule has repercussions for bodily functioning. In a literature review summarizing findings from 38 meta-analyses and 24 systematic reviews, Kecklund & Axelsson (2016) concluded that shift work participation is associated with greater risk of insufficient sleep, accidents, Type 2 diabetes, weight gain, coronary heart disease, stroke, and cancer.

Bipolar Disorder and Social Rhythm Therapy Perhaps the strongest evidence for the association between social rhythm irregularity and mental health comes from studies of bipolar disorder, a diagnosis that is saliently characterized by major disruptions in mood and daily routines (Grandin et al., 2006). Individuals diagnosed with bipolar spectrum disorders report lower SRM scores compared to controls (Shen, Alloy, Abramson, & Sylvia, 2008), as do university students determined to be at risk for bipolar depression (Meyer & Maier, 2006). Moreover, longitudinal studies suggest that increased destabilization in social rhythms and occurrence of life events leading to such irregularity precipitate the onset of manic and depressive episodes (Shen et al., 2008; Sylvia et al., 2009). Those with bipolar disorder are also more susceptible to circadian disruption from major events than controls (Boland et al., 2012). Social rhythm disruption due to environmental factors has thus been proposed to trigger affective symptoms, and stabilizing social activities has been proposed as a treatment to balance mood (Grandin et al., 2006).

Interpersonal and social rhythm therapy (IPSRT) is a psychotherapeutic intervention aiming to monitor and sustain consistency in social behavior, while addressing events that tend to provoke irregularities. Patients are educated about how their daily routines and mood are linked, pursuing consistency in their lifestyle while working with the therapist on delineated problem areas that exacerbate irregularity and emotional extremes (Frank et al., 2005). IPSRT has established efficacy for bipolar disorder as an adjunctive enhancement of traditional pharmacotherapy, facilitating increases in rhythmicity of activities faster than a standard clinical management group and achieving longer episode-free periods with decreased disorder recurrence relative to controls (Frank et al., 2005; Miklowitz et al., 2007; Nusslock & Frank, 2012). Recently, investigators have applied interventions aiming to regularize interpersonal rhythms to non-bipolar populations that have experienced disruptive life events, including bereaved older adults (Pfoff, Zarotney, & Monk, 2014) and veterans with post-traumatic stress disorder, depression, and sleep problems (Haynes et al., 2016).

Unanswered Questions and Future Directions

Methodological Considerations Despite several decades of research assessing rhythmicity in social behavior, its relation to health outcomes, and its usefulness as a treatment target in psychotherapy, significant gaps persist in the literature. One limitation is the strong reliance on repeated self-report questionnaires to assess daily rhythmicity. Although self-report measures like the SRM and affect scales have yielded useful data on individuals' perceived timing and regularity of various activities, they do not objectively capture the expression of behavior or endogenous circadian functioning. A need for more direct observation of behavior in psychology research has been noted (Baumeister, Vohs, & Funder, 2007), and technological advancements provide ever-expanding possibilities for doing so. Continuously recording audio from portable personal devices (Hasler et al., 2008; Mehl & Holleran, 2007), monitoring heart rate during a reward task under constant routine conditions (Murray et al., 2009), and aggregating social media posts to discern global trends in public discourse (Golder & Macy, 2011) all represent innovative means of collecting information not otherwise accessed by introspective self-estimates. Additionally, there is increasing ubiquity of personal mobile devices that continuously record socially-relevant data from their users (e.g., phone calls and text messages, physical location, degree of physical movement, Internet search history). Although these devices cannot isolate the internal pacemaker, they have the potential to track rhythmicity in a variety of real-world social behaviors with precise temporal resolution. Continued refinement of novel technological approaches to examining DSR will facilitate knowledge of rhythmicity not merely as it is subjectively experienced, but as it actually manifests at the behavioral, physiological, and even societal levels.

Furthermore, the current social rhythm literature consists largely of cross-sectional, correlational research conducted with uncontrolled community samples (e.g., administering 2 week of daily measures to college students, computing their regularity, and correlating this metric with self-reported health factors). In order to make inferences of directional causality regarding social rhythms and outcomes, there is a need to implement research designs that collect longitudinal data over extended periods or incorporate experimental components such as a manipulation or comparison to a control group. For example, one innovative study introduced a daily routine of structured social and physical activity to older adults in an assisted living facility. It found that instigating consistent daily routines improved slow-wave sleep and memory performance among the treatment group relative to controls, though no differences were observed in endogenous circadian phase or subjective vigor and mood (Naylor et al., 2000). Such intervention protocols are necessary to confirm that promoting social rhythmicity leads to health benefits in non-clinical populations.

Research on social rhythms would also benefit from more widespread application of sophisticated statistical frameworks for analyzing rhythm data, as the simple scoring scheme for computing overall activity regularity on the SRM (Monk et al., 1990) may not sensitively track rhythmicity in social behavior or its potential for predicting outcomes. Other means of measurement have been developed and applied to daily fluctuations in actigraphy or endogenous biomarkers, modeling data to a regression equation that displays a cosinusoidal or sinusoidal curve with a period of 24 hours. The magnitude of an activity's circadian patterning is judged by how closely its fluctuations across time conform to the 24-hour wave pattern (Cornelissen, 2014; Marler, Gehrman, Martin, & Ancoli-Israel, 2006). Non-parametric (van Someren et al., 1996) and multilevel modeling methods (Raudenbush & Bryk, 2002) have also been effectively used to investigate circadian rhythmicity. These strategies move beyond the simplicity of the SRM to provide more comprehensive and statistically sound characterization of rhythmicity in activities such as social engagement, outdoor activity, and food or alcohol consumption. They also provide additional parameters of activity (e.g., amplitude, timing phase) that might be differentially related to social behavior and health outcomes.

Environmental Versus Endogenous Influences on Social Rhythms Another important future direction involves continuing to parse out the relative contributions of intrinsically generated physiological mechanisms and externally mandated socio-cultural timetables to DSR. Evidence supports the notion that the daily timing of systems that motivate engagement with the external world and pursuit of pleasurable stimulation (i.e., PA and reward activation) have a biological basis, as their rhythmicity persists even under constant environmental conditions and parallels core body temperature (Boivin et al., 1997; Murray et al., 2002, 2009). Intrinsic systems that periodically encourage social engagement may partly set the precedent for conventional work and leisure schedules followed by large groups of people, or even entire societies. For example, the structure of events in a typical, societally prescribed workday (arrival in the morning, tending to most work-related responsibilities in the late morning and early afternoon, getting off work to pursue social leisure activities such as "happy hour" in the early evening) may be, in part, a consequence of the endogenous timing of human mood and reward propensities. Likewise, taking an evolutionary psychology perspective, the delays in circadian timing that occur during adolescence may serve an adaptive role by driving teens' pursuit of social encounters and, in particular, sexual partners, at a later time when they are likely to outcompete their older rivals.

Future studies could continue using forced desynchrony protocols that include sampling of biomarkers (such as body temperature and melatonin secretion) to determine whether other constructs related to work and social activities display inherent 24-hour periodicity. Prospective factors to be repeatedly measured under constant conditions include cognitive performance and productivity, loneliness or interest in socializing with others, and intensity of cravings for various substances. Though methodologically challenging, studies could also explore the feasibility of using neuroimaging under constant routine conditions to determine whether brain activity associated with social reward exhibits an endogenous circadian rhythm. Such investigations would help determine if the functioning of the modern world is driven by internal biology informed by humans' evolutionary history.

Just as biological timing mechanisms may manifest in society-wide work and leisure calendars, culturally mandated beliefs and practices may inversely be internalized to guide the circadian functioning of individuals. For example, commitment to a religious or spiritual system has steadily accrued support as a correlate of positive health outcomes, including sleep quality (Bonelli & Koenig, 2013; Koenig, King, & Carson, 2012). One intriguing study observed that Catholic nuns living a regimented, monastic lifestyle achieved better objective sleep than matched controls (Hoch et al., 1987). Others have documented changes in the circadian rhythms of melatonin and cortisol during the Islamic holy month of *Ramadan*, which mandates alterations of the nighttime sleep phase, social habits, and diet (Al-Hadramy, Zawawi, & Abdelwahab, 1988; Bogdan, Bouchareb, & Touitou, 2001). This suggests the possibility that religious observance entrains the timing of daily activity and underlying physiological rhythmicity via personal rituals (e.g., morning or bedtime prayer or meditation, periodic study of inspired text, fasting), or via involvement in spiritual institutions that offers a context for socializing (e.g., congregating with like-minded believers for worship at preordained times). While research has begun exploring how close relationships act on circadian timing, the role of pervasive sociological systems like religion has been largely ignored. Devout Muslims, for instance, observe the tenet of *Salah*, which entails five prayers throughout the day occurring at regularly scheduled time intervals delineated by the positioning of the sun. Such practices could constitute powerful markers for circadian rhythmicity. Future research could examine whether adherence to various social or spiritual doctrines facilitates regularity in daily routines, as such traditions may have been historically adaptive for accomplishing social cohesion and entrainment in the human species.

Conclusions

In summary, 24-hour rhythmicity in social processes exists and appears to have significant implications for functioning. Daily periodicity has been observed in research on both self-described and objectively observed socially relevant behaviors, affect and reward orientation, animal activity, and familial relationships. DSR may be partly driven by the biological clock, while also providing recursive effects on circadian timing in order to benefit sleep quality and other aspects of mental and physical health. Interventions that facilitate behavioral rhythmicity have proven useful for stabilizing bipolar symptomology and show promise for ameliorating other psychological difficulties. However, the current literature on DSR suffers from methodological limitations, and future studies should make greater use of observational or physiological data collection, sophisticated statistical approaches, and longitudinal or experimental research methods. Investigators must also continue clarifying how society-wide mandates for work, socializing, and reward-seeking exhibit underlying physiological rhythmicity in their timing, as well as how adherence to various broad cultural systems is associated with differences in DSR.

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Chronotype and Social Behavior

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In this review, the term chronotype is used as a collective term for various conceptualizations, such as circadian phase, circadian preference, as well as the terms morning-type and evening-type, as well as more colloquial terms "owls" and "larks". A late chronotype (or in colloquial terms, an "owl") is someone who falls asleep rather late, and therefore gets up later. In contrast, morning types (or colloquially labelled "larks") get up and start earlier, and hence, go to bed earlier. These terms should be used without discrimination, i.e. that it should be viewed as a kind of a diversity aspect rather than valuing one over the other (usually morning over evening). Thus, the chronotype clearly refers to the "timing"of sleep (Randler, 2014) and, scientifically, this is a variable distinct from sleep duration, which reflects the amount of time someone sleeps. In addition to sleep timing, other features are critical to chronotype. One is the time of peak performance, thus at what time a person is performing best and at optimal level of arousal (e.g., considering a tests). Here, morning people often reach their peak performance early in the day, while evening people reach their peak performance relatively late in the day (in the afternoon, in the evening, sometimes only at night; for an overview, see Adan et al., 2012).

Chronotype has a biological basis and is related to the circadian fluctuations of the body temperature, and is correlated with Dim Light Melatonin Onset (DLMO; Kantermann, Sung, & Burgess, 2015). For example, Kantermann et al. (2015) found a correlation between DLMO and scores on questionnaires, showing that owls had a later DLMO than larks, which backs up the questionnaire assessment of chronotype with biological data. Further, cortisol levels in the morning are associated with chronotype (Randler & Schaal, 2010). Specifically, morning people had higher cortisol levels immediately after awakening. Further, candidate genes have also been identified (Lane et al., 2016). General aspects are that on average women are more morning oriented than men (Randler, 2007), and there are striking developmental

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changes during the lifespan (Randler, 2016; Randler, Faßl, & Kalb, 2017). Young children are usually more morning oriented, and rapidly turn towards evening orientation, while at the end of adolescence and during post-adolescence, people become more morning oriented again, so that at the age of 60–70 years, morningness is on a similar level as in young children (Randler, Freyth-Weber, Rahafar, Jurado, & Kriegs, 2016; Roenneberg et al., 2004). Chronotype can be measured with a variety of questionnaires, based on unidimensional and multi-dimensional conceptualizations (see Di Milia, Adan, Natale, & Randler, 2013 for a review). In some studies, the chronotype has been placed close to a personality variable or at least regarded as an individual difference variable. It is clearly related to the personality dimensions but still a different trait (Lipnevich et al., 2017). Therefore, the question arises to what extent the chronotype can have an influence on social behavior and relationships.

Personality and Chronotype

Different aspects of chronotype can be linked with social behavior. One important way to examine differences in social behavior is to focus on personality. Most studies in recent times are based on the Big Five conceptualization of personality (the psycho-lexical approach), and two of the five dimensions are most relevant to social behaviors: extraversion and agreeableness. Extroverted persons are characterized as sociable, talkative and do like encouragements (e. g. "I really like to talk to other people."). Most earlier studies found a clear relationship between extraversion and eveningness, thus, evening people were more extraverted (see overview in Adan et al., 2012). However, Tsaousis (2010) detected a slight positive effect between morningness and extraversion in his meta-analysis, while there was no relationship between morningness and extraversion in individual studies. This was an interesting finding. Two more recent studies showed that morning persons are more extraverted than evening persons (Randler, Schredl, & Göritz, 2017; Ruffing, Hahn, Spinath, Brünken, & Karbach, 2015). This is an interesting and new facet where no explanation is yet available. It could be related to the questionnaires used, mainly, the questionnaires dealing with chronotype. Previous work always questioned that it seems the type of personality questionnaire being responsible for contradictory results, but most recent studies during the last 10 years used the Big Five concept. Thus, one ongoing question and direction of future research would be to assess, what influences this relationship. Lipnevich et al. (2017) presented a new meta-analysis based on 620 correlations from 44 independent samples and confirmed the well-known relationship between conscientiousness and morningness. Extraversion and Openness exhibited moderate unique relations with Eveningness, while Agreeableness was largely unrelated to all circadian preference variables. As a conclusion, we find some evidence for a clear relationship between morningness and personality, with morningness associated with more conscientiousness and eveningness associated with more extraversion.

Concerning the personality dimension of agreeableness, high values in the agreeableness scale suggest that the test person is caring, compliant and has a strong need for harmony (e. g. "I try to be kind to everyone I meet."). Agreeableness was often related to morningness with an effect size of: r = .14 (Tsaousis, 2010; meta-analysis). However, in a recent study, this relationship could not be found anymore (Lipnevich et al., 2017).

Other personality dimensions are also tested in such association studies. Individual differences in aggression and hostility are also key to social behavior. Aggression-Hostility, however, was unrelated to chronotype in a Spanish and German sample (Muro, Gomà-i-Freixanet, & Adan, 2009; Randler, Gomà-i-Freixanet, Muro, Knauber, & Adan, 2015) based on the same chronotype questionnaire, the reduced morningness-eveningness questionnaire (Adan & Almirall, 1991).

Socializing and Chronotype

Closely related to the concept of extraversion is one's sense of humor, and humor can also have a social component. Randler (2008) found that evening people score higher on the sense of humor, showing that chronotype is related to this individual trait variable. However, as humor might be a component resulting from extraversion, the analysis was recalculated controlling for extraversion as a confounding factor. Individuals scoring as evening types reported a greater sense of humor than morning individuals (with higher morningness scores). In a stepwise linear regression, Extraversion, Agreeableness, Openness, and Chronotype each accounted for a significant amount of variance in sense of Humor scores. That is, the relationship between scores on Sense of Humor and evening orientation was significant after controlling for personality dimensions. However, eveningness was related to sense of Humor scores in women but not in men, and social but not cognitive humor was predicted by eveningness (Randler, 2008), again emphasizing the different expression of social aspects of chronotypes.

More negative aspects of social behaviour have also ben related to chronotype. For example, negative behaviors at school was measured by Lange and Randler (2011). Here, the chronotype scores correlated positively with pro-social behavior, and negatively with behavioral problems, suggesting that larks do better cope with the social aspects of the school environment (Lange & Randler, 2011). Cyberbullying is a more recent construct, evolving with the social media. Victims of cyberbullying perpetration have been reported to suffer many psychological and emotional problems that can lead them as far to suicide (Kırcaburun & Tosuntaş, 2018). These authors reported that chronotype and sleep quality were significant predictors of cyberbullying perpetration (Kırcaburun & Tosuntaş, 2018), with evening-type students showing higher scores on the cyberbullying scale than neither-type students and morning-type students. Concerning aggression, a recent review by Schlarb et al. (2014) showed that children and adolescents from the evening type revealed more behavioral and emotional problems as aggression or antisocial behaviour.

Concerning social networks, Aledavood, Lehmann, and Saramäki (2018) collected their data based on a smartphone app with >700 volunteers. These authors reported that owls maintain larger personal networks, albeit with less time spent per contact, and evening people were more central in their social network. This fits well with the personality dimensions discussed above with evening owls being more extraverted. Another important point was that owls showed a homophily by preferring social contacts with other owls. In sum, evening types have a disadvantage concerning some aspects of social behaviour, while also have an advantage in some kinds of socialising, i.e. in establishing and maintaining contacts.

Although some regression models presented in research papers indicate that sleep sleep duration and chronotype might have independent influences on social behaviour (e.g., Owens, Dearth-Wesley, Lewin, Gioia, & Whitaker, 2016), it is not clear if this is direct effect of chronotype or whether it is a by-product of sleep and shorter sleep duration, because evening people suffer of sleep debt during the weekdays. This is especially the case in school pupils and adolescents. Here, only experimental sleep extension programs may give an answer and might help to investigate behavioural changes and scores on questionnaires.

Mate Choice and Pair Bonding

Another interesting aspect of social behaviour is pair behavior, which usually happens in dyads. There are only a handful of studies that looked at these aspects (for example, Richter, Adam, Geiss, Peter, & Niklewski, 2016). Piffer (2010) was the first to study this hypothesis on the basis of 134 Italian men. He found a correlation of −0.26, indicating that men with a higher evening orientation reported more sexual partners from the opposite sex. Gunawardane, Custance, and Piffer (2011) confirmed this hypothesis in a sample from Sri Lanka. Subsequently, we examined this question in German men with a somewhat more complex approach (structural equation models, Randler et al., 2012). In fact, it was also found here that men of the evening type reported a higher reproductive success. This result remained even when controlling for age, extraversion and also for propensity for going out. In addition to chronotype, older age, high extraversion, and more "going out" were statistical predictors of higher reproductive success. Jankowski, Díaz-Morales, and Randler (2014) also examined women for the first time about the construct of sociosexuality. Socio-sexual orientation is a construct that describes the propensity for occasional sex and sexual activity, especially in unbound relationships (Penke & Asendorpf, 2008). Important elements here include behaviors, desires, and attitudes. In men, there was no correlation between chronotype and sociosexuality, possibly due to the small sample size, but in women evening-oriented women showed less limited global socio-sexuality ($r = 0.27$), as well as less restricted sociosexual behavior ($r = 0.18$), attitude ($r = 0.28$) and desire ($r = 0.15$). Evening orientation can also be seen as a factor for the instability of romantic relationships and high-risk sexual behavior in women.

Subsequently, we examined the influence of attitudes of Germans. Evening orientation and short sleep duration were correlated with a higher overall score in socio-sexuality, as well as the three subscales of behavior, attitudes and desire (Randler, Freyth-Weber, et al., 2016; Randler, Jankowski, et al., 2016). Diaz-Morales et al. (2018) conducted a cross-cultural study and surveyed 1483 women from Poland, Spain, Germany and Slovakia. Again, statistical correction for age, relationship status and country showed that women with late sleep timing are less socio-sexually constrained. Thus, evening people are less restricted in their sexual encounters. Likewise, in this study, the influence of the personality variables of the Dark Triad has been corrected. The dark triad tracks subclinical personality pathology, such as narcissism, psychopathy, and Machiavellianism (Jonason, Li, Webster, & Schmitt, 2009). Although the dark triad is associated with both the evening type personality (Jonason, Jones, & Lyons, 2013; Rahafar, Randler, Castellana, & Kausch, 2017), and although the dark triad and evening type are both associated with reproductive success (Jonason et al., 2009), there were no correlations in the present study.

In general, the findings on evening types and reproduction fit well with the Maestripieri study (2014). In his study, both female and male night owls were single rather than in long-term relationships. Female night owls had average cortisol profiles and risk tendencies more similar to those of men than those of morning-type women. These results thus support the hypothesis that evening orientation is associated with psychological and behavioral traits that are crucial for short-term mating strategies (Maestripieri, 2014). So far, however, no one examined to what extent this had an effect on the reproductive fitness (the actual reproductive success measured as number of children). A current study at the University of Tübingen examined more 1800 people of both sexes in terms of reproductive success (number of children) and chronotype, and found that – in contradiction to the hypothesis – morning people of both sexes had a higher number of children (Kasaeian, Weidenauer, Hautzinger, & Randler, 2019).

Despite the evidence of a chronobiological aspect in sexual selection, there is further evidence that chronotype is actually an assortative trait when choosing a longer-term partner. Assortative mate choice has been demonstrated in many areas, such as in education, body height and religious attitudes. Two studies show that there is an assortative partner choice when it comes to chronotype (Randler, Barrenstein, Vollmer, Díaz-Morales, & Jankowski, 2014; Randler & Kretz, 2011). This shows, in contrast to the above hypothesis, that for longer-term bonds, similar partners are preferred. In fact this would be interesting research venue for agonistic force processes, with assortative mating on the one side and a preference for evening men on the other. Interestingly, the results of Jocz, Stolarski, and Jankowski (2018) from Poland showed no indication for assortative morning in chronotype. Also Hida et al. (2012) found no correlation between questionnaire scores in couples, but significant correlations between the sleep and wake-up times of a couple, and most pronounced at the mid-point of sleep center - a marker of the chronotype. Similar results were found by Gunn, Buysse, Hasler, Begley, and Troxel (2015) with Americans. Even though the questionnaire values between the couple did not correlate, the times when falling asleep and getting up were correlated. So at least for long-term relationships, a similar sleep timing seems to be beneficial.

The different activity profile of the chronotypes may also be the reason why morning types are more common for morning types. So, assortative mating may be simply a by-product, because evening people meet each other in the evening, and morning people in the morning. Due to the increasing online dating, there could be a shift towards lower correlations between the chronotypes of pair members because the mating place is no more outside but rather starts during the online dating which is at least somewhat independent of clock times. Although there is a daily mismatch of different chronotypes, Randler and Kretz (2011) found no evidence that relationship satisfaction was affected by such a mismatch.

In a special mate choice study, women were asked what chronotype they had themselves, what their partner, and which partner they would prefer (Randler et al., 2014). It was found that women preferred an even higher synchronicity, i.e., the ideal partner deviates slightly from the current partner. However, one may assume that this will be the case with almost every variable studied in partner choice questions. Interestingly, however, so far studies are missing that show that women generally prefer evening types. One reason might be that women would prefer more extraverted individuals, so as evening types usually had a higher extraversion than morning types (e.g., Adan et al., 2012; but see Randler, Schredl, & Göritz, 2017), the preference for evening types may be only a by-product of the covariance between eveningness and extraversion. This could possibly be done separately according to short-term or long-term relationships. One central question is whether this should be addressed by questionnaires or by some kind of experiments, e.g., a computer-based dating online system or by real choices. However, the corresponding experimental studies are not easy to do because many variables need to be controlled and only the chronotype should be varied. Unlike the appearance, the chronotype is a variable that is not easily visible like other facets of sexually selected traits. In a large survey study, Kasaeian et al. (2019) reported that evening people scored higher on a short-term mating strategy, while morning people scored higher on a long-term mating strategy. To address these limitations, future research should measure the reproductive outcome in total, i.e., in lifetime reproductive success as it is done in other mammals. However, reproduction in humans is strongly under anthropogenic selection because of the use of contraceptives, so future studies might look at the relationships in men and women, as well as parenting by comparing different chronotypes.

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Part III
Cognition, Motivation, and Emotion

Sleep in Social Cognition and Judgment

Brieann C. Satterfield, Adam C. Raikes, and William D. S. Killgore

Introduction

Humans are incredibly social beings, with multifaceted social interactions forming the basis of day-to-day life. The social brain is complex in that it allows us to (1) predict the actions of others based on their beliefs and desires and (2) understand the goals and intentions of others (U. Frith & Frith, 2010). Most of the complex communicative and behavioral interactions that take place during social exchanges occur outside of our conscious awareness based on automatic signals sent between two or more individuals that provide information about trustworthiness, friendliness, approachability, emotional state, mental state, etc. (C. D. Frith & Frith, 2007). Social cognition becomes much more complex when taking into consideration the deliberate and conscious signaling between two or more people that drives human communication and interaction. With the conscious awareness of sending and receiving social signals, we are able to learn from, and learn about, the people that we interact with (C. D. Frith & Frith, 2007). For example, direct social interactions can assist us in determining whether or not to trust another individual or direct behavioral observations can help us to determine the desires and intentions of another individual (C. D. Frith & Frith, 2007).

Social cognition is a broad concept that includes cognitive processes and structures that are used to guide our behavior in social situations, and can help us to better understand group behavior and dynamics, as well as bias and prejudices. In order to navigate the social world, we must be able to perceive and comprehend the behaviors and dispositions of ourselves and those around us and establish mental representations of each social character in the context of established interpersonal norms. Only then can we begin to shape our social interactions and behaviors (Frith

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and Blakemore, 2006; Van Overwalle, 2009). Because of its complexity, social cognition can be influenced by multiple factors. A powerful, but currently understudied factor that can have a dramatic effect on myriad aspects of social functioning is the amount and quality of sleep an individual has obtained. Unfortunately, in an attempt to keep up with the professional and social requirements of our modern, 24/7 society, sleep has become less of a priority and more of a nuisance for many people. In fact, insufficient sleep has become a public health epidemic (Center for Disease Control and Prevention, 2015). The National Sleep Foundation recommends adults sleep for 7 h or more per night (Bayon, Leger, Gomez-Merino, Vecchierini, & Chennaoui, 2014), however only 65% of adults in the United States meet that goal (Hirshkowitz et al., 2015). The general perception is that a missed night of sleep, or sleeping only a few hours a night regularly, is only a minor nuisance, or something to be bragged about. An extensive and rapidly growing literature clearly indicates that this is not the case. Sleep loss, either acute or chronic, impairs normal day-to-day functioning, including alertness, decision-making, self-regulation, and emotion perception — all of which can have direct implications for how we process social information. Personal and professional relationships can be adversely affected due to altered social cognitive processes, including implicit biases, reduced trustworthiness, the inability to make decisions (moral, ethical, financial), impaired teamwork, and impaired affective processing (emotional response and emotional recognition). People often fail to recognize the cognitive consequences of sleep loss and how this directly impacts the ability to recognize and appropriately respond to socially relevant situations.

Neural and Cognitive Consequences of Sleep Loss

In particular, sleep loss impairs a variety of executive functions, many of which also underlie social cognition. Following sleep deprivation, the prefrontal cortex (PFC), including the medial frontal cortex, shows reduced glucose metabolism which is not fully reversed following a single night of recovery sleep. This decline in prefrontal metabolic activity is thought to bring about many of the higher-order cognitive impairments associated with sleep loss (Thomas et al., 2000). Notably, the medial frontal cortex is thought to play a major role in facilitating social cognition (Amodio & Frith, 2006), and therefore a connection can be made between impaired social cognition and sleep loss. In addition to reduced glucose metabolism, sleep loss leads to reduced connectivity between the PFC and emotionally responsive regions, including the amygdala. The amygdala is one component of a network of structures important for processing emotionally relevant stimuli, and thus a disconnect with top-down inhibitory control imposed by the PFC can result in inappropriate emotional responses in a variety of social scenarios (Gujar, Yoo, Hu, & Walker, 2011; Yoo, Gujar, Hu, Jolesz, & Walker, 2007). Sleep loss also impairs response inhibition and inhibitory control mechanisms related to changes in activation within the ventral and anterior PFC (Chuah, Venkatraman, Dinges, & Chee, 2006). Individuals that are sleep deprived have reduced inhibitory control (Drummond, Paulus, & Tapert, 2006) and increased impulsive action (Demos et al., 2016), which can lead to hasty decisions and behaviors that can impact social interactions. Sleep loss also impairs the ability to make judgments and decisions (Killgore, Balkin, & Wesensten, 2006; Killgore, Grugle, & Balkin, 2012), in part due to elevated activation within regions of the ventromedial PFC (vmPFC), striatum, anterior cingulate cortex, and amygdala (Venkatraman, Chuah, Huettel, & Chee, 2007; Venkatraman, Huettel, Chuah, Payne, & Chee, 2011). These regions are also implicated in social cognitive and emotional processing (Adolphs, 2001; Amodio & Frith, 2006). In addition to impairments in executive functions, one of the hallmark characteristics of sleep loss is impaired vigilant attention (Lim & Dinges, 2008), which may lead to inattention to the most subtle social cues that can then impair the quality of social interactions.

The evidence on the cognitive effects of sleep loss is strong, and such effects presumably have downstream consequences on social cognition and judgment, however the literature examining the latter is sparse and often conflicting. The present chapter provides a concise and selective overview of the effects of sleep loss on social cognition and judgment. We first review the literature of social cognition, and how sleep loss influences biases, prejudices, morality, and ethical behaviors. Next, we review the negative consequences sleep loss has on social decision-making, including prosocial behaviors such as trust, bargaining, altruism, and team decision-making. Last, we briefly review how sleep loss impacts affective processing, emotion regulation, and emotional responding and how impaired emotional functioning impacts social interactions. The chapter concludes by highlighting the critical uncertainties looming in the available literature, and explores the bi-directional relationship between sleep loss and social cognition. Further, we discuss the needs and direction of future research in the area of sleep loss, social cognition, and judgment.

Social Cognition

While social cognition is a broad concept, it includes the process in which humans understand and perceive themselves and others in social situations, and how these representations are used to guide human behavior, such as social perceptions (biases and prejudices), social interactions, trust, and conflict, as well as the recognition of emotions in others and individual emotional responses. As described above, sleep loss has significant effects on inhibitory control (Demos et al., 2016; Drummond et al., 2006), which can lead to increased instances of discriminatory behavior, impaired moral judgment, and unethical behavior. The mental processes that underlie much of social cognition and its downstream behaviors have been divided into two systems. This concept of dual-system process has been built upon the notion that cognitive processes either manifest within an individual automatically (System 1) or are deliberately controlled by the individual (System 2), two processes that often compete for control (Gawronksi & Creighton, 2013). System 1 emphasizes cognitive processing that is reflexive and impulsive and often uses heuristics, while

System 2 utilizes cognitive processing that is systematic and reflective (Evans, 2008). The heuristic automatic processing of System 1 is quick, implicit, unconscious, cannot be voluntarily stopped, and requires very few cognitive resources. Conversely, the analytical systematic processing of System 2 is slow, explicit, conscious, can be voluntarily stopped, and requires substantial cognitive resources (Evans, 2008; Gawronksi & Creighton, 2013). Recent evidence suggests that individuals rely heavily on heuristic processing when faced with sleep loss, rather than use of complex cognitive strategies to make decisions and judgments (Engle-Friedman et al., 2018). The reliance on heuristics may be due to, in part, the reduced cognitive capacity brought about by sleep loss, including impairments in several areas of executive function necessary for efficient System 2 cognitive processing. Such limitations may then push sleep-deprived individuals to compensate by utilizing heuristic, simple strategies. Such impairments and compensatory strategies can undermine the cognitive processes involved in social cognition, and ultimately impact how an individual responds and behaves in the social world.

Biases and Prejudices

One key aspect of social interaction is how we perceive and interact with individuals of different races, ethnicities, religions, age, or even gender. Discrimination in socially relevant contexts can lead to inappropriate and insensitive behaviors that may have negative consequences on the overall social interaction, and these behaviors are in part mediated by our ability to engage self-regulatory processes. However, self-regulation and inhibitory processes are regulated by the PFC, a region of the brain that is significantly affected by sleep loss (Thomas et al., 2000). Significant reduction of inhibitory control can be especially problematic in occupations that require frequent or multiple social interactions and decision-making in critical and stressful situations (i.e., emergency responders, military personnel, police officers, airline pilots, medical personnel). Impaired self-regulatory and inhibitory processes due to sleep loss can cause individuals to react to various social and professional situations in ways that may be atypical or out of character, such as demonstrating biases and prejudices that would not be expressed when well-rested.

In most modern civilized cultures, it is generally unacceptable to overtly express negative biases or prejudices against other individuals. While overt prejudices and biases do occur, they are typically not sanctioned and the vast majority of people would not describe themselves as bigoted or prone to prejudicial attitudes and behavior. Nonetheless, research has shown that most individuals do indeed have underlying implicit biases that influence behavior in a subconscious manner, even when those attitudes may go against conscious beliefs and overt statements to the contrary (Greenwald & Krieger, 2006). A large body of evidence suggests that, when uncovered using sophisticated methods, a large proportion of people harbor unconscious negative attitudes toward particular groups of people, and that they are often completely unaware of these biased attitudes. In early work, Bodenhausen

(1990) used stereotypes as judgmental heuristics to explore how circadian variations play a role in the use of biased beliefs when making judgments in social situations. The theory behind this approach stems from the thought that sleep loss and circadian variation may deplete resources that are necessary for maintaining motivation and information processing capabilities, including inhibitory control. Rather than engaging in resource and motivation-expensive systematic thought (i.e., System 2), individuals may rely on inherent biases to make social judgments when faced with sleep loss (i.e., System 1). Using a subjective measure of circadian preference (i.e., Morningness-Eveningness Questionnaire) and two judgment tasks administered in the early morning or late evening, Bodenhausen (1990) found that stereotypes and judgmental heuristics were used more often when the acrophase (i.e, circadian peak) of the subject and the task administration time were conflicting. Morning types tended to make more stereotypical judgments in the evening, whereas the opposite was true for evening types (Bodenhausen, 1990). This study was among the first to demonstrate a need to consider circadian timing and fatigue in the study of social cognition. Making social judgments when cognitive processes, including executive functions, are at a suboptimal state (i.e., circadian misalignment or excessive sleepiness) may drive an individual to rely on cognitive shortcuts, such as heuristics, to make social judgments. The use of such shortcuts introduces an increased tendency to impart implicit biases (Ghumman & Barnes, 2013).

Our lab recently used the Arab-Muslim names Implicit Associations Task (IAT), a task designed to measure individual implicit biases towards Arab-Muslim names versus names of "Other People" (Alkozei et al., 2017; Greenwald, McGhee, & Schwartz, 1998), to investigate how sleep loss impacts these implicit biases. The IAT was administered at the end of a three-week sleep restriction period (i.e., 4-hours sleep per night), and following a three-week period of normal sleep (i.e., 8-hours sleep per night). Chronic sleep restriction unmasked an implicit anti-Arab-Muslim bias that was not apparent in the well-rested control condition (Alkozei et al., 2017). Further, subjective sleepiness is highly correlated with the tendency to engage in prejudicial behavior that is, in part, mediated by underlying implicit biases that are unmasked in the face of sleep loss (Ghumman & Barnes, 2013). These findings are in line with the reduced inhibitory control that often accompanies sleep loss (Chuah et al., 2006; Drummond et al., 2006), and have important real-world implications, such as an increased likelihood of negative, and even hostile, interactions with individuals of different races, ethnicities, or gender if sleep is lacking.

During the aforementioned study (Alkozei et al., 2017), sleep-restricted subjects also showed a tendency to discriminate against (i.e., detain more) individuals with negative facial features (e.g., aggressive, threatening) when asked to determine whether a passenger should be allowed to board an airplane or whether the passenger should be detained based on assessment of only their facial features. Further, subjects with higher IAT bias scores detained more individuals with higher rated negative characteristics (i.e., threatening) (Alkozei et al., 2018). Taken together, these findings suggest that sleep loss (1) impairs the ability to inhibit implicit biases, (2) increases responses to potential threat in facial cues, and (3) may also influence actual decisions in response to those biases and perceptions. While the ability to identify threatening individuals based on negative features may be advantageous in most circumstances, especially when sleep-restricted, it may also hinder the ability to act appropriately in a variety of complex social situations leading to discriminatory behavior.

Morals and Ethics

We all face moral and ethical decisions nearly every day. Some research evidence suggests that our ability to make these decisions may be adversely affected during periods of sleep loss. Moral dilemmas arise when there is direct conflict between personally held principles, such that obeying one principle will lead to disobeying another. This is true in the classic runaway trolley scenario: There is a runaway trolley that will hit and kill five people if it is not stopped. However, the only way to stop the trolley is to push a stranger off a nearby footbridge overlooking the trolley tracks, stopping the trolley, killing the stranger, but saving the other five people. The dilemma then arises: do you push the stranger to save five lives at the expense of one (Greene, 2001)? In difficult situations, we often rely on our stable moral principles and beliefs to guide our actions and decisions, however the ability to make such decisions appears to become increasingly difficult with sleep loss. In fact, emotionally arousing moral personal dilemmas, like the trolley scenario, are the most difficult for an individual to resolve.

Moral Judgment

Moral judgment encompasses the ability of an individual to assess right and wrong and to make an appropriate decision when faced with a moral dilemma (Blais & Thompson, 2013). The first step of any moral judgment is moral awareness (i.e., the appropriate identification of a moral issue) which initiates an individuals' realization of a moral dilemma and subsequent action (Blais & Thompson, 2013; Jones, 1991). However, reduced sleep duration results in degraded moral awareness (Barnes, Gunia, & Wagner, 2015), thus leading to an impaired ability to make moral and ethical decisions. Further, moral judgments that are both emotionally arousing and personally relevant lead to increased activation within the medial PFC, a region that is both essential for emotionally guided decision-making and substantially impaired during sleep loss (Greene, 2001; Thomas et al., 2000).

The earliest study to examine moral judgments in the context of sleep loss presented subjects with a series of moral and non-moral dilemmas, similar to the trolley dilemma described earlier, at rested baseline and again following a 53 h total sleep deprivation period (Killgore et al., 2007). While three-nights of sleep deprivation did not affect the decision-making process, it did significantly slow responses to moral decisions that were high in emotional conflict. Further, sleep-deprived individuals tended to favor decisions that were more utilitarian in nature, often violating their own beliefs compared to decisions made during the rested state (Killgore et al., 2007). Not only does acute sleep deprivation result in impaired moral judgment and reasoning, evidence also suggests that chronic sleep restriction can have a negative impact on moral reasoning. On the other hand, when only one night of sleep was missed, response time to *impersonal* moral judgments became shorter, but there was no significant impact on moral personal dilemmas following sleep deprivation (Tempesta et al., 2012). Finally, when sleep is reduced, principle-oriented moral reasoning is degraded and individuals tend to shift towards more rules-focused and self-oriented moral decisions, while higher-level principle-oriented reasoning becomes more difficult (Olsen, Pallesen, & Eid, 2010). Thus, lack of sleep appears to have a degrading effect on the ability to reason about moral situations.

Ethical Conduct

Ethical decisions are those that are morally acceptable by the general population and legal by law (Jones, 1991). Most research into the relationship between ethical conduct and sleep loss is rooted in theories of self-regulatory resources and the Ego Depletion model (Barnes, Schaubroeck, Huth, & Ghumman, 2011; Christian & Ellis, 2011). These theories suggest that self-regulation or self-control are maintained by finite resources that are depleted over time and with engagement in acts of self-control (Barnes et al., 2011), and are thought to be replenished with sleep (Baumeister, Muraven, & Tice, 2000). Unethical behaviors then arise when these resources are depleted as an individual is no longer able to exert self-control and resist temptations or other risky behavior. As described above, glucose metabolism in the PFC is reduced following a single night of sleep deprivation (Thomas et al., 2000). Although not empirically tested, this concept of Ego Depletion may be due to altered prefrontal functioning and is thought to underlie some of the cognitive impairments, including self-control and self-regulation, attributed to sleep loss and may contribute to the manifestation of unethical behavior.

Barnes et al. (2011) conducted a series of studies to examine the relationship between sleep loss, impaired self-control, and unethical behavior. Self-reported sleep duration was positively correlated with time spent on a cognitively demanding task, suggesting that lack of sleep is associated with increased resource depletion. Further, individuals with shorter sleep duration showed increased cheating behavior by over-reporting their performance and individuals with poor sleep quality had lower-rated ethical behavior in the workplace (Barnes et al., 2011). While self-reported sleep quantity was not directly associated with unethical behavior, the level of cognitive fatigue appears to act as a mediator between sleep and ethical conduct (Barnes et al., 2011). Further, ethical behavior, may in part, be driven by chronotype (e.g., morning lark vs. night owl). In one study, morning people tended to make more ethical decisions in the morning, and evening people tended to make more ethical decisions in the evening, both in line with their respective chronotype (Gunia, Barnes, & Sah, 2014). Taken together, these findings suggest that reductions in self-reported sleep duration and sleep quality can negatively impact ethical decision-making.

Social Decision-Making

Social cognition, as mentioned above, is a broad term used to describe how individuals think in socially relevant contexts. Here, we turn to a more specific aspect of social cognition – social decision-making. The nature of human behavior frequently places individuals in complex social environments during which important decisions must be made individually or in groups. Decision-making requires an individual to identify and process the available options, and choose the best course of action, while at the same time considering how the decision will affect others and oneself (Rilling & Sanfey, 2011).

Prosocial Behaviors

Prosocial behaviors (i.e., behaviors that benefit others) encourage positive interactions, and are important for making decisions in a social environment. The study of behavioral and neural correlates of social interactions such as trust, altruism, fairness, and bargaining (i.e., prosocial behaviors) (Rilling & Sanfey, 2011) comes from tasks that are rooted in game theory. Game theory utilizes intricate models to assess situations in which individuals must use complex reasoning in order to make decisions and understand the motivations of other individuals (Sanfey, 2007). These tasks reliably activate areas associated with decision-making (e.g., caudate nucleus) in response to errors that guide reciprocal actions, activate areas associated with emotion (e.g., anterior insula) in response to negative interactions (Rilling, King-Casas, & Sanfey, 2008), and activate the dorsolateral PFC (dlPFC) in response to acceptance of unfair offers (Sanfey, 2003). The PFC is particularly vulnerable to the effects of sleep loss (Thomas et al., 2000), thus resulting in difficulties with abstract thought, mental set shifting, perspective taking, inhibitory control and emotion regulation, which may all contribute to deficits in social interactions and decision-making.

While extensive research has examined the effects of sleep loss on individual decision-making (Harrison & Horne, 2000; Killgore, Balkin, & Wesensten, 2006; Killgore, Grugle, & Balkin, 2012; Satterfield & Killgore, 2019), little work has focused on decision-making in social contexts. Three games have been used to assess prosocial behaviors in the context of sleep loss: (1) the Ultimatum game, (2) the Dictator game, and (3) the Trust game. In the Ultimatum game one person is assigned as the proposer and the other as the responder. The proposer must decide how to divide a given amount of money with the other player. The responder must then accept or reject the offer. If they accept, the money is divided as proposed, but if they reject both players receive nothing (Güth, Schmittberger, & Schwarze, 1983). In the Dictator game, the role of the responder is removed and the decision to divide the money is solely that of the proposer (Forsythe, Horowitz, Savin, & Sefton, 1994). In the Trust game, the proposer decides how much money to initially share with the responder (i.e., a measure of trust/altruism). The decided amount is then tripled and the responder must then decide how much to give back to the proposer (i.e., trustworthiness). One study examined the effects of 36 hours of sleep loss on these three tasks (Anderson & Dickinson, 2010). Results showed that sleep deprivation caused subjects to reject higher monetary offers and trust the other player less, even when it resulted in lower payoffs for themselves. This suggests that when compared to their well-rested behavior, sleep-deprived subjects were more comfortable with aggressive bargaining and less willing to accept unfair offers, even at the expense of their own monetary benefit. Further, sleep loss may increase paranoid thought processes (Kahn-Greene, Killgore, Kamimori, Balkin, & Killgore, 2007) and the fear of being taken advantage of, and thus causes individuals to be less trusting of others (Anderson & Dickinson, 2010).

The same prosocial decision-making tasks were also assessed under both rested and partial sleep-restricted conditions (Dickinson & McElroy, 2017). Dickinson and McElroy (2017) found that sleep restriction lead to decreased proposer giving in the Dictator game, suggesting that sleep restriction leads to reduced altruistic actions. Similar to findings during sleep deprivation, subjects showed decreased levels of trust during the Trust came (i.e., reduced amount shared with the responder) and reduced trustworthiness (i.e., reduced amount given back to the proposer) (Dickinson & McElroy, 2017). Taken together, findings from both sleep deprivation and sleep restriction studies suggest that prosocial behaviors, including bargaining, trust, and altruism, are significantly reduced. This may then have downstream consequences leading to the potential for impaired social interactions and decision-making in real-world scenarios.

Team Decision-Making

In addition to its adverse effects on one-on-one interactions and associated prosocial behaviors, sleep loss can have direct consequences on team-dynamics and decision-making. Teamwork is important in several occupations that require individuals to work in a collaborative environment at various hours of the day in around-the-clock operations, including military personnel, emergency responders, medical personnel, police officers, and firefighters. Further, these occupations require focus and critical decision-making skills in fast-paced, and often stressful situations. Impairment in team communication and decision-making can have catastrophic, and even far-reaching consequences. The unique nature of teams also means that the distribution of tasks between group team members will vary depending on the situation and environment (Barnes & Hollenbeck, 2009), and thus individual performance also plays a key role in team decision-making. Social psychology explains individual performance underlying team decision-making with two phenomena – group motivational losses and group motivational gains, which are combined in the Collective Effort Model (Baranski et al., 2007). Group motivational losses are typically described in terms of the social loafing effect, or the tendency of an individual to work less in a group compared to when alone (Latané, Williams, & Harkins, 1979). Conversely, motivational gains occur when an individual puts forth more effort in a group setting compared to when alone. The collective effort model thus captures the interaction between group performance, individual performance, and the associated outcomes (Baranski et al., 2007).

Baranski et al. (2007) conducted an overnight sleep deprivation study to investigate the effects of sleep loss on team decision-making. They used a computer simulated Navy surveillance and threat assessment task administered regularly across time awake. For each task bout, subjects completed four conditions during which they (1) worked in groups of four, with one leader and three subordinates to make individual threat assessments that were ultimately decided by the leader, (2) worked again in groups of four, with each subordinate having distinct responsibilities from the others, (3) repeated the task with feedback provided about accuracy of the threat assessment, and (4) performed the task individually. Overall, the number of errors committed increased and processing times slowed with increasing time spent awake. Further, solo performance was worse compared to overall team performance, suggesting that sleep loss favors motivational gains, at least in situations where team members must interact indirectly. Sleep loss also had a positive effect on team dynamics, in that teams demonstrated increased camaraderie and solidity as the sleep deprivation period progressed (Baranski et al., 2007). However, a study that simulated Navy watch schedules (i.e., circadian misalignment) across four consecutive days found that while team cohesion increased across repeated administrations of a communication task, there was a shift towards social loafing (i.e., motivational losses) across study days and increasing sleep debt (Sparrow et al., 2015). Taken together, these findings demonstrate that while team cohesion appears to increase with the time spent working together, it is also important to consider the team environment, whether it be face-to-face, or indirect communication, and the overall composition of the team.

Affective Processing

Another key aspect of social cognition is the ability to recognize the emotions of others and oneself. Prosocial behaviors and interactions in dynamic group environments often necessitates the identification of complex and sometimes ambiguous emotional responses by others and to calibrate personal emotional responses in appropriate ways. The inability to recognize and respond appropriately to the emotions of others can lead to a breakdown of team dynamics, inhibit prosocial behaviors, and create interpersonal conflict. As with prosocial behaviors and team-based decision-making, the literature in this area demonstrates that sleep deprivation diminishes the capacity to recognize some emotions, to identify emotion-related social cues (e.g., sarcasm), and to calibrate individual responses in negatively valenced scenarios. While a complete review of the relationship between sleep loss and emotional processing is beyond the scope of this chapter, we briefly review some key findings that relate to social interaction (see Goldschmied, chapter "How Sleep Shapes Emotion Regulation", this volume, for review of sleep and emotion regulation).

Sleep restriction and deprivation have wide-spread effects on the emotional awareness and responsiveness of the individual. Sleep loss leads to impairments in individuals' understanding and perceptions of their own emotions (Killgore et al., 2008), poorer overall moods (Dinges et al., 1997; Lingenfelser et al., 1994; Talbot, McGlinchey, Kaplan, Dahl, & Harvey, 2010; Tempesta et al., 2010), a propensity to view neutral stimuli as negative (Tempesta et al., 2010; Tempesta, De Gennaro, Natale, & Ferrara, 2015), increased perception of, and emotional responsiveness to, both neutral and negative events (Simon et al., 2015; Talbot et al., 2010; Zohar, Tzischinsky, Epstein, & Lavie, 2005), and increases the likelihood of responding poorly (e.g., aggression, assigning blame, failing to take responsibility) to frustrating situations (Kahn-Greene, Lipizzi, Conrad, Kamimori, & Killgore, 2006; Krizan & Hisler, 2018). These effects on the individual collectively impair social interactions, making the individual less likely to be aware of the emotions s/he is experiencing, have a poorer overall mood, and increasing the likelihood of responding to interactions negatively. Furthermore, sleep loss leads to lower emotional expressiveness to positive stimuli (Minkel, Htaik, Banks, & Dinges, 2011), plausibly impeding social interactions by limiting responsiveness to positive interactions (see Sundelin and Holding, chapter "Sleep and Social Impressions", this volume).

With respect to recognizing the emotions of others, findings are inconsistent. Studies on emotion detection generally rely on tasks in which individuals view photographs or computer-simulated images of facial expressions that are either "pure" (a single emotion) or morphed to be more ambiguous with blends of two or more emotions. Across the literature, sleep deprivation impairs the speed and accuracy of recognizing facial emotions, particularly when the facial expression is ambiguous, though the specifically impaired emotions vary from study to study (Cote, Mondloch, Sergeeva, Taylor, & Semplonius, 2014; Crönlein, Langguth, Eichhammer, & Busch, 2016; Huck, Mcbride, Kendall, Grugle, & Killgore, 2008; Killgore, Balkin, Yarnell, & Capaldi, 2017; Maccari et al., 2014; van der Helm, Gujar, & Walker, 2010). Furthermore, sleep deprivation biases individuals to view facial expressions as being threatening, regardless of the conveyed emotion (Goldstein-Piekarski, Greer, Saletin, & Walker, 2015), impairs individuals ability to empathize with the emotional states of other individuals (Guadagni, Burles, Ferrara, & Iaria, 2014), and slows the ability to detect sarcasm delivered from others (Deliens et al., 2015).

Cumulatively, these findings highlight that sleep loss impairs the ability to quickly and accurately recognize and respond to environmental, intra-, and interpersonal affective cues. Two complementary explanations are possible for these effects. First, sleep deprivation leads to increased activation of the emotional salience system, including the amygdala, when presented with negative stimuli (Yoo et al., 2007). Second, sleep loss appears to impair prefrontal activation (Thomas et al., 2000) and leads to decreased (pre)frontal connectivity to both negative and neutral stimuli (Simon et al., 2015; Yoo et al., 2007). The reduction in frontal connectivity, in turn, may lessen the emotional activation threshold, yielding an increased propensity to respond to neutral and negative stimuli with an emotionally mis-calibrated response. However, further work is needed in this area to better explain the conflicting responsiveness to specific emotions and ambiguous situations.

Exemplar: Marital Relationships

Marriage and cohabitation can serve as a prime exemplar of social and affective processes that are affected by sleep loss. Inherent in these relationships are the needs for prosocial behaviors, team decision-making, emotion recognition, and individual emotional regulation. All of these processes, as noted, are detrimentally influenced by sleep loss (Killgore et al., 2008; Simon et al., 2015; Tempesta et al., 2010, 2015; Yoo et al., 2007; Zohar et al., 2005). From a research perspective, married couples are also a convenient sample, given their daily interactions (for a review of sleep and close relationships, see Gunn and Eberhardt, chapter "Sleep in the Context of Close Relationships", this volume).

Prior work demonstrates that, within these relationships, poor sleep and sleep loss are associated with more disagreements (McFadyen, Espie, McArdle, Douglas, & Engleman, 2001), greater hostility (Gordon & Chen, 2014; Hasler & Troxel, 2010), increased incidences of interpersonal conflict, more negative partner interactions (Hasler & Troxel, 2010), decreased empathic accuracy (Gordon & Chen, 2014), less successful conflict resolution (Gordon and Chen, 2014), and lower relationship satisfaction (Strawbridge, Shema, & Roberts, 2004). These effects are present when both individuals experience sleep loss (Wilson et al., 2017). However, Gordon and Chen (2014) demonstrated sleep loss on the part of one partner can influence not only his/her own abilities but also those of the other partner. Additionally, there is possibly a bidirectional relationship creating a feedforward-feedback loop where poor daytime partner interactions leads to poorer nighttime sleep (Hasler & Troxel, 2010; Prigerson, Maciejewski, & Rosenheck, 1999), ultimately contributing to poor next-day interactions (Gordon & Chen, 2014; Wilson et al., 2017). Collectively, these findings highlight the need for adequate, high-quality sleep in the maintenance of close interpersonal and social relationships.

Critical Uncertainties and Future Directions

While the emerging findings presented here provide a compelling view that insufficient sleep impairs numerous aspects of social cognition, interaction, and judgment, there remain uncertainties that must be addressed. First, the majority of studies relating sleep loss to social cognition – including prosocial behaviors, decision-making, and affective processing – are conducted using acute bouts of total sleep deprivation of varying lengths (e.g., 26.5-h in Killgore et al., 2017 to 55-h in Cote et al., 2014) in a laboratory setting. While experimental control is high under these scenarios, they do not likely reflect the typical real-world sleep patterns or experiences routinely encountered by most people. It is unlikely, for instance, that individuals regularly engage in 24+ hour bouts of continuous sleep deprivation unless dictated by extreme work conditions (e.g., medical residents, military Service members).

The greater reality is that many individuals simply fail to get adequate, high-quality sleep on a regular basis (Bayon et al., 2014; Hirshkowitz et al., 2015) for a variety of reasons, including neurological conditions, work and family stresses, and poor sleep hygiene. Compounding this issue, circadian disruptions – including shift-work, military watch cycles that do not conform to traditional 24-hour days, trauma-induced circadian shifts – are commonplace. Current studies fail to capture the effects on social interactions in the individuals with atypical sleeping patterns or chronic partial sleep restriction. However, these conditions reflect the ecological landscape to which we need to be able to generalize research findings. Therefore, there is the need for focused research identifying the relationships between social cognition, interaction, and judgment with sleep loss conditions that better reflect the sleep loss patterns experienced outside of the lab. This necessarily must include considerations not only for the types of loss experienced (as noted, extended total sleep deprivation is uncommon relative to repeated partial sleep loss) but also the magnitude of loss (single sessions extending for more than 24 hours vs. repeated losses of several hours).

Another issue that affects generalizability of research studies is the fact that thus far, most prosocial, decision-making, and emotion recognition tasks have typically been conducted individually on a computer (e.g., viewing faces on a computer; playing a prosocial game on a computer) or via self-report (Anderson & Dickinson, 2010). Thus the effects of sleep loss on these essential social abilities are only broadly generalizable to performing tasks on a computer or to conditions involving one modality of perception. Little research has examined the effects of face-to-face interactions. Additionally, no studies to date have examined team (3+ person) dynamics when one or more individuals experience sleep loss of some kind. Thus, the ecological validity of this area of research is severely lacking at present. This gap in ecologically valid research has very practical implications for military units and emergency response teams that necessarily undergo sleep loss, including sleep deprivation, and must function harmoniously as a unit to accomplish a mission. The absence of literature on team dynamics and sleep loss is a critically missing aspect of the literature. As discussed throughout this chapter, there is strong and compelling evidence that insufficient sleep affects many of the core features of social cognition, but future work will need to begin to expand these findings beyond the sterile confines of the laboratory and incorporate more realistic, ecologically valid, and broadly applicable situations.

In light of the above-mentioned gaps in the literature, there is further work to be done to clarify the relationship and reciprocal effects of sleep and social cognition (see Gordon, Mendes, and Prather, chapter "Sleep and Social Processes", this volume). In particular, laboratory research in this area needs to evolve beyond traditional paradigms (laboratory-based sleep deprivation) to more naturalistic settings and sleeping conditions. While sleep deprivation may be a necessary aspect of certain work environments or living situations (e.g., parents with young children), many more individuals experience chronic partial sleep loss as a regular part of life. Many also engage in shift work that results in circadian disruptions. Studies that leverage these various sleeping habits and daily rhythms will provide insights that are particularly generalizable to current social contexts.

Furthermore, future research would benefit from studies that employ testing methods other than computer-based, individualistic responses. Prosocial behaviors are a necessary component of harmonious functioning within small groups and teams but these behaviors cannot be adequately quantified when individuals complete prosocial behavior tasks on a computer in social isolation. Face-to-face interactions and team dynamics must be quantified in a more thorough and systematic way. Additionally, team dynamics when one or more individuals experience sleep loss, and particularly when there is a hierarchy within the group (e.g., sleep loss in leadership vs. sleep loss in non-leadership), has implications within various sectors of work, including military service (for review of sleep and organizational behavior, see Rogers, Budnick, and Barber, chapter "Sleep and Social Behavior in Organizations: Implications for Task Performance", this volume).

By expanding current research efforts in these ways, we can gain a more comprehensive view of how sleep may impact interpersonal relationships and interactions on a day-to-day basis. By quantifying these effects, it may be possible to educate individuals on the impact and indicators for unintentionally altered social functioning as a result of insufficient and inadequate sleep. Furthermore, such educational efforts and targeted interventions could be broadly used to improve social and martial relationships, work environments and team dynamics, as well as overall job productivity.

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Sleep's Role in Effortful Performance and Sociability

Mindy Engle-Friedman and Steven G. Young

How we perform at home, at work, with our families and with others is a function of many factors. Often the role of sleep in those activities is overlooked. Although people may anecdotally recognize that poor sleep makes them ill-tempered or easily distracted, the full scope of impairment associated with lack of sleep is rarely appreciated. Yet, as a growing literature shows, sleep quality and duration affect the ability to engage in effortful cognitive and behavioral tasks, including navigating and understanding social interactions. In addition, since sleep need varies, individual differences also impact the effect sleep or sleep loss has on our decisions to expend energy and on what activities those critical resources will be used. In the present chapter, we provide an overview of research exploring the role of sleep in the availability and use of psychological resources and energy, both in performance domains (e.g., academic and workplace) and in social behavior. Additionally, we discuss open questions and future research directions with an emphasis on gaps in our knowledge of how sleep impacts human performance and sociability.

Sleep, Resources, and Effort

The ability to perform to capacity across many domains of daily life seems to be determined, at least in part, by how much sleep we have accumulated over the course of the night, the continuous and uninterrupted nature of that sleep, and longer-term cumulative sleep debt. This chapter will review the role of sleep in performance

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capacity, how humans attempt to compensate for the challenges to capacity caused by sleep loss, the energetic costs of social behavior, how sleep loss influences that behavior, and the possible physical substrates referred to as resource capacity.

When an organism applies exertion beyond basic functioning or chooses alternative strategies to maintain acceptable levels of performance, that exertion is referred to as effort. This chapter will provide an overview of research across disciplines that seeks to identify how sleep affects the capacity for performance, access to resources necessary for performance, and behavioral and subjective effort responses to the absence of sleep. One area of great behavioral importance is social behavior. This chapter will highlight the role of sleep on observable social behavior, with an emphasis on social actions that typically require effort and explicit cognition. Lastly, the cortical, physiological and neurological reactive to sleep loss that influence behavioral sequelae will be considered.

Effort

Before understanding how sleep quantity and quality moderate effort and performance, we should first define *effort*, a concept that has a long history in psychology. For example, early discussions centered around whether effort (conceptualized as attending to and thinking about a stimulus) was a purely "intellectual" endeavor detached from physical limitations, or instead an embodied process subject to fatigue and resource availability (Dewey, 1897). The intervening years have settled this particular debate and contemporary examinations of effort define the term as the challenge an organism experiences in allocating attention to a task and engagement in activity that is bounded by physiologically-based processing capacity (Kahneman, 1973). Each activity or task we engage in has unique demands of attention and information processing. Each organism has a limited processing capacity that varies from moment to moment depending on the state it is in (Hockey, 1997; e.g., Todd, Hertwig, & Hoffrage, 2015). The organism or system operates under automatic control when its basic information processing needs are met, the demands on the system are low, and strain is not detected. In these benign situations, effort is expended but the resources needed are matched by those available. However, as situational variables like time pressure, task duration, and non-task distractions place demands on the organism, additional resources are needed for basic information processing and to maintain performance (see Foster & Lavie, 2009; Lavie, 2005). In other words, maintaining speed on a task, persisting for a long time on task, or fighting to maintain attention in the face of competing demands all increase the effort needed to perform a task. If resources are unavailable or if they become depleted, the person will become fatigued or exhausted, reduce task engagement and performance quality, and eventually abandon task-related action (Ackerman, 2011). Interesting, highly stimulating and competitive tasks that offer feedback can maintain engagement for at least a short period of time (see Horne & Pettitt, 1985; Wallerstein, 1954; Wilkinson, 1961).

The extent to which effort is allocated to task demands exists both as a subjective state and a physically grounded and observable variable. Subjective effort is the sense of having exerted oneself beyond the basic demands of the task and can be reported consciously during or after task performance (Knicker, Renshaw, Oldham, Simeon, & Cairns, 2011). On the other hand, objective behavioral effort is determined using observable and measurable outcomes, including speed of performance, work rates, number of problems attempted and choice of tasks of various degrees of difficulty.

Sleep Loss Leads to Increases in Subjective Effort

Sleep loss both triggers a change in capacity to perform at optimal levels and as well as the perception of increased task difficulty. The brain seems to determine the resources needed to complete the task, assesses whether those resources are accessible, judges the task in relation to available resources and decides whether resources should be used or conserved for higher priority tasks. While the comparison of task demands and resource availability are likely made at the cortical level, the subjective awareness of some elements of the process are available including the extent to which the task feels challenging and the person's interested in engaging in it. In one study, even 1 day of sleep loss caused college students to rate a reading task as significantly more difficult and requiring more time (i.e., more effortful) when compared with students who had their typical complement of sleep (Engle-Friedman, Hayrapetyan, Orodel, & Loshak, 2018). Following 2 days of total sleep loss and the requirement to work continuously, participants perceived that the work load had increased and reduced their walking pace (Rodgers et al., 1995) and physically fit athletes who experienced fatigue judged that the task had become more difficult (Proffitt, 2006). Adolescent athletes who reported that their previous night's sleep was less than what they needed to feel rested reported poorer mood and reported that their sports practice drills were more difficult, and the athletes with the most frequent awakenings preferred the simplest practice exercises (Engle-Friedman, Palencar, & Riela, 2010). Collectively, these examples illustrate that sleep deficits produce changes in subjective effort, including estimates of how long a task takes, how much work the task requires, and task difficulty. Additionally, these increased estimates of task difficulty have motivational and affective consequences.

Sleep Loss Leads to Reductions in Objectively-Measured Effort

Laboratory-based objective indications of decreased effort following sleep loss include reductions in work rates (e.g. Chmiel, Totterdell, & Folkard, 1995) and the number of solutions participants have attempted in response to experimenter-generated problems (e.g. Blagrove, Alexander, & Horne, 1995). The choices people make about alternatives requiring different levels of effort also change following sleep loss. When participants can select tasks from those of varying difficulty levels they choose simpler math addition problems (Engle-Friedman et al., 2003), non-academic tasks that require little effort (Engle-Friedman & Riela, 2004) and only the high priority tasks when offered low and high priority choices (Hockey, Wastell, & Sauer, 1998). Time spent reading for school, dressing neatly and dressing fashionably is reduced following a night of lost sleep (Engle-Friedman et al., 2003; Engle-Friedman & Riela, 2004) and participants are more likely not to follow the task rules, possibly taking an expeditious task completion strategy thereby limiting expended energy and effort (Nilsson et al., 2005).

The use of heuristics or mental short-cuts also increases with sleep loss. In comparison to students who experienced their typical sleep, those with no sleep were more likely to skip instructions. They were also more likely to use the what-is-beautiful-is-good heuristic by rating as poor quality a consumer item with a favorable written review but which was physically less attractive. Those with the greatest reported fatigue were most likely to rate positively the physically attractive consumer item and negatively rate the unattractive consumer item despite the content of the consumer review (Engle-Friedman et al., 2018).

After Sleep Loss Effort Is Maintained for Shorter Periods of Time

Effort can be maintained during sleep loss if the circumstances are right. Task elements that can help maintain effort are incentives and feedback (e.g. Horne & Pettitt, 1985; Steyvers & Gaillard, 1993), the participant's interest in the task and assessment of the task's relevance. Games that involve sensory stimulation, competition or motoric output or those that involve electric shock provide further examples of contexts that lead to persistence even in the face of sleep deprivation. When the sleep deprived person is aware that the last session of the assessment is approaching, often following the study's most prolonged sleep deprivation period, an increase in task performance and effort is commonly observed (Angus & Heslegrave, 1985).

The performance facilitation by these factors, however, is limited. Feedback, for example, shortened reaction time but did not improve accuracy in one study (Steyvers, 1987) and in another study, incentives could not maintain baseline performance past 36 hours of sleep deprivation (Horne & Pettitt, 1985). These effects illustrate that eventually the energetic cost of sleep deprivation will overcome situational factors that encourage persistence.

Theoretical and Applied Value of the Study of Sleep Loss, Effort and Performance

Investigations of sleep and effort provides both theoretical and applied benefits. Understanding of the substrates of capacity for performance and how sleep impacts those substrates can help us protect resources vital to our optimal functioning. It also offers both micro and macro assessments of how effort is effected and performance is impacted when sleep is lost. Experimental work in this field helps identify the compensatory responses and the interaction between various behavioral responses, as well as the interactions of genetic, cortical, neurological, physiological and perceptual systems under sleep loss conditions.

Loss of Sleep Is a Ubiquitous Problem

Nearly 70% of adults in the US believe they sleep fewer hours than they need averaging a weekly 6.5 hours but feel they need 7 hours to function optimally (National Sleep Foundation, 2014). Over 50% of adolescents 15–17 years old, nearly a third of those 12–14 years old and 8% of those 6–11 years old, sleep 7 or fewer hours per night (National Sleep Foundation, 2013) even though adolescents (10–17 years) have been found to require at least 9 hours of sleep for best performance (Carskadon & Acebo, 2002). Children and adults engage in computer and internet activities, complete homework and finish workplace-based projects at night curtailing total sleep time (National Sleep Foundation, 2013, 2014). Sleep apnea and medical conditions prevent and interrupt sleep leading to insufficient sleep which affects next day performance. All told, getting insufficient sleep is a commonplace problem across the life-span. This has implications for daily functioning and wellbeing, including affecting day-to-day judgment and decision making, social interactions, and self-regulation.

Daily Choices

Wide-ranging surveys indicate that children and adults sleep less than their optimal amount. It also appears sleep loss impacts their decision-making. Following less sleep than preferred, for example, serious adolescent athletes reported poorer mood and considered their sports practice drills to be more challenging, and with more frequent awakenings these athletes avoided the most difficult practice exercises (Engle-Friedman et al., 2010). The choices students make in the classroom, during homework completion, and in social settings when they have had less sleep than they need has not yet been thoroughly investigated. When sleep loss affects decision-making and choice behavior in settings where important learning and growth opportunities are present, students' educational development may be disadvantaged. For example, lab research finds sleep deprivation decreases verbal learning in young participants (e.g., Drummond et al., 2000). Relatedly, the transfer of learned information to long-term memory is impaired following sleep loss (Gais, Lucas, & Born, 2006). Meta-analytic evidence finds similar results across academic domains and in naturalistic contexts (Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010).

The quality of one's previous night's sleep also affects next-day health-related choices. Adults who reported trouble with falling asleep, frequent awakenings and total sleep time were more likely to eat fast-foods or to eat at restaurants rather than preparing meals at home (Engle-Friedman et al., 2010). The purchase of prepared meals away from home may require less effort but they also be less nutritious than meals prepared at home. Sleep loss experienced by those with sleep problems may result in the added and underappreciated impact on the effort involved in meal preparation. The consumption of fast food including foods high in fats and carbohydrates following sleep loss is likely a result of an interaction between systems responsible for effort, temperature regulation and energy metabolism.

Even a few hours of lost sleep causes core body temperature to drop in humans (Shaw, 2005) and we attempt to reduce feeling cold by increasing the ambient heat by adding clothing (Horne, 1998). In the absence of sleep, humans use one third more energy than they would if they were sleeping and conserving that energy (Jung et al., 2011). The inability to retain body heat was originally observed in rats who expend more energy than normal and increase their food consumption when sleep deprived (Rechtschaffen & Bergmann, 2002).

Sleep affects the ability to store energy and to make it available. Energy regulation through food intake is affected by the hormone gherlin, which stimulates appetite, and by the hormone leptin, which inhibits the desire to eat (Spiegel, Leproult, & Van Cauter, 2005). After two nights of sleep limited to 4 hours in bed gherlin is increased by 28% and leptin is decreased by 18%, with appetites directed toward high calorie foods (Spiegel, Tasali, Penev, & Van Cauter, 2004). Energy is made more available with sleep loss and less is stored. When sleep is restricted for 5 days, insulin, the hormone responsible for energy storage, is released 40% more slowly and the acute insulin response to glucose is reduced by 30% (Spiegel, Leproult, & Van Cauter, 1999). Sleep loss appears to create a physiological cascade in response to the detection of energy depletion. Instead of storing energy, energy becomes easily accessible and hormones signal that energy stores need immediate replacement. Therefore, the desire to engage in less effortful food preparation is paired with reduced energy stores, a desire to eat high calorie foods and a fast food market that provides easy access to such offerings.

Sleep loss plays a critical role in driving performance and accident likelihood. The risk of vehicular accidents that involve injuries has been related to sleep loss (Connor et al., 2002). In comparison with those who get eight or more hours of sleep, on average those who sleep 6–7 hours are two times as likely, and those sleeping fewer than 5 hours are 4–5 times more likely to experience a vehicular accident (Stutts, Wilkins, & Vaughn, 1999). Though drivers often report feeling tired when they drive long distances they continue driving anyway. Over 1 in 10 report having nodded off or having fallen asleep while driving a car in the last year. Moreover, strategies used to overcome the fatigue caused by sleep loss were insufficient to maintain maximally safe and effective driving performance. In addition, drivers do not expend the needed effort involved in changing course, locating a place to sleep and delaying arrival at their destination (Tefft, 2010).

Societal Impacts

While sleep loss research has typically focused on the individual within the controlled laboratory setting, the impacts of sleep loss may have broad societal costs. The accumulated effort-related decrements in performance by many functioning in a state of fatigue and sleepiness are likely underappreciated. In the healthcare domain, research has examined how sleep deficits can impact decision making. A review of the prescribing of antibiotics by 204 primary care physicians that met the "sometimes indicated" and "never indicated" criteria progressively increased over their 3-hour work sessions (Linder et al., 2014). In an examination of 4000 health care workers studied over the course of the work shift, an 8% decline in the frequency of hand washing was reported (Dai, Milkman, Hofman, & Staats, 2015). In a study of parole decisions made by judges, the more effort-demanding favorable verdicts were made at a rate of 65% at the start of the court session to 0% at the end (Danziger, Levav, & Avnaim-Pesso, 2011). And most profoundly, fatigued persons have shorter reaction times in a shooting simulation of Black armed suspect depictions, supporting the critical concern that fatigue can cause a reliance on racial bias and stereotypes (Ma et al., 2013).

Social Cognition and Behavior Following Sleep Disruption

The consequences of inadequate sleep extend to interpersonal domains, including the processing of social information and behavior in social contexts. As one example, sleep deprivation is linked to decreased sensitivity to facial expressions of emotion. A wealth of recent research has found that sleep loss decreases detection accuracy only for relatively subtle emotion displays that were created by blending neutral faces with an expressive version of the same target (e.g., Cote et al., 2014; Huck et al., 2008). A recent reanalysis of these data found that the impact of sleep deprivation was most notable for affiliative facial expression like happiness and sadness, with identification of these expressions becoming less accurate following sleeplessness, while recognition of threatening expressions like anger was unaffected after a night of sleep loss (Killgore, Balkin, Yarnell, & Capaldi, 2017).

Moreover, related work suggests that the perception of threating expressions like anger may even be heightened in participants deprived of sleep (Goldstein-Peikarskli, et al., 2015, but see Cote et al., 2014).

These findings have considerable implications for social functioning. Emotional displays convey vital social information about the expresser's current internal state and likely behaviors (e.g., smiling signals happiness and beneficent approach intentions while snarling signals anger and harmful approach intentions e.g., Parkinson, 2005). Misidentifying these signals has obvious social consequences; in the case of sleeplessness, opportunities to form positive interpersonal bonds or offer aid to those in need will be missed if expressions of happiness and sadness are not accurately decoded. Moreover, a tendency to overestimate threat from faces will lead to avoidance of benign people. More generally, poor emotion identification contributes to awkward and disfluent social interactions (e.g., Gray, Mendes, Denny-Brown, 2008), suggesting an increase in dissatisfying and uncomfortable social interactions following sleep loss (see also Sundelin and Holding, chapter "Sleep and Social Impressions", this volume).

Consistent with this notion, relative to rested controls, participants denied sleep demonstrate reduced empathic concern for others. This effect manifests in both self-report emotional distress and experienced arousal in response to observing images of strangers in emotionally provocative situations (e.g., grieving at a funeral; Guadangi, Burles, Fererra, & Iaria, 2014). Thus, decreased emotional responsivity that accompanies poor sleep extends beyond poorly identifying emotional expressions but affects interpersonal processes like helping intentions and empathic arousal (see Goldschmeid, chapter "How Sleep Shapes Emotion Regulation", this volume, for further discussion about the role of sleep in emotions).

Perhaps more directly, changes in sociability have been observed to follow periods of sleep deprivation. The ability to express oneself to others after sleep loss is impaired. After no sleep, the ability to generate words, to use the correct voice intonation and to flexibly move between semantic categories is reduced with increases in monotonic or flattened voices (Harrison & Horne, 1997). This impairment in communication could hinder effective relationship maintenance and building. An early controlled experiment by Laties (1961) withheld sleep for a 37-hour period in randomly selected male participants, who worked on both group and individual tasks. Although task performance was unaffected comparing rested to sleep deprived participants, those in the deprivation condition reported general negative social interactions, increased verbal aggression and decreased mood. A recent review verifies this link between sleep deprivation and interpersonal aggression in numerous contexts and across studies employing various research methodologies (Kamphuis, Meerlo, Koolhaas, & Lancel, 2012; Krizan & Herlache, 2016).

Other intragroup processes are affected by sleep loss as well. For example, social loafing involves poorer performance when one works in a group setting when compared with individually performed tasks (Latane, Williams, & Harkins, 1979). Sleep deprived participants who knew that the group score and not their own individual score would be evaluated, completed fewer trials and had increased incorrect responses when compared with those who were sleep deprived and worked individually (Hoeksema-van Orden, Gaillard, & Buunk, 1998). These findings suggest that a reduction in effort will occur when a sleep deprived person believes that other group members will make equal or greater contributions to the outcome, so they are free to exert a lower level of effort – one that is most comfortable for them at that time.

These negative social-behavioral outcomes extend to close relationships as well. For instance, in one large scale naturalistic demonstration using daily sampling methods to understand how sleep affects romantic couples, poor sleep was found to predict negative mood in both the sleeper and their partner the next day (Moturu, Khayal, Aharony, Pan, & Pentland, 2011) and is a contributing factor in relationship strife (e.g., decreased ability to resolve conflicts and empathize with a partner, e.g., Gordon & Chen, 2014) demonstrating both direct and diffuse impacts of sleep loss in social relationships.

Sleep and Self-Regulation

In a different social domain, sleep deprivation is associated with decreased regulatory ability and impairments in effortful social cognitive tasks (Barnes, Schaubroeck, Huth, & Ghumman, 2011, see Hisler and Križan, chapter "Dynamics between Sleep and Self-Control", this volume for review). For example, sleepy participants engage in more stereotyping than well-rested controls (Ghumman & Barnes, 2013). Notably, stereotype activation is well-known to occur automatically, whereas making more individuated and unbiased assessments require considerable cognitive effort and resource availability (e.g., Bargh & Chartrand, 1999; Devine, 1989; Moskowitz, 2010). Therefore, evidence suggests that sleeplessness compromises the ability to effortfully control activated stereotypes. Other forms of self-regulation and control are disrupted as a consequence of sleep deprivation, including regulating one's own emotions and inhibiting impulsive behaviors (for a review see Palmer & Alfano, 2017). This follows from the impacts of sleep deficiencies on effortful processing and cognitive control more generally. Just as sleep impairs performance on tasks that require resources and energy, this is true of controlled and regulating one's own emotional experiences. On a neurocognitive level, these regulatory failures are consistent with sleep deprivation decreasing activation in the prefrontal cortex (i.e., the brain region responsible for controlled cognition and self-regulation; e.g., Durmer & Dinges, 2005).

Together, this work illustrates the social cognitive and interpersonal costs of sleep deprivation. Insufficient sleep can impact emotional processes, including expression identification, empathy, interpersonal behavior, and control of one's own emotions. Moreover, it can also impact intergroup relations by leading to increased stereotyping. These diffuse effects cut across many areas of social psychology and suggest that fatigue and sleep deprivation play a perhaps underappreciated role in social cognition and behavior.

Challenging Methodological Barriers

The greatest methodological barrier to appreciating the impact of sleep loss on effort is that effort is most often assessed through self-report. Sleepers and non-sleepers are asked to identify the intensity of the effort they exerted on a previous task on Likert scales. In some studies, computerized visual analogue scales with effort represented on a 100 mm line are presented, while in other studies participants choose numbers ranging from 1 to 10 on symmetric agree-disagree scales. What effort feels like and how one assesses one's own effort exertion is complicated by the fact that measures of subjective effort are not consistent between studies. Depending on the lab and the study within an individual lab, participants have been directed to provide their subjective experience of their effort during the task (e.g. Nilsson et al., 2005; Odle-Dusseau, Bradley, & Pilcher, 2010), the effort required by the task (Drummond, Meloy, Yanagi, Orff, & Brown, 2005), the demanding nature of the task (Hockey et al., 1998), their effort involved in maintaining primary work goals or performance (Hockey & Sauer, 1996; Hockey et al., 1998), their concentration on the task (Drummond et al., 2005; Hockey et al., 1998), task difficulty (Drummond et al., 2000, 2005), their motivation to perform the task well (Drummond et al., 2005; Odle-Dusseau et al., 2010), and the difficulty of the upcoming task and their anticipated success on the task (Pilcher & Walters, 1997).

Refining the Measurement of Subjective Effort

The subjective experience of effort is a conundrum due to the variability in methods of measurement, the various physical dimensions tapped by those assessment methods, and individual differences in the interpretation of and response to the questions asked. Respondents are not given reference points or physical guidelines to use when making these determinations and reports of effort exerted (whether in the fully rested or in the sleep deprived state) may reflect a personality style that involves persistence and determination. How does a person determine their available resources? How do they determine whether they have spent their reserves or have more to call up? These are subjective experiences that are not well-understood. In addition, individual differences in responding may have less to do with physical resource limitations, and more to do with a person's natural style of responding including persistence, competitiveness or need for closure.

Participants under conditions of sleep loss have been asked to report the extent of effort they exerted when they responded on reaction time, vigilance, math addition, short-term memory and complex cognitive tasks. This wide range of domains in which subjective effort is measured indicate that measuring this construct is commonplace. Yet, reports of increased motivation and effort are not always related to improved performance (e.g., Odle-Dusseau et al., 2010). Moreover, participants who are sleep deprived do not reliably report increased effort exertion when compared with those who are fully-rested, despite sleep deprivation presumably compromising the resources necessary for effort. Reported effort has not differed under sleep and sleep loss conditions when assessed following addition tasks (Engle-Friedman et al., 2003), memory tasks (Drummond et al., 2000; Nilsson et al., 2005) and reaction time tasks (Nilsson et al., 2005) and object naming, basic arithmetic, and storytelling (Nilsson et al., 2005).

Subjective Effort: What Does It Mean?

What does it mean if a person, who has slept less than the amount they feel they need, reports increased effort on a task? This is a challenging question. The sleep-deprived person may report increased effort in performance when they are aware of a decrease in resource availability and tasks previously perceived to be easy now seem more difficult. Reports of greater effort following sleep deprivation could also reflect the activation of non-automatic, focused and voluntary alternative strategies to engage physiological, neurological, cortical and energetic resource reserves. It could also be a combination of the two or of other unaccounted experiences that occur when a person is asked to perform when there are limitations on their resource availability.

Notably, not only do tasks appear more effort-intensive following sleep loss, but participants also report putting forth less effort themselves. In other words, after insufficient sleep numerous tasks seems harder, and people reduce how hard they try to perform them. These reports could reflect the perception that the demands of the task are too onerous for the person given their sleep loss induced reduction in resources and the person has decided to eliminate the demand and conserve remaining resources. Trajectories of effort expenditure may rise with accumulated sleep loss and during the progression of assessment from early in the task period to late in the task period. Studies examining the time course of choice behavior will add to our understanding of how sleep affects resource capacity, how and when demands can be made on that capacity, when behavioral strategies are used to reduce the loss of that capacity, and when capacity is so severely expended that no effort can compensate.

Methodologically, the study of subjective effort needs greater rigor regarding the connection between the felt demand of the task, the perceived internal limitations, situations in which additional or alternative strategies are called-up, situations in which the task is abandoned and the language to describe those sensations and experiences. Subjective effort research in general and subjective effort research under sleep loss conditions thus requires an agreed upon a set of uniform questions clarified with specific instructions to be used across laboratories, under various conditions and tested for reliability. Such consistency in measurement might result in a consistent metric by which participants can share their experience of effort and by which researchers can understand that experience.

The Timing of Subjective Effort Assessment

The inconsistency in self-reported effort following sleep loss across labs may be a function of the variability in the time elapsed between the effort expenditure in the performance of a task and when the participant reports her feelings of effort expenditure. When self-reports of fatigue and mood are collected within the task period instead of collected at the rest break or after task completion, reports of fatigue are unsurprisingly greater (Heslegrave & Angus, 1985). No changes in effort reports may also reflect the vulnerability to interference of the memory of effort exertion (e.g. Drummond et al., 2000). In one study, when subjective reports of task difficulty and subjective effort on the learning task were collected 10 min after performance there were no differences in fully rested and participants deprived of 35 hours of sleep, and in a third study, it was unclear whether participants deprived of over 30 hours of sleep were able to recall their performance-related effort, and the rested and sleep deprived groups showed no difference on subjective reports of effort (Nilsson et al., 2005). The absence of differences in effort reports following full sleep and a night of no sleep could be a result of interference with and the loss of memory for the effort expended. Effort assessments occurring too long after the designated performance period has passed prevents the reliable assessment of the subjective experience when it was felt.

Individual Differences

Given the little known about the effort trajectory during sleep deprivation, it's not surprising that Hockey et al. (1998) found that in comparison to restful sleep, most participants reported expending more effort when sleep deprived while there were some who reported exerting less. Case studies give only a glimpse into the variability of the effort process. Case in point, two medical residents were monitored for effort and physiological indices over a 3-month period. One resident reported low workload, high levels of support and control, low levels of fatigue and anxiety and high levels of positive affective states. There was no relationship between subjective effort and cortisol, and adrenaline. The second resident's data showed a different picture. There was a relationship between subjective effort and cortisol, between subjective effort and noradrenaline, and between perceived work demands, fatigue, subjective effort and adrenaline (Hockey & Sauer, 1996). When considering these inconsistences in the how subjective effort is measured and whether it relates to performance (i.e., subjective-objective effort correlations), it becomes paramount to not only entertain methodological but also theoretical reasons for divergent findings. Specifically, more research should systematically examine how personality and individual differences affect how sleep impacts subjective effort, objective effort, and how well these variables correspond. Put simply, any subjective-objective effort correlations may be highly moderated by individual differences. Similarly, a direct relation between subjective effort and actual performance may also be obscured by moderating factors, including personality.

Physiological Vulnerabilities to Sleep Deprivation

The physiological determinants of effort reduction following sleep loss may be reflected in patterns of adenosinergic activity in the nucleus accumbens (NAcc). Waking central nervous system activity is coincident with elevated metabolism and increased concentrations of extracellular adenosine (Basheer, Strecker, Thakkar, & McCarley, 2004). During wakefulness increases in adenosine are correlated with subjective experiences of fatigue (Davis et al., 2003). During sleep, dramatic increases in cortical interstitial space allow for the removal of toxins including adenosine (Xie et al., 2013).

Receptors responsible for arousal inhibition and sleep promotion also control behavioral effort through a selective interaction between adenosine A2A receptors and antagonists of dopamine D2 receptors (Mingote et al., 2008). A2A antagonists can reverse the behavioral effects of dopamine antagonists on effort-related choice behavior (Salamone et al., 2013) suggesting that stress on this system may be responsible for fatigue and psychomotor slowing. Adenosinergic activity at the A2A receptors promotes sleep and effortful behavior is inhibited at the same synapses. Future studies examining the cascade responsible for reduced behavioral effort due to sleep loss may better clarify the influence of wakefulness generated adenosine, up-regulation of adenosine receptors at the NAcc after sleep deprivation, and the arousal inhibiting adenosinergic projections that affect effort.

Additional Future Directions

The previous section highlights unanswered questions relating to the physiological processes related to sleep and sleep loss. However, numerous future directions remain unexplored in broader areas of psychology. For example, given that the ability and willingness to engage in effortful cognition is compromised by sleep loss, while more automatic processes (e.g., behavioral and emotional impulsivity, stereotyping) are left unaffected, a broader integration with dual-processes theories in cognitive and social psychology is likely to be fruitful (see Satterfield, Raikes, and Killgore, chapter "Sleep in Social Cognition and Judgment", this volume). For example, a wealth of research has examined how decision making, reasoning, persuasion, and other tasks can be affected by either fast, effortless implicit processes or more cognitively taxing, effortful thinking (e.g., Smith & DeCoster, 2000). Thus, a broad prediction is that heuristics and implicit processes will become more powerful predictors of cognition and behavior as sleep quantity and quality decrease. This should be the case due to sleep loss compromising the ability and willingness to engage in effortful processes. As one specific instance, consider the domain of attitude change and persuasion. Here, the Elaboration Likelihood Model (Petty & Cacioppo, 1986) posits that peoples' attitudes can be altered through either peripheral or central cues. The former are implicit cues (e.g., spokesperson attractiveness, message framing) that lead to attitude change when a person is not thinking carefully about the persuasive message, while the latter (e.g., evidence, logical argumentation) will be most influential when a person is thinking carefully. It seems logical that sleep deprived individuals would be easily swayed by peripheral cues rather than central cues. Such findings would have both theoretical and applied implications.

Another promising future direction is examining how sleep loss affects a desire for interpersonal closeness and affiliation. Establishing and maintaining social bonds is a critical human motive (e.g., Baumeister & Leary, 1995). However, there are clues suggesting that this normally pervasive desire may be muted following sleep loss (e.g., increased irritability and interpersonal aggression). Accordingly, it would be interesting to examine more closely participants' interest in socialization relative to isolation both during and immediately following sleep deprivation. Such investigations would likely expand on the understanding of how sleep loss affects behavior in academic, organizational, and relationship contexts beyond what is currently known (and summarized above e.g., Kamphuis, et al., 2012; Moturu et al., 2011). For instance, employee performance on collaborative tasks may be especially impaired following poor sleep, not only because of the general cognitive impacts of sleep loss, but due to a decreased willingness to engage in social tasks. Similarly, the consequences of poor sleep on student absenteeism or drop out may be amplified in classes that require frequent group work if socializing is viewed as especially daunting or undesirable when sleep deprived. Future research will also benefit from a study of the broad societal impacts of sleep loss on behaviors that require effort. Those performing critical work in health and safety industries may make decisions under conditions of fatigue and sleep loss that may have serious impacts but would not be made if fully rested.

Conclusion

Sleep is a critical human function, and our capacity to function and execute tasks at work, school, and during social exchanges is determined in part by how much and how well we've slept. Nevertheless, sleep deprivation is commonplace, leading to decrements on tasks ranging from those dependent on low-level cognition to those requiring complex interpersonal skills. Commonplace across these domains is the need to exert effort of some kind (e.g., attention allocation, sustained engagement, accurate responding, deliberation) in order to maximize performance. Here is where poor or insufficient sleep disrupts performance: by virtue of compromising the resources and energy available to an organism, sleep loss prevents devoting sustained and effective effort. This can be seen in subjective reports of effort and in objective measures of behavior (e.g., time spent working on a task). Consequently, understanding how sleep affects task performance is of importance across various psychological areas, ranging from the study of basic cognitive processes (e.g., memory encoding and retrieval) to applied questions about organizational dynamics. The goals of this chapter include not only summarizing how sleep relates to effortful performance in these various domains, but also outlining methodological quandaries and fruitful next steps for sleep research.

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How Sleep Shapes Emotion Regulation

Jennifer R. Goldschmied

Introduction

The relationship between sleep and emotion is one that is understood almost intuitively. Parents recognize that a child's tantrum may be the result of a missed nap or a sleepless night caused by a cold, workers can identify when their boss has had a late night or missed the first cup of coffee, and even strangers can surmise that the person who just cut them off in traffic might have 'woken up on the wrong side of the bed.' The emotional consequences of sleep loss have been noted anecdotally, and include emotional lability, increased irritability, and decreased tolerance for distress or frustration. In psychiatric disorders, like major depressive disorder and post-traumatic stress disorder, the association between impaired emotion and sleep disturbances can be even more striking. Empirical research on the emotional effects of sleep loss, however, is only in its infancy. In this chapter we will present the most recent research demonstrating the relationship between sleep and mood and discuss two ways in which sleep loss may lead to mood dysfunction, with a specific focus on the effects of sleep on emotion regulation. We will conclude with a brief discussion of sleep loss and emotion in psychiatric disorders, possible neurobiological mechanisms, and future directions for research.

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Does Sleep Affect Mood?

Most of what we know about the impact of sleep on mood comes from studies examining sleep loss. Methodology varies tremendously, but several paradigms have provided insight into the importance of sleep to appropriate mood functioning. Sleep loss can be categorized as (1) sleep deprivation, a complete absence of sleep over a 24 hour period, or (2) partial sleep deprivation, which is generally defined as total sleep of less than 6 hours, or (3) sleep fragmentation which may due to a medical or sleep disorder, where sleep is disturbed over the course of the night, but sleep duration or timing is minimally affected. While the cognitive effects of total sleep deprivation such as decreased reaction time and impairments in short term memory are well known (Lim & Dinges, 2010), the effects of sleep deprivation on mood are now starting to be examined. For example, in a seminal meta-analysis of the effects of sleep deprivation in healthy subjects, it was shown that mood was significantly more disturbed compared to measures of performance (Pilcher & Huffcutt, 1996). Specifically, Kahn-Greene and colleagues (2007) showed that following 56 hours of continuous wakefulness, self-reported depressed mood, anger and frustration all increased following sleep loss, while Franzen and colleagues (2008) and Tempesta et al. (2010) both showed that sleep deprivation resulted in increases in negative mood on self-report. There is also evidence to suggest that sleep deprivation may particularly affect females more than males. Goldstein-Piekarski et al. (2018) reported that sleep loss resulted in significantly greater anxiety in females than males, while Short and Louca (2015) demonstrated that healthy female adolescents exhibited greater depressed mood and anxiety following sleep deprivation than their male counterparts, indicating that females are at heightened vulnerability to sleep loss.

Although characterizing the effects of total sleep deprivation on mood is an important endeavor, there has been a greater focus on partial sleep deprivation or sleep restriction paradigms in the literature as they provide a more ecologically valid reflection of real-life conditions. Whereas most adults do not experience regular episodes of total sleep deprivation, the incidence of short sleep duration, defined by the Centers for Disease Control as less than 7 hours per night, is approximately 35% in the United States, and this figure has significantly increased over the last two decades (Luckhaupt, Tak, & Calvert, 2010). In addition to being more prevalent than sleep deprivation, chronic partial sleep deprivation has also been shown to have significantly more deleterious effects. In the same meta-analysis indicating that sleep deprivation significantly affected mood, Pilcher and Huffcutt (1996) also determined that chronic partial sleep deprivation had a greater negative effect on both cognitive performance and mood than did total sleep deprivation. Moreover, Dinges et al. (1997) showed that sleep restriction to 4 hours over a period of 7 days resulted in continued mood degradation, while the negative effects on alertness showed a brief plateau effect.

With specific regard to the effects on mood, studies have shown that sleep restriction results in a loss of positive mood, more so than an increase in negative mood using the Positive and Negative Affect Schedule (PANAS; Talbot, McGlinchey, Kaplan, Dahl, & Harvey, 2010; Reddy, Palmer, Jackson, Farris, & Alfano, 2017). This is an important distinction as some research has assessed affect or mood on a continuum with positive mood as an anchor on one end and negative mood as an anchor on the other. However, emotion researchers have noted that positive and negative affect are independent constructs that can coexist simultaneously (Watson, Clark, & Tellegen, 1988), and thus should be assessed separately as done here, with measures like the PANAS. Therefore, these studies may suggest that sleep restriction affects the positive valence system more robustly than the negative valence system. In a very recent study, however, Shen and colleagues (2018) showed that while short sleep duration was associated with lower positive affect, poor sleep quality was associated with higher negative affect. Additionally, Krizan and Hisler (2019) showed that sleep restriction was associated with higher negative affect than was the control condition. These studies then indicate that the relationship between sleep and affect may not be simple to characterize.

In the context of examining ecologically valid models of sleep loss and their effects on mood, an important paradigm to consider is that of fragmented sleep. Several medical and sleep disorders, in addition to medications with side effects on sleep, can result in sleep fragmentation defined by repetitive short interruptions of sleep due to brief arousals. In this way, although total sleep time may not be affected, sleep quality is significantly degraded due to disruption of the normal stages and architecture of sleep. Obstructive sleep apnea (OSA), a sleep disorder characterized by repetitive episodes of cessations of breath caused by a blockage of the upper airway, causes significant sleep fragmentation and is associated with mood changes. For example, in their review, Schröder and O'Hara (2005), report that a significant proportion of individuals with OSA show signs of clinical depression. Akashiba et al. (2002) have also showed that patients with severe OSA had significantly higher depression scores than healthy sleepers. In addition to research in OSA, experimental sleep disruption has also been shown to result in decreased positive affect, but not negative affect (Finan et al., 2017), mirroring some partial sleep deprivation studies.

In contrast to the studies that aim to look at the relationship between sleep and mood by examining sleep loss, napping paradigms have also been utilized to elucidate the contribution of brief bouts of supplementary sleep to mood functioning. Napping has been shown to be one of the most effective countermeasures to fatigue and sleepiness (Horne & Reyner, 1996), and although only a limited number of studies have examined the direct effect of naps on mood, the results have been mostly consistent, demonstrating that naps improve mood, with a specific facilitation to positive mood rather than an attenuation of negative mood. For example, Taub and colleagues (1976) demonstrated that napping increased subjective energy, while Hayashi and colleagues (1999) and Luo and Inoue (2000), found that napping increased motivation and joy, respectively. More specifically, Kaida and colleagues (2007) found that a brief nap improved dimensions of positive mood status as measured by the Mood Checklist 3. Similar to sleep restriction, there is also some evidence that napping may provide an additional benefit to females. Looking at women in the late-luteal phase of their menstrual cycle, Lamarche and colleagues (2010), showed that napping improved mood and alertness. Although the literature on napping and mood is still emerging, these studies provide preliminary support that supplementary sleep can improve mood via improved positive affect.

How Does Sleep Affect Mood?

As discussed above, there is some evidence to suggest that adequate sleep is necessary for proper emotional functioning, and that sleep loss negatively affects mood. However, an important and crucial question remains: How? In what way does sleep affect mood? Two candidate methods have emerged in the literature and will be discussed in more detail. One posits that sleep affects how emotional information is processed thereby rendering certain emotions more or less influential thereby affecting downstream regulation of mood. Another postulates that sleep affects how an individual can regulate their emotions, making individuals who experience sleep loss more vulnerable to emotional dysregulation and worse mood functioning. We will further explore both of these candidate methods below.

Many studies on sleep and emotion have focused on how sleep loss affects the processing of emotional information, which includes how an individual perceives and reacts to an emotional stimulus as well as how one remembers emotional stimuli. In terms of examining how one perceives emotion stimuli, one method that has been used is to evaluate how individuals rate emotional and neutral images before and after a period of wakefulness or a period of sleep. For example, using this methodology during both partial and total sleep deprivation, Pilcher and Huffcutt (1996) demonstrated that individuals rated emotional images lower in both valence and arousal across the testing period. Although this effect was seen for both positive and negative images, the authors noted greater effects for decreases in the ratings of positive images. A similar result was found by Tempesta and colleagues (2015) who showed that positive stimuli were rated more negatively by sleep deprived individuals and poor sleepers than by those individuals who self-reported as good sleepers.

The processing of neutral information may also be specifically affected during sleep loss. In one study, neutral stimuli were rated as more negative during sleep deprivation, while neither objectively positive nor negative images were rated as more negative (Tempesta et al., 2010). Relatedly, another study demonstrated that after sleep deprivation, neutral images produced an equal amount of reactivity, as assessed by ERP, as emotional images. The authors suggest that these findings indicate that sleep deprivation causes a lack of discrimination between emotional and neutral information via an attentional impairment (Alfarra, Fins, Chayo, & Tartar, 2015). Moreover, Simon et al. (2015) showed that neutral images were equally as distracting as negative emotional images only after sleep deprivation. Similar to Alfarra and colleagues, they suggest that sleep deprivation results in the superfluous processing of potentially non-relevant, neutral stimuli due to altering the threshold for emotional reactivity.

As Tempesta et al. (2018) and Palmer and Alfano (2017) highlight in their respective reviews, it seems that the results of studies examining the effects of sleep loss on ratings of emotional stimuli are inconsistent. Whereas several of the studies mentioned previously have found a negative bias imposed by sleep loss, Baran and colleagues (2012) showed that following a period of wakefulness, individuals rated negative emotional images as less negative, while other studies found no change in the ratings of emotional stimuli following sleep loss (Franzen, Buysse, Dahl, Thompson, & Siegle, 2009). Although Franzen et al. (2009) found that the subjective ratings of emotional images did not change with sleep loss, their study revealed that sleep deprivation did have an effect on physiological reactivity to emotional stimuli. This study highlights an important consideration with regard to study methodology: the use of subjective vs objective assessment. In the majority of the studies examining the effect of sleep loss on the evaluation of emotional stimuli, individuals are asked to report their subjective ratings, which could potentially lead to various forms of response bias. Objective assessment would therefore be preferred to subjective assessment; however, it is significantly more difficult to find an objective way to measure the evaluation of emotional stimuli. The use of subjective ratings also introduces the likelihood that stimuli characteristics including the type of stimuli used or the valence and/or arousal level, may affect the accuracy of the assessment.

Advanced neuroimaging techniques have begun to characterize brain activation to emotional stimuli following sleep loss. Using these methods, several interesting patterns have emerged. First, some studies have noted a decrease in the activation of the prefrontal areas following sleep deprivation (Chuah, Venkatraman, Dinges, & Chee, 2006; Venkatraman, Chuah, Huettel, & Chee, 2007). Because prefrontal areas primarily support executive functions such as attention, memory, and decision-making, it is likely that the patterns of activation associated with sustained wakefulness would result in impaired executive functioning. Second, sleep loss seems to enhance activation in emotion and reward-related areas during the presentation of positive stimuli. For example, Mullin et al. (2013) demonstrated increased ventral striatum activation to behavioral rewards following sleep deprivation, while Gujar et al. (2011) showed increases in the mesolimbic reward areas including the amygdala, putamen, and insula during the presentation of positive images. This pattern of decreased activation in the prefrontal cortex (PFC) coupled with increased activation of emotion-related areas such as the amygdala have led some to theorize that sleep deprivation prevents the top down inhibitory control of emotional responsiveness, resulting in heightened reactivity to emotional stimuli (Goldstein & Walker, 2014). In fact, studies have shown that sleep deprivation does decrease the connectivity of these areas (Yoo, Gujar, Hu, Jolesz, & Walker, 2007), and that this pattern of decreased connectivity is associated with increased reactivity to pleasure-evoking stimuli (Gujar et al., 2011), increased approach-related behavior to rewarding stimuli (Goldstein & Walker, 2014), and increased fear responsiveness (Feng, Becker, Feng, & Zheng, 2018). Taken together, the research on both subjective ratings of emotional stimuli and neuroimaging following sleep deprivation seem to indicate that sleep loss does affect the way in which we process emotional stimuli and may do so via the loss of inhibitory control by the PFC on the amygdala and other emotion-related brain areas.

Sleep may also affect our emotions through its interaction with our memories. A rich literature has implicated sleep in the encoding and consolidation of memory, and sleep deprivation with the impairment of memory formation (For Review, see Rasch & Born, 2013). Research has also shown that healthy individuals show a memory bias for emotional, as compared to neutral, information (Phelps, 2004) which suggests that sleep may somehow selectively consolidate emotional memories. In a series of elegant studies, Payne et al. (2008, 2011, 2012) demonstrated that a period of sleep can aid in the consolidation of emotion foreground items at the expense of neutral background items, and that this was associated with specific activation of the amygdala and ventromedial prefrontal cortex, providing evidence that sleep does, in fact, preferentially consolidate emotional information. In this way, it has been suggested that emotion during encoding somehow tags the memory for better consolidation during the subsequent sleep period (Diekelmann, Wilhelm, & Born, 2009). It should follow then that sleep deprivation should impair emotional memory performance, although this remains to be established. Tempesta and colleagues (2017) demonstrated that sleep deprived individuals did show memory impairments as compared to the individuals who slept; however, these impairments were seen with both neutral and emotional stimuli. Relatedly, as REM sleep has been shown to be important to emotional memory consolidation (Walker & Stickgold, 2006), one study examined the effect of selective REM-deprivation on emotional memory consolidation and found that accuracy of neutral and emotional memory recall was not affected.

In summary, although there are inconsistencies in the findings, the existing research does seem to suggest that reward-related and executive functioning areas are impacted by sleep loss, that sleep is important in the consolidation of emotional memory, and that this seems to affect the way in which we evaluate and recall emotional information, although a valence-specific pattern has yet to be determined.

Sleep and Emotion Regulation

It is possible that sleep affects mood as a result of the way in which we process emotional stimuli following sleep loss, but sleep loss may also affect mood indirectly by altering how individuals interpret and manage difficult situations, therefore altering one's ability to regulate his emotional response to varied stimuli. For example, toddlers who nap show fewer negative responses to an unsolvable task than do those who do not (Berger, Miller, Seifer, Cares, & Lebourgeois, 2012), which may suggest that sleep can facilitate the control of negative emotions. It has also been shown that sleep loss can prime an individual to experience more negativity; Zohar et al. (2005) demonstrated that medical residents who experienced sleep loss and a disruptive daily event reported more negative emotion than those who did not have limited sleep, while Killgore et al. (2008) showed that sleep deprivation limits coping skills and may increase one's perception of stress.

Emotion regulation has been defined as 'the processes that an individual uses to modify the type, intensity, duration, and expression of emotion thereby fostering an optimal level of engagement with the environment' (Gruber & Cassoff, 2014). In this way, the ability to appropriately adapt one's emotional responses to their situation and environment is a crucial evolutionary mechanism to ensure that individuals can behave appropriately with others around them, and effectively integrate into society. If sleep loss negatively affects the ability to regulate one's emotions, it could affect the individual's social, professional, and personal standings in our very socially connected world. Given the recent increase in prevalence and all-encompassing nature of social media use, the ability to regulate one's emotions may be more important than ever as individuals are interacting with others around the clock. Social media use, however, may not only be affected by sleep loss but may also be the cause of it, as research has shown that the use of social media, especially at night, is associated with greater sleep disturbance in young adults (Levenson, Shensa, Sidani, Colditz, & Primack, 2017; Twenge, Krizan, & Hisler, 2017).

Emotion regulation, however, is not a single process. The ability to regulate one's emotions has been theorized to require several distinct and independent steps, each of which is vulnerable to the effects of sleep loss. In their informative review, Palmer & Alfano (2017) utilize a framework of emotion regulation adapted from Gross (2014) to theorize how sleep loss may have a negative impact. They highlight five key components of Gross's model: situation selection, situation modification, attentional deployment, cognitive change, and response modulation. They note that there is evidence from the literature that can support the idea that sleep loss can affect the ability to complete each of these component steps appropriately, resulting in a failure of emotion regulation more broadly.

Emotion Recognition

One important aspect that may facilitate emotion regulation may be our ability to judge another person's emotions. Several studies have investigated the effects of sleep loss on the recognition of facial expressions and emotions, however due to inconsistent results, no definitive conclusions can be drawn. Two studies do suggest, however, that sleep deprivation results in the slowing of emotion recognition. Pallesen et al. (2004) showed that sleep deprived individuals have longer reaction time to recognize emotional expressions, both positive and negative, in cartoon drawings, while another reported that sleep deprivation in females specifically resulted in the blunting of the recognition of angry and happy faces (van der Helm, Gujar, & Walker, 2010). Interestingly, the same group showed that individuals who sustained wakefulness across the day were more likely to rate a face as angry or fearful than those who napped, which they suggested may be an evolutionary strategy to be more sensitive and orienting toward threatening stimuli. Although it is difficult to reconcile that sleep deprivation can cause a blunting in the recognition of angry faces while sustained wakefulness can cause individuals to rate an angry face more intensely, this work still suggests that sleep may play an important role in the recognition of human emotions. One potential factor which may explain these inconsistencies may be varied methodology. Highlighting the importance of methodological differences, a study using a multi-modal emotion recognition assessment task showed that sleep deprivation had no effect on recognition accuracy (Holding et al., 2017). Similarly, Sack and colleagues (2019) recently reported that when longer video clips of emotional faces were presented, sleep deprived participants demonstrated better recognition accuracy than control participants, but when short video clips were used, no differences were found. The authors suggested that these results reveal the importance of stimulus duration. This is an important concept given that many of the studies examining sleep's effects on emotion recognition ask participants to respond to images of faces presented with short presentation intervals, which could affect the relative salience of emotional versus configural information.

There is also evidence to suggest that individuals who appear sleepy are not only at risk for making inaccurate assessments of others' emotions, but that they are also vulnerable to negative judgments by others. In an innovative study, individuals were presented with two sets of images of faces, those who were well-rested and those who had been sleep deprived. Impartial raters reported that they would rather not socialize with the individuals who appeared sleepy, suggesting that individuals who suffer from sleep loss may not only misjudge the facial expressions of others but may also be subject to bias themselves (Sundelin, Lekander, Sorjonen, & Axelsson, 2017).

Processing Negative Emotions

In addition to affecting the recognition of emotions in facial expressions, sleep loss may also impede emotion regulation in other ways. For example, individuals experiencing sleep deprivation showed impaired frustration tolerance, exhibiting a higher likelihood of blaming others for problems, and decreased willingness to accept blame to reduce conflict (Kahn-Greene, Lipizzi, Conrad, Kamimori, & Killgore, 2006). This finding is supported by other studies showing that both sleep restriction (Krizan & Hisler, 2019) and poor sleep quality (Denis et al., 2017) are associated with an increased tendency to exhibit externalizing behavior suggesting that sleep loss and poor sleep quality may predict a disinhibition of aggressive behaviors. Alternatively, better sleep quality is associated with increased activation in empathy-related brain areas (Guadagni, Burles, Ferrara, & Iaria, 2018), indicating that sleep is essential to perspective-taking and the ability to cooperate to solve problems, while napping has also been shown to increase frustration tolerance (Goldschmied et al., 2015). Increased impulsivity has also been associated with sleep loss. Killgore et al. (2008) showed that the ability to delay gratification, or delay approaching a rewarding experience, was decreased significantly after sleep deprivation, demonstrating that those who experienced sleep loss were more likely to pursue rewards than those who did not. Taken together, these findings suggest that sleep loss may impede emotion regulation by decreasing the ability to empathize with others and avoid conflict while increasing the likelihood of behaving impulsively and aggressively.

Emotion Regulation Strategies

Because there is ample evidence to suggest that the component processes of emotion regulation are affected by sleep loss, researchers have also attempted to characterize the effects of sleep loss on the utilization of emotion regulation strategies. Several of these strategies have been defined in the literature, and include *distraction*, i.e., the orienting of one's attention away from an emotional stimulus, *suppression*, i.e., the process of attempting to lessen focus on a specific emotion-laden thought, and *cognitive reappraisal*, i.e., the ability to reframe an emotional thought or experience in order to decrease the emotional impact (Gross, 1998). There is evidence to suggest that sleep deprivation does indeed decrease the utility of using these strategies. In a study looking at an electrophysiological marker of autonomic arousal to emotional images, sleep deprivation impaired the effects of using distraction and cognitive reappraisal (Zhang, Lau, & Hsiao, 2019), suggesting that despite a sleep deprived individual's conscious desire to use these strategies, the lack of sleep may prevent their effectiveness.

As previously mentioned, sleep deprivation may not always be an ecologically valid model of real-life sleep disturbance. Examining how subjective sleep quality may affect the use of emotion regulation strategies, O'Leary and colleagues (2017) showed that the use of maladaptive emotion regulation strategies mediated the relationship between poor sleep quality and depressive symptoms in a 6-month longitudinal study of currently depressed, healthy individuals, and those with remitted depression. This suggests that individuals who don't achieve high quality sleep are unable to select an appropriate emotion regulation strategy which, in turn, leads to an increase in symptoms of depression. Likewise, Mauss et al. (2013) demonstrated that poor sleep quality was associated with worse performance on a cognitive reappraisal task. Similarly, in their review on sleep and emotion regulation, Vandekerckhove and Wang (2017) report that individuals with insomnia, who often report fragmented or low-quality sleep, tended to use suppression more than healthy sleepers who used other, more effective emotion regulation strategies. Taken together, this work demonstrates the importance of sleep quality to the successful implementation of emotion regulation strategies in order to improve mood and functioning. However, this does not preclude that the relationship between sleep and emotional functioning may be more complicated than this, and that the reverse may also be true; that being unable to properly regulate one's emotions may also significantly impair sleep quality.

Interestingly, the use of emotion-focused coping, common in individuals with insomnia (Morin, Rodrigue, & Ivers, 2003), has been shown to increase the amount of time it takes to fall asleep, but also to decrease the amount of time spent awake in the middle of the night, and increase sleep efficiency and total sleep time. This suggests that although there is an immediate downside to using this type of strategy, there are also tangible benefits in terms of sleep architecture (Vandekerckhove & Wang, 2017). The authors highlight the importance of selecting a coping strategy based on the situation as the research around emotion-focused coping has identified that it can be particularly beneficial when stressors or problems are uncontrollable. Problem-focused coping strategies, on the other hand, are preferred in situations where the stressor has a potential solution. The type and level of stress may also be particularly significant in the relationship between sleep and the ability to regulate one's emotions. Minkel et al. (2012) demonstrated that following sleep deprivation, individuals reported greater stress than those who were well-rested in a low-stressor condition. However, in the high-stressor condition, sleep deprived individuals reported similar stress levels to the control group. The authors suggest that these results indicate that sleep deprivation can lower the threshold for how stress is perceived. This is similar to the theory, mentioned previously in the context of heightened reactivity to neutral stimuli, that suggests that sleep deprivation taxes cognitive resources, resulting in the loss of discrimination of relevant and non-relevant information, or in this case, clouding the discrimination between low and high stress in a low-stress condition.

Conclusions and Future Directions

Sleep is crucial to the maintenance of appropriate emotional regulation. Sleep loss and sleep disturbance have been shown to be associated with decreased positive affect, and sometimes increased negative affect, and this relationship may be mediated by an increased reactivity to negative stimuli or the inability to properly regulate negative emotions such as aggression or impulsivity using appropriate strategies. That sleep and emotion regulation are intricately tied together, however, has frequently been noted in the context of psychiatric disorders. Sleep disturbances are included as a potential symptom of every known psychiatric illness. It is therefore possible to speculate that sleep is associated with emotion dysregulation specifically in these disorders. In fact, there is evidence to suggest that both major depressive disorder (MDD) and post-traumatic stress disorder (PTSD) may be developed or maintained due to sleep abnormalities. MDD, for example, has been shown to be associated with impaired sleep homeostasis (Goldstein et al., 2012; Plante et al., 2013), and it is suggested that the inability to generate a drive to sleep may be related to mood impairments (Borbely & Wirz-Justice, 1982), although the exact neurobiological mechanism driving this relationship has yet to be identified.

One potential mechanism linking sleep and emotion regulation in psychiatric disorders may be alterations in REM sleep. REM sleep has been implicated in sustaining the noradrenergic balance in the brain (Goldstein & Walker, 2014). It has been postulated that increased REM activity during sleep, historically noted in

MDD, could result in the depletion of noradrenergic activity during the following wake period thus causing an impairment in 'emotional salience detection,' and increased reactivity to both neutral and emotional stimuli (Goldstein & Walker, 2014). Similarly, Goldstein & Walker posit that REM sleep could also be implicated in PTSD. They propose that individuals with PTSD frequently experience sleep loss and a lack of REM sleep which could subsequently impair the noradrenergic balance thus producing an impairment in emotional discrimination and associated hypervigilance. Although compelling, because it is currently not possible to measure neurotransmitter concentrations in humans, these theories remain speculative.

Unfortunately, because much of the research in the area of sleep and emotion has been inconsistent, with some results showing that sleep loss has large effects on certain valence systems and stimuli while others have shown that sleep loss has no effects on certain emotional constructs, it is difficult to draw any definitive conclusions as to how and why sleep shapes emotion regulation. To that end, large scale studies are needed to elucidate this intimate relationship. As previously mentioned, it will be crucial that any future studies consider (a) examining the effect of both sleep duration and sleep quality on the processing of neutral stimuli, (b) assessing both positive and negative affect, (c) utilizing multi-modal, dynamic stimuli (e.g. images and video clips), (d) for varying lengths of time, (e) under both low and high demand conditions, (f) in equal samples of males and females, and (g) using both subjective and objective measures as all of these factors have been shown to impact study results.

Several researchers have also noted that 1 day of total sleep deprivation may not be a robust enough challenge to produce significant changes in mood (Palmer & Alfano, 2017; Vandekerckhove & Wang, 2017; Killgore et al., 2011). For example, Killgore and colleagues (2011) have shown a distinction in performance at 51 hours of sleep deprivation vs 75 hours, suggesting that even small increases in the amount of sleep deprivation can potentially have significant changes on mood. Therefore, future studies should consider using partial, chronic sleep deprivation paradigms or longer sleep deprivation protocols. It will also be critically important to begin to examine potential mechanisms. Although it is an important first step to characterize the effects that sleep loss has on emotion regulation and mood, it will be even more informative for researchers to identify *how* sleep loss effects them in order to develop treatments for psychiatric disorders like major depression and post-traumatic stress or strategies to improve emotion regulation in individuals who may suffer from sleep loss or sleep disturbance.

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Dynamics between Sleep and Self-Control

Garrett Hisler and Zlatan Križan

Temptations and desires are an inevitable part of life. Athletes want to eat sugar-laden food when they are on a diet, college students want to go to a weekend party instead of spending Friday night studying for a test, and tired employees want to take a nap during a slow day at work. Despite these desires, people do not ubiquitously break their diets, forgo test preparation, or sleep at work. This is possible because humans are endowed with self-regulation, an ability to exert control over behaviors, emotions, and cognitions in order to achieve more distal future goals. Much research has focused on how people self-regulate, when they fail, and what they do to succeed. In this chapter, we consider the essential role that sleep processes play in self-control and how self-regulation contributes to sleep behavior, stressing the bi-directional relation between sleep and self-control processes.

Self-Regulation and Self-Control

While the definition of self-control appears straightforward, how self-regulation unfolds can be quite broad and complex. Self-regulation broadly refers to the purposeful pursuit of goals, which often involves the restraint of unwanted thoughts, desires, or impulses that impede goals (Hofmann, Schmeichel, & Baddeley, 2012). However, such acts of restraint are part of a more specific process referred to as self-control (Hofmann, Schmeichel, & Baddeley, 2012; Inzlicht, Schmeichel, & Macrae, 2014; Kotabe & Hofmann, 2015). More broadly, the process of self-regulation begins before any thought or desire actually needs to be controlled. For instance, a

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recovering alcoholic can choose to see a movie instead of joining a friend at bar, thereby avoiding the desire to drink a beer altogether. Such "situational" strategies for self-control are important parts of self-regulation (Duckworth, Gendler, & Gross, 2016). Avoiding a temptation in the first place is easier to do than facing that temptation and then having to battle it. Unfortunately, there is little research that speaks to how sleep affects self-regulatory processes outside of when a person must purposefully exert control over impulses and desires (i.e., self-control). As a result, we largely focus on how sleep affects self-control, but do at times speculate about how sleep relates to broader situational dynamics of self-regulation.

Sleep and Self-Control Failure

There is an ever-growing body of evidence that people are more likely to fail at self-control when sleep is too short or disrupted. In one study, employees deprived of sleep were more likely to steal money, break workplace rules, and insult others (Christian & Ellis, 2011). Similarly, after a night of poor quality or quantity of sleep, bosses engaged in more abusive behaviors towards their employees, and test-takers were more likely to cheat on a test by reporting a better score than they actually received (Barnes, Lucianetti, Bhave, & Christian, 2015; Barnes, Schaubroeck, Huth, & Ghumman, 2011). In addition to caving into their desires, unrested people also show a reduced ability to persist on effortful tasks. When their sleep duration was shortened, participants in one study spent less time persisting on a demanding visual search task and quit exercising sooner than normal (Barnes et al., 2011; Baron, Reid, & Zee, 2013; see Engle-Friedman, chapter "Sleep's Role in Effortful Performance and Sociability", this volume, for review). Similarly, underslept employees were less engaged in work and spent more time procrastinating their responsibilities (Kühnel, Sonnentag, Bledow, & Melchers, 2018; Lanaj, Johnson, & Barnes, 2014). Putting this experimental and daily diary evidence together shows that sleep loss impairs self-control both inside the laboratory and in the real-world. Moreover, preliminary evidence indicates that interventions can successfully enhance self-control by improving sleep. When sleep quality and negative affect were improved through a randomized sleep intervention, participants reported lower self-control difficulties, helping coworkers more, and less verbal aggression (Barnes, Miller, & Bostock, 2017).

Before discussing why proper sleep is an important part of engaging self-control, it is first necessary to describe when self-control occurs and how it unfolds.

How Does Self-Control Occur?

In order for self-control to occur, a person must have a current desire that is in conflict with a goal (Kotabe & Hofmann, 2015). Desires are visceral motivational forces that compel action towards an immediately rewarding stimuli, such as wanting to eat sugary foods, lusting after an attractive coworker, and craving a cigarette. In contrast, goals are abstract cognitive concepts of desired end-states that are pursued intentionally for their long-term benefits. Typical examples are keeping a healthy diet, maintaining faithfulness to one's spouse, and managing one's finances. In order for self-control to occur, a desire must be co-activated with a goal that is in opposition with a desire. For instance, the desire to curse out a neglectful boss must be co-activated with the opposing goal of keeping a job to support a family. Note that co-activation of the desire and goal relies upon *attention*; if neither the desire nor the relevant goal is attended to, then no self-control conflict occurs and the enacted behavior is likely to be in-line with the singularly activated desire or goal. Moreover, it is not enough that a goal and an incompatible desire are co-activated, there must also be a sense and recognition of conflict. This conflict is usually consciously sensed as distress or anxiety, while neurally marked by activity in the anterior cingulate cortex (Inzlicht & Legault, 2014; Yeung, Botvinick, & Cohen, 2004). It is this feeling of conflict which signals that a goal is threatened and that motivates engagement of self-control to resolve the conflict and feelings of distress. In short, necessary precursors of self-control are desires, goals, and the recognition of desire-goal conflicts.

Once conflict occurs and self-control is initiated, the ultimate determinant of whether a desire is pursued depends on whether the amount of *effort* put into adhering to the goal is greater than the strength of the desire (Kotabe & Hofmann, 2015). However, the amount of effort that can be put into controlling the desire depends on current *cognitive abilities* leveraged to enact self-control (i.e., inhibition, task-switching, working memory ability) and the *motivation* to control the desire (e.g., strength of higher order goal, affect in the moment). The importance of executive functions for self-control is summarized by Hofmann, Schmeichel, and Baddeley (2012)). In brief, working memory is important for accurately activating and representing goals in mind as well as shielding them from interference by desires. Task-switching is critical for switching between goals as they become relevant to changing desires and for switching between different methods for achieving the same goal. Inhibition is necessary for the suppression of conscious desires and goal-opposing habitual behavior. In contrast, motivation for self-control typically refers to how much a person aspires to obtain a goal and influences the extent to which cognitive capacities are engaged (Brewer, Lau, Wingert, Ball, & Blais, 2017; Inzlicht, Schmeichel, & Macrae, 2014). Thus, motivation, cognitive capacities (i.e., attention and executive functions), and effort are the main mechanisms of self-control.

While other factors such as competing goals (e.g., balancing time commitments towards studying for class and working a job) and self-efficacy (e.g., feeling confident that self-control will be successful) also impact self-control, these factors are less integral to self-control and research is lacking on how sleep affects them. Currently, the bulk of the evidence points to sleep as an important determinant of the precursors and mechanisms of self-control.

What Is Sleep and Why Does it Matter for Self-Control?

Sleep is often seen as a state of reversible disengagement from the environment during which processes vital to biological and psychological growth and restoration occur. For instance, during sleep, toxins are cleared from the brain, memories are consolidated, and metabolism is regulated (Diekelmann & Born, 2010; Sharma & Kavuru, 2010; Xie et al., 2013). The architecture of normal sleep consists of alternating cycles of non-rapid eye-movement sleep (NREM) and rapid-eye movement (REM) sleep, alongside transitional stages (Carskadon & Dement, 2011). Overall, the initiation and maintenance of wakefulness is the function of three processes: (1) the homeostatic pressure to sleep that increases with wakefulness and decreases with sleep, (2) circadian rhythms in alertness that counterbalance accruement and dissipation of sleep pressure in a way that constrains wakefulness to the day and sleep to the night, and (3) the "waking up" process described as sleep inertia (Åkerstedt & Folkard, 1997). As a result, it is important to keep in mind that cognitive and affective processes at any given time are a complex function of sleep pressure, circadian rhythm, and sleep inertia. Optimal functioning (including self-control) is generally promoted when sleep pressure is low after a good night of sleep, when sleep inertia is low after transitioning into full wakefulness, and when the circadian rhythm for wakefulness is near its peak (Burke, Scheer, Ronda, Czeisler, & Wright, 2015).

Critically, as a person remains awake, motivations begin to shift, cognitive capacities weaken, and effort expenditures become more conservative, all of which impact the precursors (i.e., temptations and desires) and mechanisms (i.e., cognitive capacities, motivation, effort) of self-control. The only known way to substantially and meaningfully reverse these changes is by sleeping, making sleep a restorative factor in the cognitive processes, motivations, and effort strategies that underlie the initiation and optimal functioning of self-control (Balkin & Wesensten, 2011).

Sleep Underlies Changes in Cognitive and Emotional Functioning

The most profound cognitive effect of sleep loss is to impair the (limited) capacity to purposefully maintain and direct attention. The frequency and duration of attentional lapses increases the longer a person is awake and occurs in tandem with reduced activity in the thalamus, a brain structure central in arousal and attention (Lim & Dinges, 2008). After a period of extended wakefulness, sleeping restores attention performance back towards typical levels, with longer recovery sleep leading to greater gains towards baseline attention performance (Belenky et al., 2003; Jay et al., 2007). Importantly, reductions in attention represent a triple threat to self-control. First, attention is necessary for engaging self-control in that attention is needed to detect when environmentally salient desires (e.g., a cake on the table) may be in opposition to less-salient goals (e.g., maintaining a healthy diet; Mann & Ward, 2007). A sleepy person at a reception party may absent-mindedly eat cake and fail to even consider that he or she is on a diet. Second, if a temptation is captured in attention and attention is not redirected away, the temptation may begin to be cognitively and affectively elaborated, taking up additional space in working memory and ramping up the intensity of the temptation (Kavanagh, Andrade, & May, 2005). For instance, seeing a piece of cake may bring to mind how good the cake tastes and sensations of hunger which then crowd out thoughts regarding how the cake is unhealthy or incompatible with a diet. Third, the capacity to direct attention is hypothesized to be the main substrate of more complex cognitive control processes essential to self-control (Kaplan & Berman, 2010). When the capacity to purposely concentrate begins to falter, so do executive processes such as working memory (Schmeichel, 2007). Thus, sleep plays a modulatory role in attention capabilities and superior attention improves the ability to attend to goals that are in opposition to desires, to redirect attention away from temptations, and recruit more complex cognitive abilities (i.e., executive functions).

Like attention, executive functions also show reductions in functioning as time awake increases. Less sleep results in worse working memory and inhibition as well as increased task-switching costs, though the effect on working memory may be partially due to concomitant attentional impairments (Killgore, 2010; Lim & Dinges, 2010; Tucker, Whitney, Belenky, Hinson, & Van Dongen, 2010). These decrements in executive function may occur because sleep appears to maintain normal neural functioning and connectivity within the brain, especially in the prefrontal cortex areas which house executive functions necessary for self-control (Krueger et al., 2008). After sleep deprivation, patterns of decreased frontal activity are often seen at rest and during effortful tasks (Drummond & Brown, 2001; Thomas et al., 2000; Wu et al., 2006). These neurological changes along with declines in cognitive performance begin to return to baseline levels after sleeping (Couyoumdjian et al., 2010; Drummond, Paulus, & Tapert, 2006; Wu et al., 2006). Some evidence suggests that restoration of cognitive operations such as working memory and planning are particularly dependent on amount of slow-wave sleep (Anderson & Horne, 2003).

Cognitive tasks seem to be especially impaired by sleep loss when the task involves a significant degree of emotional processing (Killgore, 2012). This has critical implications for self-control because desires, temptations, and impulses at the heart of self-control conflicts are emotionally or viscerally charged and require regulation of these affective responses (Lopez et al., 2017). Difficulty in controlling emotional impulses and desires after sleep loss is reflected in the increased activation of the amygdala to emotionally-valanced stimuli, with concomitant deterioration in functional connectivity between the prefrontal cortex and the amygdala (Gujar, Yoo, Hu, & Walker, 2011; Yoo, Gujar, Hu, Jolesz, & Walker, 2007). The increased activation of the amygdala and reduced connection between the amygdala and prefrontal cortex implicate enhanced reactivity to emotionally evocative stimuli and an impaired ability to exert top-down control over emotional reactions. Increased pupil diameter when viewing negative stimuli and greater risk-taking also point to amplified reactivity to emotional information after sleep loss (Franzen, Buysse, Dahl, Thompson, & Siegle, 2009; Killgore, Balkin, & Wesensten, 2006). Finally, sleep loss can impair the ability to accurately identify complex emotions in others, suggesting a reduced ability to regulate behavior and emotions appropriately in line with other's emotions and reactions (Huck, McBride, Kendall, Grugle, & Killgore, 2008).

While sleep loss clearly amplifies emotional reactivity, some evidence suggests that rapid-eye movement (REM) sleep may be key to reversing this reactivity. For instance, after extended wakefulness, participants rated angry and fearful faces as more negative and rated happy faces as more positive in comparison to their baseline ratings (Gujar, McDonald, Nishida, & Walker, 2010). After napping, however, these amplified emotional ratings returned to baseline, but only for participants who achieved REM sleep (however, see Lara-Carrasco, Nielsen, Solomonova, Levrier, & Popova, 2009 for contrary REM findings). Overall, because executing self-control relies upon executive functions and often requires restraining emotions and resisting pleasurable temptations, the extent that sleep restores proper neurocognitive functioning should be reflected in restoration of self-control.

Sleep Underlies Changes in Motivation

Similarly, sleep restores changes in motivational factors that occur with extended wakefulness. Sleep loss has the foremost effect on sleepiness, which signals the current physiological pressure to sleep and the associated impairments that occur with sleep loss (e.g., eye closures, Åkerstedt, Anund, Axelsson, & Kecklund, 2014). Lack of sleep ultimately makes people sleepy and although caffeine and changes in time-of-day can temporarily reduce sleepiness, only sleep can truly alleviate sleepiness (Balkin & Wesensten, 2011). As sleepiness increases, so does the desire to sleep, which may interfere with pursuit of goals and create a self-control conflict itself (e.g., taking a nap over continuing to study). Behind the desire to eat, the desire to sleep was recorded as the second most common source of reported self-control conflicts (Hofmann, Baumeister, Förster, & Vohs, 2012). Thus, sleeping is key to reducing a common demand on self-control; the desire to sleep itself.

Sleepiness also represents a drive that inhibits the pursuit of other desires, inadvertently preventing self-control conflicts. It is difficult to cheat on one's spouse by seducing an attractive coworker when sleepy and with little energy to put into the seduction. Research along this line has shown that sleepiness may increase risk-taking, but only if sleepiness is not extreme (Hisler & Krizan, 2019). Effortful risk-taking may drop off at higher levels of sleepiness as individuals approach falling asleep. Finally, while the desire to sleep can be a temptation, it can also be a goal that may compete with the pursuit of other goals (Veilleux et al., 2018). For instance, a student who wants to both get good grades and be healthy would need to balance time studying and time sleeping (amongst a plethora of other daily goals). For this student, feelings of sleepiness may serve as a signal that the sleep goal is not being sufficiently met and motivate behavior towards the goal of obtaining adequate sleep and away from the goal of studying. Altogether, sleepiness can create temptations and goals which shape self-control demands as well as affect the motivation to engage self-control, though whether these changes undermine or promote self-control will depend on the context and the degree of sleepiness.

In addition to sleepiness, sleep loss increases mental fatigue. Mental fatigue is often conceptualized as a motivational signal of the increasing cost-benefit ratio of maintaining the use of executive functions (Hockey, 2013). Because executive functions are advanced cognitive functions with a limited bandwidth and maintaining use of these functions on one task may lead to diminished returns over time, mental fatigue is thought to motivate disengagement of executive functions so that they are free for other endeavors. Because self-control relies upon executive functions, mounting fatigue decreases motivation for engaging self-control (Molden, Hui, & Scholer, 2016). Importantly, participants restricted to only 4 hours of sleep over 5 days within a lab had increasingly stronger feelings of fatigue (Banks, Van Dongen, Maislin, & Dinges, 2010). When finally allowed to sleep for longer, feelings of fatigue began to decline, demonstrating that sleep is critical to recovering from fatigue. Outside of the lab, sleep has been linked to people's day-to-day fatigue experiences. In a study both behaviorally and subjectively assessing fifty participants' sleep for 6 weeks, both longer nightly sleep duration and better subjective quality of sleep independently reduced next-day fatigue (Åkerstedt et al., 2014). It is also worth noting that this study examined the overlap between sleepiness and fatigue, two concepts that are often used interchangeably. Estimates derived from this study showed that participants could go from the bottom of the sleep scale (1: "very alert") to the top of the sleepiness scale (9: "very sleepy, fighting sleep, an effort to keep awake") and would have only a two-point increase in fatigue (scale ranged from 1–5). Thus, while feelings of sleepiness and fatigue co-occur, they are not completely identical and may be unique motivational factors in self-control that are affected by sleep disruption.

A final motivational factor of self-control to consider is negative affect. Feeling stressed, anxious, or angry can lead to breakdowns in self-control by reducing motivation to engage self-control and by narrowing attention to temptations that might alleviate unpleasant emotions or distract attention away from them (Schmeichel & Inzlicht, 2013; Wagner & Heatherton, 2014). Classic examples include stressed dieters eating ice cream and anxious participants preferring smaller immediate rewards over larger future rewards (Gray, 1999; Herman & Polivy, 1975). Importantly, sleep loss is consistently linked to elevated anxiety, stress, sadness, and hostility (Babson, Trainor, Feldner, & Blumenthal, 2010; Dinges et al., 1997; Paterson et al., 2011). Moreover, curtailed sleep amplifies angry and negative reactions to aversive events, such as irritating noise and setbacks to goal progress (Krizan & Hisler, 2019a, 2019b; Zohar, Tzischinsky, Epstein, & Lavie, 2005). These changes in mood and emotion are likely partially a function of a decreased ability to regulate emotions (Baum et al., 2014; Mauss, Troy, & LeBourgeois, 2013). Putting this chain of evidence together, recent work has found that increased negative affect and stress accounted for a substantial portion of the effect of less sleep on next-day self-control difficulties (Hisler, Krizan, & Dehart, 2019). Finally, recovery sleep after a series of nights of limited sleep seemingly reverses increases in negative affect (Haack & Mullington, 2005).

Sleep Underlies Changes in Effort

Overlapping with some of the losses in motivation that can occur with sleep loss, inadequate sleep is linked to preferring less effortful goals and expending less effort. When given control over task difficulty, participants with insufficient or disrupted sleep will engage in easier tasks than when they were rested (Engle-Friedman, Palencar, & Riela, 2010; Engle-Friedman et al., 2003; see Engle-Friedman, chapter "Sleep's Role in Effortful Performance and Sociability", this volume, for review). Importantly, participants reported putting the same amount of effort into the easier tasks they selected while sleep deprived as the harder tasks they selected while rested (Engle-Friedman et al., 2003). The equal levels of effort expenditure suggest that when sleep deprived people are allowed to select their tasks, they do not necessarily shy away from expending the same amount of subjective effort but will more easily reach their typical effort and performance levels. Moreover, there were no differences in overall task performance between sleep deprived and rested states, suggesting that sleep deprived participants selected easier tasks to compensate for compromised state. However, when participants lack control over their environment, different patterns of effort expenditure and performance emerge. When forced to complete the same cognitive tasks with no control over task difficulty over three consecutive days of no sleep, performance of the sleep deprived participants was 55% that of participants who were allowed to sleep (Haslam, 1985). After the sleep deprived participants were informed they would be able to nap soon, their cognitive performance jumped to 85% that of the rested group. Thus, without task control, unrested people do withhold effort and performance suffers as a result.

Additional evidence that people will adopt less effortful approaches to tasks comes from a study in which military officers adopted more passive or avoidant leadership styles after being deprived of sleep, while showing less effortful transformational and transactional leadership (Olsen, et al., 2016). Similarly, when given the forced choice to earn a small amount of money by completing a less effortful task or to earn a large amount of money by completing a more effortful task, sleep deprived participants prefer the less effortful option despite earning less money. (Libedinsky et al., 2013). In terms of self-control, these findings implicate that sleep loss may lead to prioritizing less effortful self-control goals (e.g., prioritizing studying over exercising), exerting less effort towards inflexible goals, and reducing the maximum amount of effort exerted during self-control. Such conservative approaches to effort expenditures when the environment allows also appear in group situations. After 20 hours of continued wakefulness, people had larger decrements in task performance when in groups than when completing the task alone, suggesting increased social loafing when sleep deprived. (Hoeksema-van Orden, Gaillard, & Buunk, 1998). Moreover, when people in groups were told individual member performance data would be made public (as opposed to just overall group performance), performance improved. Both patterns suggest that participants were not putting full effort into the task and allowing others group members to make up for their loafing, pointing to important effort compensation processes that occur both within individuals (increasing effort following incentives) and between individuals (helping your sleepy co-worker).

Sleep Loss Undermines the Initiation and Execution of Self-Control

Altogether, after a night of sleep that is too short or disturbed, people should experience deteriorated executive functions, reduced attention, greater sleepiness, more intense mental fatigue, more negative affect, and declines in effort expenditures. These psychological repercussions should alter the number, type, and intensity of goals and desires that are experienced and thereby undermine the initiation of self-control. First, as executive functions decline, goals should become less active and temptations more active. Specifically, because desire-related information is processed more quickly than goal-related information, desires should take up the limited space in working memory first and crowd out goals (Hofmann, Schmeichel, & Baddeley, 2012; Sullivan, Hutcherson, Harris, & Rangel, 2015). Second, decrements in attentional capacities can lead to a diminished ability to redirect attention away from temptations and towards goal-relevant information, resulting in an increased likelihood that temptations are encountered and goals go forgone (Hofmann, Schmeichel, & Baddeley, 2012). Third, as sleepiness mounts, the desire to sleep can become a temptation which conflicts with goals, such as wanting to nap instead of exercising or cooking a healthy meal. Alternatively, the need to sleep can become a goal which then conflicts with other goals, such as in the case of a student balancing time spent sleeping with time spent studying. Fourth, with increased mental fatigue, the motivation to adhere to demanding goals declines while the desire to engage in immediately rewarding behaviors amplifies (Inzlicht & Schmeichel, 2012). Fifth, increased negative affect can increase the desirability of temptations that are immediately gratifying or that distract away from negative emotions, such as eating ice cream after a bad day. Sixth and finally, decreases in effort expenditures can lead to decreases in prioritizing effortful goals and increase the temptation to forgo goals. These six main consequences of poor sleep should increase the accessibility and desirability of temptations while simultaneously decreasing the accessibility and desirability of goals. Because a desire-goal conflict is necessary for self-control to occur, this suggests that the initial effect of sleep loss on self-control is to reduce the chances that such a conflict even happens, thereby stunting the chances that self-control is engaged.

If self-control is engaged, sleep loss can also impair the mechanisms needed to successfully exert self-control (i.e., cognitive capacities, motivation, and effort). First, by disrupting executive functions and attention, the main cognitive capacities needed to enact self-control are disrupted (Hofmann, Schmeichel, & Baddeley, 2012; Kotabe & Hofmann, 2015). Second, by amplifying sleepiness, mental fatigue, and negative affect, the motivation to enact self-control is dissipated. These increases in mental fatigue should also simultaneously hamper the efficient functioning of the cognitive processes given that the experience of fatigue is increases the aversiveness of using executive functions. Third and final, reduced effort expenditures should result in a limited willingness to exert effort in self-control. By impairing these three core mechanisms of self-control, sleep loss impairs the chances that self-control will be successful.

In accordance to these theorized effects, a recent two-week long daily study sought to explicitly test if, and how, sleep restores inhibitory ability, a key form of self-control (Hisler & Križan, manuscript in preparation). In this study participants were instructed to continuously wear actigraphs to behaviorally measure sleep as well as video tape themselves attempting to inhibit the urge to blink for 2 minutes every day sometime between 9 to 10 pm in the evening and between 9 to 10 am the following morning. During each of these eye blink inhibition assessments, participants also completed a brief mobile assessment of cognitive inhibition (via the Stroop task) as well as a self-report of motivation to inhibit blinking, the amount of effort put into not blinking, and the intensity of the desire to blink. Findings revealed that on nights in which participants slept for longer than usual, they also had greater overnight improvements in eye blink inhibition (i.e., improvement from one the prior evening to the next morning). Moreover, these overnight improvements in inhibition were partially because longer sleep reduced the intensity of the desire to blink. These findings implicate that sleep restored inhibitory ability and this restoration was partially due to weakening the intensity of desire. While this study provided an initial key test of how sleep restores self-control, there is much more work to be done on how sleep influences other types of self-control and the mechanisms through which it does so.

Altogether, a lack of sleep theoretically poses a double threat to self-control by first undermining the likelihood self-control occurs, and then by decreasing the chance that self-control would be successful even if it is engaged. While proper sleep is essential for optimal regulation of behaviors, emotions, and cognitions, there is also growing evidence that self-regulation is vital for healthy sleep, a point we turn to next.

Self-Regulation Is Critical for Healthy Sleep

Each night before going to sleep, people can face a variety of temptations or stressors which can interfere with sleep. Common examples include wanting to watch one more episode of a favorite TV show, texting a friend on a smartphone, and ruminating about a stressful day at work. Use of electronics and experiences of stress in the evening can disrupt sleep, but such effects could be mitigated by self-regulatory behaviors such as setting structured "offline" time from electronics during the evening or by down-regulating stress and negative emotions (Carter, Rees, Hale, Bhattacharjee, & Paradkar, 2016; Kim & Dimsdale, 2007). These examples illustrate that self-control can aid sleep in two key ways. First, given that many people have morning obligations that start at a set time, such as work or school, getting a full night of sleep can often require strategically avoiding or purposefully disengaging from behaviors which delay bedtime and sleep onset. Second, self-control is instrumental in down-regulating arousing emotions which oppose the psychologically relaxed mental state needed to fall asleep and which seep into sleep and undermine it.

Getting to Bed on Time

In terms of getting to bed on time, people who are higher in trait measures of self-control obtain sufficient sleep more often than those low in trait self-control and do so because they more readily disengage from alluring behaviors when it is time to go to bed (Exelmans & Van den Bulck, 2017; Krizan & Hisler, 2019a, 2019b; Kroese, Evers, Adriaanse, & De Ridder, 2016). In contrast to these individual differences across people, the influence of fluctuations in self-control within a person and going to bed on time is not as straightforward. Contrary to the expectation that better self-control is needed to go to bed on time, on days in which people feel less able to exert self-control in the evening, they are actually *less* likely to procrastinate going to bed (Exelmans & Van Den Bulck, 2018; Kühnel, Syrek, & Dreher, 2018). While initially unintuitive, such findings are in line with the idea that feeling unable to exert self-control coincides with feelings of fatigue and tiredness and that sleep alleviates feelings of fatigue. Thus, feeling tired in the evening likely coincides with feeling unable to exert self-control while also motivating going to bed early.

However, the process of going to bed early may be interrupted if a person encounters a tempting behavior. If a person feels low in self-control and has a desire to watch TV or finish household chores, then poor self-control in the evening can lead to procrastinating bedtime (Exelmans & Van den Bulck, 2018; Nauts, Kamphorst, Stut, De Ridder, & Anderson, 2018). It can be too tempting and easy to stay up watching another episode of a favorite TV show rather than getting off the couch to get ready for bed. Altogether these findings suggest that feelings of fatigue associated with being low in state self-control can motivate going to bed earlier, but if a person encounters a temptation in this state, such as a favorite TV show, then the individual may not be able to resist the temptation in order to go to bed. Note that this may largely be constrained to temptations that are effortless in nature, such as watching TV or using a smartphone. More effortful temptations such as leaving the house to go drinking with friends the night before a workday would be less likely as they can seem aversive in a tired state (Hisler & Krizan, 2019).

A final factor in getting to bed on time to consider is self-licensing. Participants who report having to resist more temptations and desires during the day also report greater bedtime procrastination (Kamphorst, Nauts, De Ridder, & Anderson, 2018). Having a day that is demanding on self-control may motivate a person to spend time at night doing enjoyable things rather than going to bed on time because he or she has "earned it" by dealing with the hassles of the day (Nauts et al., 2018). Considering the influence of self-licensing and fatigue implicates that exerting self-control throughout the day can both promote and inhibit getting to bed on time. It seems likely that contextual factors such as what people did throughout the day and what they will do that night are important factors in how self-control influences getting to bed on time. More research is needed on this possibility.

Quelling the Demons of the Day

While self-regulation is important for getting to bed on time, it is also critical for dealing with stress and arousing emotions that can disrupt falling asleep and the quality of sleep. Stress, ruminating about the events of the day, and negative emotions such as worry, anger, and guilt can delay sleep onset, reduce sleep duration, and disrupt the continuity and architecture of sleep (Kahn, Sheppes, & Sadeh, 2013). Managing or avoiding situations that can invoke these negative psychological states and being able to effectively regulate these states when they do occur appears to be key to obtaining good sleep. For instance, after having negative emotion induced by being told they "failed" an intelligence test, participants who coped with these feelings by directly facing, identifying, and expressing them had longer sleep durations, more continuous sleep, and better architecture of sleep (Vandekerckhove et al., 2011; Vandekerckhove et al., 2012).

In general, people who have better regulation of emotions and more emotional stability also have better sleep (Duggan, Friedman, McDevitt, & Mednick, 2014; Hintsanen et al., 2014; Krizan & Hisler, 2019a, 2019b). Self-control may be particularly important in this dynamic as people higher in self-control are exposed to fewer stressors, are less reactive to stressors, and more effectively deal with stressors (Galla & Wood, 2015). Stress is less disruptive for everyday functioning for highly self-controlled individuals and may be one reason why these individuals also demonstrate less sleep related daytime dysfunction (i.e., sleepiness and amotivation) in response to daily stressors (Schmidt, Hupke, & Diestel, 2012). Thus, effectively managing negative emotions and stress, by down-regulating them or by avoiding them altogether, is also critical for obtaining healthy sleep.

Conclusion

Each day people face a variety of challenges, stressors, and temptations which require careful regulation of emotion and behavior to effectively overcome. Each night people go to sleep to physiologically and psychologically recuperate from such daily activities. These daytime and nighttime behaviors are both fundamental to long-term health and well-being and an ever-expanding array of evidence indicates that they are intertwined. The number of demands on a person's ability to self-regulate and the effectiveness of this regulation depends upon how he or she slept the night before and how that person slept is dependent on his or her the ability to restrain and control daytime behaviors and emotions. Sadly, this bi-directional relation suggests a reciprocating process in which people who sleep poorly will have less self-control and, in turn, will be at a disadvantage for getting healthy sleep. Fortunately, sleep and self-control are both intervenable phenomena and intervening upon one to improve the other remains a possibility ripe for future research. In addition, it is important to acknowledge the pervasive role self-regulation plays in many areas of psychological functioning. The purposeful and strategic control of emotions, cognitions, and behaviors plays a key part in many fundamental psychological theories and models such as cognitive processing models (dual process models), aggression (the general aggression model), health (the theory of planned behavior), and persuasion (elaboration likelihood model). As such, understanding the dynamics between sleep and self-control provides an opportunity to not only better understand sleep and self-control, but to also better understand how sleep interfaces with everyday psychological functioning.

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Part IV
Dyads, Groups, and Organizations

Sleep and Social Impressions

Tina Sundelin and Benjamin C. Holding

You have probably at some point heard someone say you look tired, but have you ever thought more about what that actually means? Does it have anything to do with your sleep history or is it an indication of something else? What features do we use to determine whether someone has slept and is performing at their best? Does looking tired influence how others perceive our abilities and social status? And does actually being sleepy affect how we perceive and understand other people? The current chapter will delve into these questions. Although this is still very much a growing topic, there are some interesting indications that sleep affects social perceptions and impressions of others in a variety of ways.

What Are Social Impressions?

Social impressions are formed based on several factors, and influence our behaviors towards others on a daily basis. When forming such impressions, we rely on what is generally called social perception, in other words the things we see and perceive in others, such as their facial expressions, body movements, general appearance, what they say, and how they say it (Hall, Mast, & West, 2016). Just focusing on the face, there is long-standing research showing that it provides a wealth of social information

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that is perceived by others. Seeing a photograph of a face is enough for us to draw conclusions about traits like that person's trustworthiness, extroversion, and intelligence (Todorov, Olivola, Dotsch, & Mende-Siedlecki, 2015). The extent to which these conclusions are accurate is less certain. Often the inferences are based on stereotypes (if someone has bigger eyes they are expected to be more trustworthy; if their "neutral" face appears less happy they are perceived as less extroverted), and although these may result in a self-fulfilling prophecy, there is rarely a one-to-one relationship between facial features and personality (Todorov et al., 2015). Instead, we are more likely to make accurate judgements when focusing on transient features, such as smiling or frowning. Because this information is a type of social behavior, we can infer the current mental state of the owner of that face, and perhaps their intentions towards us (Van Kleef, De Dreu, & Manstead, 2010).

For our understanding of emotional displays to be accurate however, we need to be able to correctly gauge what the other person is expressing. This is referred to as emotion recognition or cognitive empathic accuracy, the ability to read and interpret the emotional state of another person through their facial expressions, body movements, and voice prosody (Ickes, Stinson, Bissonnette, & Garcia, 1990). This ability, along with affective empathy, or feeling the other's emotions, has been suggested to facilitate social interactions (Eisenberg & Miller, 1987; Mast & Hall, 2018). But of course it takes two to tango. The ability to understand someone doesn't only depend on our ability to interpret their behavior, but also on how clearly that person conveys their emotions and intentions (Human & Biesanz, 2013).

From a theoretical perspective, there is reason to believe that sleep history and perceptions of sleep in both ourselves and others affect social impressions. First and foremost, good sleep is important for cognitive functioning (Lim & Dinges, 2010) and is related to how positively or negatively we perceive and remember stimuli (Walker & van der Helm, 2009). Moreover, sleepiness is related to motivation such that we are generally less motivated to engage in non-sleep-related leisure activities when sleepy (Mikulincer, Babkoff, Caspy, & Sing, 1989; for review see Engle-Friedmann, this volume). In other words, depending on the importance of the social situation we are in, we may make more or less of an effort both regarding understanding those arounds us and making a certain impression on them. Last but not least, sleep duration and sleep quality affect our mood (Haack & Mullington, 2005), which in turn can have an impact on what we think of others (Forgas & Bower, 1987) and, as noted above, how trustworthy or extroverted we appear to them. These are all factors that suggest sleep affect social impressions, both our perceptions and impressions of others and others' perceptions and impressions of us.

In this chapter we first discuss how sleep loss affects the way that people perceive and understand others. We then take a look at the reverse direction and the impressions other people get when perceiving someone who is sleep deprived. Finally, we focus on the questions that remain and potential avenues for future studies.

Sleep and Perceiving Others

Face Perception

Paying attention is naturally helpful when trying to accurately perceive someone. One of the most reliable findings in sleep research is that in order to pay attention, especially for longer periods of time, you are much better off with enough sleep (Lim & Dinges, 2010). An example of how inattention due to poor sleep could affect social perception comes from a study on face recognition. In this study, people who slept less than 6.5 hours per night for three nights were worse at recognizing an unknown face than those who slept 7 hours or more (Beattie, Walsh, McLaren, Biello, & White, 2016). When looking at two photos of the same individual, the short sleepers were less likely to correctly identify them as the same person. Similarly, people with general insomnia symptoms, over and above short self-reported sleep, were worse at this task than those without sleep problems. However, those with insomnia symptoms were more likely to say that two facial photos were of the same person when they were not. They were also more confident about these incorrect decisions. Of course, in both these situations it is hard to discern whether impaired face recognition was due to decreases in social attention or motivation, or other reasons.

Insomnia is a collection of symptoms that are difficult to compare with short or insufficient sleep, due to its psychometric characteristics (Benjamins et al., 2017). There is actually reason to believe that this sleep disorder is not a uniform disorder at all, but instead consists of several subtypes that are clearly distinguishable from each other based on levels of distress, reward sensitivity, and reactivity (Blanken et al., 2019). Nonetheless, most research on insomnia has treated it as a coherent diagnosis, and this is the case also regarding its role in social impressions. Specifically, there have been several studies suggesting that people with insomnia have a selective attention towards certain facial attributes, namely those signaling tiredness. These have found that those with insomnia spend more time looking at faces that appear tired compared to faces that don't, and that they spend especially long looking at the eye region (Akram, Robson, & Ypsilanti, 2018), which has been found to be important in evaluating tiredness (Sundelin et al., 2013). However, although people with insomnia tend to have a more negative perception of their own appearance and believe themselves to look more tired than they actually do (Akram, Ellis, Myachykov, & Barclay, 2016), they actually perceive tired people around them as looking less tired (Akram, Sharman, & Newman, 2018). Potentially, there are motivational aspects at play here, but more research is needed regarding the different subtypes of insomnia and their relation to the perception of oneself and others before convincing conclusions can be drawn. For example, insomnia is often coupled with anxiety, which may contribute to some of these findings (Johnson, Roth, & Breslau, 2006; Plana, Lavoie, Battaglia, & Achim, 2014).

Recognizing Emotions and Intentions

The question of motivation versus attention (or general cognitive ability) following sleep loss becomes particularly relevant when looking at emotion recognition. Being able to understand, and potentially empathize or sympathize with, others' emotions can facilitate social interaction (Mast & Hall, 2018) and several researchers have tried to answer the question of whether sleep is important for this ability. In 2008, 26 volunteers who were kept awake for almost two and a half days reported having slightly lower emotional intelligence and empathy towards others after those 56 hours compared to before (Killgore et al., 2008). Following this initial finding, research using a wide variety of sleep-loss paradigms, ranging from light sleep restriction to several nights of sleep deprivation, and an even wider variety of emotion recognition or categorization tasks, has produced conflicting results (Beattie, 2018). Some studies find an effect only on recognizing sadness (Cote, Mondloch, Sergeeva, Taylor, & Semplonius, 2014), others on recognizing anger and happiness (but only for women; van der Helm, Gujar, & Walker, 2010). One study suggests we might actually be better at recognizing emotions in others after a night shift (Sack, Broer, & Anders, 2019), while a large study found no reliable effect at all of sleep deprivation or general sleep quality on emotion recognition (Holding et al., 2017). Perhaps under some sleep-loss circumstances, certain emotions are harder to understand, and perhaps when these situations arise, we are slightly less empathic (Guadagni, Burles, Ferrara, & Iaria, 2014). In general, however, the evidence is suggesting that sleep is not vital for recognizing and understanding others' emotional states - at least not when it comes to facial or verbal expressions.

Some research has indicated that although insomnia symptoms were not related to emotion recognition, people with such symptoms rated others' facial emotions as less intense (Kyle, Beattie, Spiegelhalder, Rogers, & Espie, 2014). A small study does suggest that individuals with insomnia more often mistake angry faces for fearful ones, finding that those individuals focused less on the eyes and more on the nose- and mouth area when determining these emotions (Zhang, Chan, Lau, & Hsiao, 2019). One study has looked at empathic accuracy as it relates to sleep in actual social interactions. This study focused on romantic couples during conflict conversations, finding that their self-reported sleep the previous night predicted how good they were at correctly assessing their partner's emotions (Gordon & Chen, 2013).

It is possible that while we are able to correctly categorise emotions even when we haven't slept sufficiently, it might take us longer to do so (Cote et al., 2014). This could also be related to a slowing of gauging others' intentions. For example, a study looking at whether one night of total sleep deprivation affected the ability to detect sarcasm found that sleepy participants were just as apt at understanding whether something would be perceived as sarcastic, but it took them slightly longer to come to this conclusion compared to those who had slept (Deliens et al., 2015). This delay may be partly due to a decreased overall processing speed, but it could also be related to a shift in the threshold of detecting relevant social stimuli, or decreased activation of the so-called theory of mind network in the brain (Siegal &

Varley, 2002). After 24 hours of sleep deprivation, one study found a tendency to perceive more faces as threatening compared to after 8 hours of sleep. This tendency was mirrored in the central and peripheral nervous systems, suggesting a different processing of cues related to threat and safety (Goldstein-Piekarski, Greer, Saletin, & Walker, 2015). Even when threat is not the main focus of the study, some research indicates that sleep deprivation leads to less trust of others, at least when it comes to trusting strangers with your money in economic games (Anderson & Dickinson, 2010; Dickinson & McElroy, 2017). Another indication that trust is decreased after a night of sleep loss is the finding that sleepy people want to keep others at a greater social distance. The point at which an approaching stranger is too close has been found to be about 5 cm farther away after a night of sleep loss compared to after a good night's sleep (Ben Simon & Walker, 2018). The argument here is that sleep-deprived people are worse at inferring other's intentions, as suggested by decreased activity in the theory of mind network, and more sensitive to someone potentially threatening approaching them, as supported by increased activity in the brain areas that correlate with intrusion of personal space.

Stereotypes and Trust

When it comes to trusting others, there is a lot of research showing that we are more likely to trust people who belong to our ingroup than those who belong to an out-group (e.g. Tanis & Postmes, 2005). If someone does not belong to our group, be it a sports team or an ethnicity, we are more likely to have negative attitudes towards them (e.g. Hewstone, Rubin, & Willis, 2002). On top of this, when people are in a hurry or cognitively tired they are more likely to use cognitive shortcuts such as stereotypes when evaluating others (Hilton & von Hippel, 1996). Some have argued that sleep, by alleviating tiredness, can counteract the tendency to use such shortcuts. For example, suffering from chronic sleep restriction seems to affect the weight we give to facial features when deciding whether someone is dangerous, meaning that having a stereotypically negative appearance makes a worse impression on someone who hasn't gotten enough sleep (Alkozei et al., 2018). Indeed, the sleepier people reported feeling, the more they used stereotypes to describe a member of an outgroup and the more positively they evaluated the CV of an ingroup member applying for a job (Ghumman & Barnes, 2013). It is also possible that any implicit biases we may have towards others are harder to hide when we haven't slept sufficiently (Alkozei et al., 2017; Ghumman & Barnes, 2013), since it takes effort to overcome such biases - effort we might not want or be able to expend when we're tired.

On a more positive note, many of us may be aware of not being quite on top of our game when we haven't gotten enough sleep. In that case, we might choose to rely on people around us to compensate for our shortcomings. In a study where participants were sleep deprived for a night, they trusted the advice given by others more than did those who had slept. Participants were asked to give estimates of the distances between several European cities before finding out the estimates given by someone else, an advisor. The advisors were described as either highly competent or medium competent, and the sleep-deprived participants tended to follow the adviser's suggestions more, especially when the competence was described as medium (Hausser, Leder, Ketturat, Dresler, & Faber, 2016). This suggests that in some cases we actually put more trust in others when we are too sleepy to have faith in ourselves and might need help.

Sleep and Being Perceived by Others

The notion that sleep loss would have an effect on the way we look has such a long history that it has almost become folklore. Terms like "beauty sleep" have developed from an insight that a good night's sleep will be noticed by others. Indeed, scientific research also has a surprisingly long history of showing that sleep loss can lead to changes in how we are perceived by others. In this section, we will look at different ways that sleep may impact the persona that we disclose to the outside world.

In the mid-twentieth century, researchers from the Walter Reed Army Institute of Research conducted a series of experiments that were perhaps the first to reveal how sleep loss affected the way humans are perceived by others. In the earliest study, 15 participants were exposed to four days of sleep deprivation while 23 external observers rated how sleepy the participants appeared at regular intervals. The study found that as the days progressed, participants appeared increasingly sleepy, providing empirical evidence that the effects of sleep loss could indeed be noticed by others (Murray, Williams, & Lubin, 1958). Soon afterwards, another study revealed that sleepy people talk differently (Morris, 1960). Participants completed a series of recorded interviews, which were compared from baseline to up to 98 hours of sleep deprivation. The researchers reported "striking" changes to the rhythm, tone, and clarity when speaking.

These first glimpses provide the backdrop for a wave of science over the last decade showing that sleep appears to be importantly intertwined with human physiology and behavior in ways that are noticeable by others.

Perceiving Sleep Loss in Faces

The idea that we can tell if someone is tired just by looking at their face is obvious to many. Features like drooping eyelids and dark circles under the eyes are used to identify signs of fatigue in modern westerners (Holding, Sundelin, Cairns, Perrett, & Axelsson, 2019; Sundelin et al., 2013) all the way to traditional Chinese medicine practitioners (Chen, Liu, Zhang, Yan, & Zeng, 2015). But is it really true that our faces are such an open book that others can tell if we've slept or not?

In 2010 a study with the title "Beauty Sleep" experimentally investigated this question. Facial photographs were taken of participants after 8 hours of sleep and after 31 hours of wakefulness. A separate group subsequently rated these faces on tiredness, health, and attractiveness. The raters were unaware of the purpose of the study and did not know the sleep history of the participants, but still found them looking more tired, less healthy, and less attractive, providing support to the old adage of beauty sleep (Axelsson et al., 2010). A follow-up study then asked, what is it about a face that we focus on when making judgements about an individual's level of fatigue? Based on suggestions from laypersons and sleep experts, a list was made of potential facial markers of tiredness, including hanging eyelids, red eyes, swollen eyes, dark circles under the eyes, pale skin, wrinkles/fine lines, and droopy corners of the mouth. Using a subset of the same photographs as in the previous study, a new group of raters evaluated the faces on how much they displayed each specific feature. The facial markers above were all found to be indicative of fatigue and sleep loss. For example, when sleep deprived, the participants were rated as having paler skin, more hanging eyelids, and darker circles under the eyes, compared to when they were well-rested (Sundelin et al., 2013). The decrease in attractiveness and more hanging eyelids were replicated in a subsequent study using a less severe sleep restriction (Talamas, Mavor, Axelsson, Sundelin, & Perrett, 2016).

There is also evidence of poor sleep quality and sleep disorders leading to changes in appearance. One study addressed this by photographing patients with obstructive sleep apnea (OSA) before and after two months of standard treatment with continuous positive airway pressure (CPAP). Patients post-treatment were rated as appearing more youthful, attractive, and alert (Chervin et al., 2013). These findings were recently conceptually replicated in patients with severe OSA, revealing that one-month of CPAP treatment compared to placebo led to patients being rated as looking younger than before treatment (Yagihara, Lorenzi-Filho, & Santos-Silva, 2019). In both of these studies, it is difficult to ascertain whether it is the improvement in sleep that leads to the change in appearance, or rather a general improvement in health. However, there is reason to believe that chronic poor sleep is indeed associated with facial appearance. When 30 women classified as poor sleepers (poor subjective sleep quality and typically sleeping for 5 or less hours per night) were compared against good sleepers (good subjective sleep quality and sleep duration between 7–9 hours), it was found that poor sleepers were rated as appearing older and had skin that showed more visible signs of aging (Oyetakin-White et al., 2015).

Perhaps unsurprisingly, there are consequences to being perceived as less attractive, healthy, and youthful. Youth is related to perceived attractiveness, especially for women (Henss, 1991), and the more attractive someone is the more positive interpersonal qualities they are ascribed (Langlois et al., 2000). Similarly, if someone appears less healthy, others may perceive that person as less trustworthy and less competent (Jaeger, Wagemans, Evans, & van Beest, 2018). Based on this, sleep loss likely leads to a decrease in how socially appealing our faces appear to others, and experimental evidence indeed supports this notion (Sundelin, Lekander, Sorjonen, & Axelsson, 2017).

Sleep Disruption and Emotion Expressions

A problem with the studies in the previous section is that they rely on the idea that a static image is all a person has to go on during impression formation. But this is of course rarely the case, and research in other domains is increasingly suggesting that there should be a shift toward more ecologically valid stimuli (Risko, Laidlaw, Freeth, Foulsham, & Kingstone, 2012). Moving in this direction, one study investigated how sleep disturbance changed the emotional responsiveness of faces. Video recordings were made of sleep-deprived participants and control participants watching "emotionally provocative" movie clips (Minkel, Htaik, Banks, & Dinges, 2011). Two raters watched these video recordings and coded the number of emotional displays the participants' showed in response to the movie clips. Both for clips that were positive (amusing) and negative (sad), sleep-deprived participants were found to have less facial expressiveness. Sleep-deprived people have also been found to be slower at making emotion expressions (Schwarz et al., 2013). As our expressions help other people understand us (Human & Biesanz, 2013), it is perhaps not surprising that following a conflict conversation, the romantic partners of those who had slept poorly were less able to accurately assess their partner's emotions (Gordon & Chen, 2013).

Verbal Cues of Sleep Loss

Up to this point, we have focused on non-verbal signs of insufficient sleep. But our voices also play an important role in providing information that is used by others to make social judgements. The strongest evidence for sleep-related verbal cues originates from a study of 55 adolescents and adults who were interviewed in the evening (representing a well-rested condition) and then again in the morning after no more than 2 hours of sleep. In the morning they spoke with a lower pitch, used fewer words, and the adolescents used relatively fewer positive words. When trained raters evaluated the interviews, they found that more negative emotion and less positive emotion were expressed in the morning compared to the evening before (McGlinchey et al., 2011). Although it is hard to know whether these effects are due to sleep loss or the time of day, or an interaction between the two, an earlier study found that sleep-deprived individuals used less appropriate intonation when reading children's stories. Trained raters also reported that these individuals sounded more fatigued during the sleep-deprived reading (Harrison & Horne, 1997). So it seems that not getting enough sleep can make people sound different when they are speaking, providing a conceptual replication of the vocal changes that were first observed 50 years ago (Morris, 1960).

Social Judgements

Since both non-verbal and verbal cues of sleep loss are apparent to outside observers, and given that we expect sleep-deprived people to behave more negatively in certain social settings (Vohs, Glass, Maddox, & Markman, 2011), it makes sense that our social judgements of sleepy people lean towards the unfavorable. In a recent study, 18 individuals were interviewed for 10 minutes, both when well-rested and when sleep-deprived (Ben Simon & Walker, 2018). The interviews were filmed, and short clips of them were rated by 1033 individuals who were blind to the experimental purpose and participant condition. The videos were rated on a number of socio-emotional and fatigue-related factors. When sleep deprived, participants were considered less desirable to interact with socially (Ben Simon & Walker, 2018), replicating the findings of a previous study using static images of sleep-restricted people (Sundelin, Lekander, Sorjonen, & Axelsson, 2017). Sleep-deprived participants were also rated as appearing lonelier, and the judges even rated themselves as feeling lonelier after watching a sleep-deprived clip, suggesting that the loneliness perceived in sleep-deprived people is perhaps contagious (Ben Simon & Walker, 2018).

In a professional context, there are signs that judgements of leadership quality varies depending on how much sleep the boss is getting. Investigating this within a military setting, researchers from the Royal Norwegian Naval Academy measured leadership performance during a navigation simulation following 5 days of approximately 2.5 hours of sleep per night. This was repeated in a counterbalanced order, meaning that the leaders' performance after sleep loss was compared to their own performance after sufficient sleep. Two expert raters coded and scored the leadership behavior and found that the leaders had a more passive-avoidant style of leadership when sleep deprived (Olsen, Pallesen, Torsheim, & Espevik, 2016). Similar effects have also been observed in other kinds of leadership situations (Barnes, Guarana, Nauman, & Kong, 2016) and a separate study found that large differences between the timing of weekday and weekend sleep also lead to decreases in leadership quality ratings by others (Gaultney, 2014), highlighting that it is not just overall sleep duration that matters, but also the timing of that sleep.

Uncertainties

The field of sleep and social impressions is, despite its early beginnings, still a young one. There is a limited number of studies both regarding the effect of sleep on perceiving others and being perceived. Many of the findings described in this chapter rest on single studies with small sample sizes, and where there are several studies there are often conflicting results. Regarding the effect of sleep loss on facial appearance, there are a number of inconsistencies in the current literature as well as question marks about how meaningful some of the effects may really be outside of an experimental setting. For example, in the largest study of its kind, Holding and colleagues did not find that one night of total sleep deprivation was associated with any differences in how fatigued or healthy participants were perceived (Holding et al., 2019). Clearly, more research is needed in order to understand under what circumstances it is possible, or not possible, to perceive signs of sleep loss in others. The same is true for the role of sleep in emotion recognition, where several studies have suggested that sleep loss impairs our ability to understand others' emotions, but there is little consensus as to which emotions are affected and under what conditions.

Additionally, many of the effect sizes seen in previous research have been small, often despite severe sleep deprivation that is not typically seen in day-to-day life. Furthermore, most studies have been conducted in laboratory-controlled conditions, which is good for experimental rigidity, but not optimal for ecological validity. This is especially the case when the focus is on social effects, and the tests are performed alone, in front of a computer or camera.

Future Directions

Research Design and Methodological Improvements

Over decades of research, the question of how sleep affects social impressions has benefitted from a variety of study designs, from extreme multi-day sleep deprivation to naturalistic studies. However, if we are to understand the relevance of these findings and how they relate to people in their everyday lives, we need more studies using sleep-restriction protocols that mirror how people actually sleep. We also need more studies investigating how objective sleep quality (rather than subjective sleep quality, the construct validity of which is still up for debate; Gabryelska et al., 2019) and sleep disorders such as insomnia affect how individuals perceive and are perceived by others. Furthermore, because of the time and cost of running experimental sleep research, many of the samples in existing studies are too small to draw reliable conclusions. Ambitious studies with larger samples and measures over longer periods of time would help alleviate this problem. This would also reduce the risk of spreading information based on spurious results, and help identify directions of and mechanisms behind the effects. Such studies could additionally be combined with new techniques and technologies to more accurately measure changes in nonverbal and verbal social cues following sleep loss, not to mention actually focusing on social interactions and real-life settings. Finally, there is a need for more replications, direct as well as conceptual, in order to gauge the robustness of the findings in current research.

A Focus on Theory and Implications

There are many exciting directions for future research to take. As mentioned previously, a substantial improvement over the majority of current research would be to focus on dynamic facial changes, both for impression formation and emotion recognition. For example, perhaps there are changes that occur in one's smile or eyes that affect how people perceive emotions in individuals who are tired. Research has shown that being sick changes the way people are perceived by others when they walk (Sundelin et al., 2015); perhaps there are similar effects for sleep deprivation.

A separate under-researched question is how the effects of sleep on social impressions are moderated by the level of knowledge about the other person, for example if the rater or sleepy person is a friend or a stranger. Perhaps we are more perceptive to sleep-related social cues if we know someone well, and that in turn could make us more or less forgiving of social missteps. We may also be better at hiding our sleep loss with new acquaintances, depending on how motivated we are to do so. On the other side of the coin, we may be better at gauging others' intentions following sleep loss if we know the other person well, since this might require less cognitive resources compared to understanding a stranger. These are currently entirely open questions.

It would also be beneficial to put greater focus on how time of day and relevant circadian mechanisms interact with sleep to impact social impressions. It may be that at certain times of the day, sleepy individuals are particularly at risk of getting or making poor social impressions. Although this was suggested as early as 1990 (Bodenhausen, 1990), little research has followed up on this question. Another future direction would be to investigate how different levels of sleepiness between the actor and observer may interact. We know that a state of sleepiness can impact both the signals we convey to others and how we interpret and perceive social cues from others. Yet we know little about the interaction between these. What if both people are sleep deprived? What if there is a whole team with different amounts of sleep (see for example Baranski et al., 2007)? This is fertile ground for future research.

Other than understanding the mechanisms behind the effects of sleep loss, there is much to gain by studying how these effects impact performance in the real world. Are there techniques that can be used to mask the effects of sleep loss on social impressions, for example with make-up, napping, or coffee? Can motivation play a role in how sleep affects our impressions of others? And what about the implications of good sleep on general well-being – could sleep-related improvements in our appearance, empathic ability, and behavioral demeanor lead us to have more fulfilling social lives? Given the importance of social interactions, if the answer is yes then prioritizing sleep could have extensive benefits beyond health and cognition, both individually and on a population level.

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Sleep in the Context of Close Relationships

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In over 50 years of sleep research, scientists have learned that sleep and sleep behaviors are an integral component of health and wellbeing. Yet, most of what we know about sleep is observed at the individual level. In reality, the social environment influences sleep via a cascade of interconnecting processes. At the broadest level are societal constructs such as technology, public policy, globalization, environment, and geography (Grandner, 2017; Tudge, Mokrova, Hatfield, & Karnik, 2009). For example, work schedules, neighborhoods, and policy (broad level constructs) all influence sleep timing, sleep duration (i.e. total time asleep), and sleep behaviors (Fuller-Rowell et al., 2016; Kalil, Dunifon, Crosby, & Su, 2014; Owens, Belon, & Moss, 2010). In this chapter, we argue that *proximal processes*, everyday social interactions within our immediate environment (Bronfenbrenner & Morris, 1998), have a powerful influence on sleep timing, duration, and quality. We conceptualize close relationships, (i.e., spouses, family members, friendships) as proximal processes that influence sleep through interpersonal interactions, shared health beliefs, and/or shared living arrangements.

This chapter provides an overview of the extant literature on family relationships and sleep, potential mechanisms by which family relationships influence sleep, a discussion of gaps in the literature, and, finally, suggestions for future research. To demonstrate how family relationships influence sleep, we will use two types of relationships as exemplars: couples' relationships and parent-youth (school-age and adolescent) relationships. We chose these two types of relationships to demonstrate how different relational processes associate with sleep.

In contrast to infants, toddlers, and preschool-aged children, school-aged youth generally have consolidated nighttime sleep patterns. In addition, school-aged youth and adolescents are also beginning to make, or are already making, autonomous decisions (Steinberg, 2001), which likely includes decisions about sleep timing, and

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daily activities that influence sleep. Parent-youth negotiations about activities and sleep potentially sets the stage for life-long beliefs and decisions about sleep at a time when youth begin to have biologically driven preferences for later bedtimes (Carskadon, Vieira, & Acebo, 1993).

Explicit or implicit negotiations about health behaviors, including sleep, are also inherent in couples' relationships (Homish & Leonard, 2008; Lee et al., 2018). Moreover, about 61% of couples opt to bed share (National Sleep Foundation, 2005), which can influence sleep patterns (Meadows, Arber, Venn, Hislop, & Stanley, 2009) and one's sense of *felt* security, a feeling of safety that is capable of attenuating the stress response (Troxel, Cyranowski, Hall, Frank, & Buysse, 2007). In contrast to parent-youth relationships; however, the dynamics in couples' relationships likely involves more individual autonomy.

Background and Organizing Framework on Close Relationships and Sleep

Although we will focus on cohabitating or dyadic relationships and sleep, the importance of the social environment is apparent even at the individual level. Lonely adults have more wakefulness at night than non-lonely individuals (Cacioppo et al., 2002). On the other hand, higher levels of social support are associated with less wakefulness and shorter sleep latencies than lower levels of support (Troxel, Buysse, Monk, Begley, & Hall, 2010). In 12–15 year old adolescents, social determinants of sleep (e.g., peers, parents) were more predictive of sleep than biological developmental factors (i.e. puberty; Maume, 2013). Among individuals, any interpersonal conflict is associated with greater sleep disturbance the following night (Brissette & Cohen, 2002) and distress due to interpersonal problems is associated with more presleep cognitions (Gunn, Troxel, Hall, & Buysse, 2014). Furthermore, following a paradigm of social rejection, individuals had shorter sleep durations compared to their baselines (Gordon, Del Rosario, Flores, Mendes, & Prather, 2019) Thus, social interactions, even with others outside the home, are linked to sleep and sleep behaviors.

The impact of cohabiting social relationships on sleep is likely amplified due to physical proximity and psychological connectedness. To that end, we describe three potential mechanisms by which proximal processes such as close relationships influence sleep. First, cohabitating individuals are literally positioned to have direct and indirect influence on sleep and daily activities that influence sleep. A couple's shared environment facilitates mutual influences on the timing and duration of social interactions, exercising, and meals (Jarosz, 2017; Murtorinne-Lahtinen, Moilanen, Tammelin, Ronka, & Laakso, 2016; Perales, del Pozo-Cruz, & del Pozo-Cruz, 2015). In married couples, health behaviors are concordant and begin to converge. For example, Homish and Leonard (2008) found that during the first four years of marriage, partners eating habits and exercise habits become more similar.

Convergence on daily social activities, such as eating and exercise, in turn, influence sleep timing (Soehner, Kennedy, & Monk, 2011). Family members also directly influence sleep by engaging in behaviors that interfere with other's sleep (e.g., watching television while a family member is attempting to sleep) and by enforcing social control (e.g., "it's time for bed").

Second, close relationships influence interpersonal security, which can facilitate psychophysiological responses that promote or hinder sleep onset and sleep maintenance. Sleep is a vulnerable process that requires reversible temporary loss of consciousness. To protect against predators, our ancestors cultivated strong interpersonal bonds and social networks that provided safety from predators, especially during sleep (Dahl & Lewin, 2002; Worthman & Melby, 2002). In the absence of interpersonal security, we adapt to danger by having heightened vigilance (or arousal to maintain wakefulness), which is counterproductive for sleep (Dahl & Lewin, 2002). Modern day humans are not as vulnerable to predators, but the modern brain responds to threat and stressors in much of the same way (Bernardy, Friedman, & American Psychological Association; Cannon, 1939). Thus, a lack of interpersonal security, (e.g., interpersonal stress, interpersonal conflict, loneliness, social rejection, etc.) can increase psychophysiological arousal which is counterproductive for sleep (Gordon et al., 2019; Palagini et al., 2018).

Finally, coregulation and synchrony of biological processes, such as sleep, are emerging as one feature of attachment within close relationships. Attachment is defined as an enduring affectionate tie between two individuals. Attachment theory began as a way to describe the type of bonds between infants and young children and their mothers (Ainsworth & Bell, 1970), but one's attachment style is developmentally stable, even into adulthood (Doyle & Cicchetti, 2017). *Coregulation* occurs as a function of attachment to loved ones and is defined as "the reciprocal maintenance of psychophysiological homeostasis within a relationship" (Sbarra & Hazan, 2008, p. 143). For example, psychophysiological processes such as cortisol and blood pressure are coregulated within couples and mother-youth dyads (Papp, Pendry, & Adam, 2009; Saxbe & Repetti, 2010; Wilson et al., 2018). Sleep and sleep behaviors may also be coregulated within couples (Gunn, Buysse, Hasler, Begley, & Troxel, 2015) and parent-child dyads as a function of their attachment (see Williams, this volume).

In the following paragraphs, we review the literature on couples' and parent-child relationships using the aforementioned mechanisms (e.g. shared environment, interpersonal security, sleep coregulation) as a guiding framework for understanding close relationships and sleep.

Couples' Relationships and Sleep

Shared environment and sleep For most adults, sleep is a dyadic behavior. Sixty-one percent of couples sleep with their partner (National Sleep Foundation, 2005) and individuals report better sleep quality when they sleep with their partner

(Pankhurst & Horne, 1994). Despite a preference for bed-sharing, individuals in a couples' relationship had less restorative, stage 3 sleep when they shared a bed compared to when they slept alone (Monroe, 1969). This may be due to bed-partners movements. Although a bed partner's movements may not reach consciousness awareness, one-third of sleep movements are associated with a sleep movement in a partner (Pankhurst & Horne, 1994). Sleep behaviors (e.g. bed timing, wake timing) within couples often parallel one another. Couples tend to go to bed at similar times, have similar sleep onset latencies, a similar number of wakings (Meadows et al., 2009), and when one member of a couple reports better sleep quality, their partner is also more likely to report better quality of sleep (Lee et al., 2018).

The finding that couples have similar sleep behaviors is parallel to the literature on other health behaviors within couples. For example, when couples begin to live with one another their diets converge (Bove, Sobal, & Rauschenbach, 2003). The shared environment gives couples more opportunities to influence each other's behaviors. In addition, couples engage in *social control*, influence on one another's behavior through positive methods such as persuasion, positive reinforcement, and modeling and/or negative methods such as negative emotional expression, pressuring, or restricting (Lewis, Butterfield, Darbes, & Johnston-Brooks, 2004). Eighty percent of married men and 59% of married women cite their spouse as the primary individual that reminds or tells them to engage in health behaviors (Umberson, 1992). Compared to single individuals, married individuals report receiving more pressure and persuasion to engage in healthy behavior, and married men report the greatest levels of pressure and persuasion (August & Sorkin, 2010). This pattern appears to extend to sleep. Lee et al. (2018) found that after controlling for contextual factors and covariation *within* couples, the effects of partner influence on an individual's sleep was more apparent for men. In other words, when women slept longer than usual, their partners tended to sleep longer than usual.

Interpersonal security and sleep In addition to opportunities for social control, sleep within couples is also vulnerable to relationship characteristics. Attachment style in adult couples' relationships is associated with sleep at the individual and dyadic level. Wives with avoidant and anxious attachment styles have worse sleep (Troxel et al., 2007; Troxel & Germain, 2011). Both husbands and wives who are more anxiously attached have less restorative, stage 3 sleep (Troxel et al., 2007; Troxel & Germain, 2011). This finding suggests that sleep may be one proxy for couples' relationship functioning.

To that end, in a study of several hundred couples, individuals who report greater partner responsiveness (e.g. feeling cared for, understood, and validated) report better perceived sleep quality. In addition, greater spouse responsiveness indirectly predicted greater sleep efficiency (i.e. the percentage of time in bed that the participant is actually asleep) through lower levels of anxiety (Selcuk, Stanton, Slatcher, & Ong, 2017). These findings provide support for indirect effects of interpersonal security on sleep. That is, spouse responsiveness (which is one aspect of interpersonal security) is associated with lower arousal, which then facilitates restful sleep.

Tests of lagged associations in couples' day-to-day interactions and sleep provide further support for cross-sectional findings. Women had better sleep efficiency and longer sleep durations on days when they had relatively more self-disclosure to their spouses while men had fewer nighttime wakings on days they disclosed more to their wives (Kane, Slatcher, Reynolds, Repetti, & Robles, 2014). Disclosure implies a sense of trust and security in the relationship and has a positive correlation with marital satisfaction (Hendrick, 1981). Thus, it is possible that among satisfied married couples, more disclosure will increase one's sense of security and influence sleep that same night. Studies on daily interactions have similar findings. Women who reported more positive daily interactions and less negative daily interactions with their partners experienced better sleep quality the following night (Hasler & Troxel, 2010). Women also had poorer sleep efficiency and longer sleep onset latency (i.e., time it takes to fall asleep) on days when they had relatively more negative interactions with their partner. Among men, there were no associations between positive and/or negative daily interactions and sleep (Hasler & Troxel, 2010). In contrast, in a study of military veterans and their partners, positive and negative behaviors during conflict was associated with poor sleep efficiency in both partners (Fillo et al., 2017). However, the authors noted that the study was likely underpowered to detect significant gender interactions. In a larger study (N = 152), patients with osteoarthritis had worse mood and worse sleep when partners responded negatively to their pain complaints (Song, Graham-Engeland, Mogle, & Martire, 2015). Findings remained after controlling for gender, but gender interactions were not reported. Recent findings notwithstanding, it is possible that, compared to men, women's sleep is more closely connected to interpersonal fluctuations. This would be consistent with other health and marriage research that shows women's physiology (e.g. heart rate, blood pressure, cortisol levels) is more sensitive to relationship interactions than men's physiology (Kiecolt-Glaser & Newton, 2001),. However, it will be important to continue to evaluate gender differences in studies of relationship characteristics and sleep in heterosexual couples.

The role of couples' relationship characteristics and sleep is most evident when the relationship itself is a source of stress. High conflict and interpersonal stress contributes to greater arousal (El-Sheikh, Kelly, & Rauer, 2013), which is counterproductive for sleep. Women have shorter sleep durations on average when their husbands report more conflict (El-Sheikh et al., 2013). When women were psychologically aggressive during conflict, both members of the couple had worse sleep efficiency, and over time men showed decreases in sleep efficiency when women were psychologically aggressive (El-Sheikh, Kelly, Koss, & Rauer, 2015). Among couples that reported more psychological aggression, women were more likely to have poor sleep efficiency and shorter sleep durations when they reported more anxious symptoms, and men were more likely to have worse sleep efficiency and shorter sleep duration when they reported more depressive symptoms (El-Sheikh et al., 2015). This suggests that the mechanisms by which high-conflict relationships influence sleep may be different for men and women.

Sleep Coregulation As previously mentioned, coregulation of biological processes is an emerging area of research on close relationships. As a function of attachment to one another, couples appear to have coregulated emotions (Butler & Randall, 2013) and physiology (Sbarra & Hazan, 2008). Although this is an emergent area of research, it appears that couples' sleep may also be coregulated. Pankhurst and Horne (1994) studied bedsharing couples' sleep using actigraphy and found that couples have similar sleep-wake patterns. Gunn and colleagues also demonstrated that couples have more sleep-wake concordance (i.e., they are awake or asleep at the same time) than would be expected due to chance (Gunn et al., 2015). Couples' concordance is also linked to relationship factors. Hasler and Troxel (2010) found that when couples have a concordant sleep onset, women report fewer negative interactions the following day. At the dyadic level, associations among relationship characteristics and sleep appear to be dynamic. When wives reported low marital satisfaction and husbands were more anxiously attached, couples sleep was more concordant throughout the night (Gunn et al., 2015).

Summary of couples' relationships and sleep Couples' relationships are associated with sleep at the individual and dyadic level. Couples influence one another's sleep through direct (social control) and indirect (shared environment, coregulation) means. It is important to note that although much of the literature focuses on how couples' relationship predicts sleep outcomes, bidirectional associations are also evident. For example, Wilson et al. (2017) found that when both spouses have sleep durations shorter than is typical for them, they are more hostile during a laboratory interaction task. In a study of day-to-day interactions and sleep in couples, spouses reported more marital satisfaction following nights with sufficient sleep (Maranges & McNulty, 2017). Moreover, conflict resolution is more likely when both spouses have sufficient sleep (Gordon & Chen, 2014). These findings suggest the importance of examining bidirectional and lagged associations in studies of couples' sleep. Findings also suggest that focusing on sleep in relationships may be one way to improve couples' relationship satisfaction. Troxel and colleagues found that men (not women) were less likely to develop insomnia symptoms after undergoing marital therapy. (Troxel, Braithwaite, Sandberg, & Holt-Lunstad, 2017). However, research on sleep outcomes at the couple level is limited, and to our knowledge, there are no published findings on dyadic approaches to improving sleep within couples.

Parent-Youth Relationships and Sleep

Youth obtain less sleep as they progress through adolescence. On average, 6th graders obtain 8.4 hours per night and 12th graders obtain 6.9 hours per night (National Sleep Foundation, 2006), which is lower than the recommended 8–10 hours for optimal functioning (Hirshkowitz et al., 2015). Much of the literature is focused on factors that increase total sleep duration and facilitate consistent sleep timing in youth. As such, many studies on parent-youth relationships focus on parent characteristics that enhance or interfere with youth sleep.

Shared environment and sleep As with the couples' relationships and health literature, research on families and health behaviors indicate that family members engage in similar health behaviors. For example, parental inactivity is a strong predictor of child inactivity (Fogelholm, Nuutinen, Pasanen, Myohanen, & Saatela, 1999). There are few studies on shared sleep behaviors in families, but data suggest that despite differences in bed- and wake-timing, parents and youth have concordant sleep behaviors. For example, sleep duration tracks closely between parents and youth. Parents have shorter or longer sleep durations when their adolescents have shorter or longer sleep durations and vice versa (Fuligni, Tsai, Krull, & Gonzales, 2015). Parental influence may be both direct and indirect. Brand and colleagues found that mother's sleep was indirectly related to adolescent poor sleep via inconsistent, restrictive, and harsh parenting (Brand, Gerber, Hatzinger, Beck, & Holsboer-Trachsler, 2009). The association between sleep parent distress and youth sleep may be bidirectional. Chardon and colleagues found that youth sleep problems amplified the positive association between youth internalizing symptoms and parental distress (Chardon et al., 2018). These findings suggest bidirectional interdependence among parent and youth distress and youth sleep.

Interpersonal security and sleep Likewise, parental factors that contribute to adolescent interpersonal security may be reflected in adolescent sleep. In a longitudinal study of several hundred families, greater parental sensitivity to a child's needs and less hostility in third grade predicted fewer sleep problems two years later compared to parents who were less sensitive and more hostile. In addition, more closeness and low conflict predicted a decrease in child's sleep problems two years later (Bell & Belsky, 2008). Similarly, mother-child attachments characterized by greater security in third grade was associated with less sleepiness in 5th grade (Keller & El-Sheikh, 2011). Mother's fatigue, perceived overload, depressive symptoms, and parental distress were associated with greater child sleep disturbance and shorter sleep duration in a study of children ages 3 to 14 years old (Meltzer & Mindell, 2007). One possible mechanism for this association is through the child's parasympathetic system. For children with lower respiratory sinus arrhythmia, a physiological correlate of the parasympathetic system, maternal depression predicted greater movement in the child's sleep (Keller, Kouros, Erath, Dahl, & El-Sheikh, 2014). This suggests that secure attachment in parent-child relationships is a proximal process that helps children down-regulate arousal, and in turn, have more restful sleep.

Parents often play dual roles in their adolescent's sleep behavior, and these roles are similar to the influence couples have on each other's behavior. Parents create an environment that is conducive to sleep (e.g. warm and secure), and they monitor (or control) their adolescent's sleep habits. Monitoring becomes increasingly important during adolescence, as this developmental stage is marked by a biological shift towards later bedtimes and rise times. This phenomenon is partly attributed to hormonal changes occurring during puberty (Carskadon et al., 1993), but it can be mitigated by parents' behavior. In a cross-sectional study, parental warmth was associated with longer sleep on school nights for the younger participants (mean age = 8.9 years). In contrast, older adolescent's total sleep time (mean age = 15.2) was linked to more parental rules about bedtime, but not parental warmth (Adam, Snell, & Pendry, 2007). These findings suggest that for older children, monitoring remains important. However, parents tend to allow adolescents more autonomy over their bedtimes (Meijer, Reitz, & Dekovic, 2016). Thus, despite having similar nighttime sleep needs (8–9 hours), it is common for adolescents to have insufficient sleep later bedtimes and early school start times.

Despite the need for adequate sleep, parents may be ambivalent about instilling an earlier bedtime—especially when youth do not seem sleepy. Going to bed when not sleepy increases the risk for sleep problems in adults (Morin, Vallieres, Ivers, Bouchard, & Bastien, 2003). However, Short et al. (2011) found no differences in sleep onset latency in children who bedtimes were and were not monitored. In fact, general monitoring was moderately associated with less sleep disruption (Maume, 2013). In a three-wave longitudinal study, general monitoring was associated with better subjective sleep quality as participants aged (Meijer et al., 2016). Monitoring across throughout adolescent develop likely facilitates circadian entrainment, which in turn, facilitates consistent sleep timing and adequate sleep duration. Thus, although adolescents have a preference for later betimes, parents can influence this preference by setting and monitoring bedtimes. When parents monitor, adolescents are more likely to have earlier bedtimes and adequate sleep duration (Randler, Bilger, & Diaz-Morales, 2009).

While parental monitoring appears to benefit an adolescent's sleep schedule (e.g. sleep onset time and sleep duration), an adolescent's subjective sleep quality (i.e., their assessment of their nighttime sleep) appears to be associated with parent-youth relationship quality. In a three-year, prospective study of 13 years-olds, better parent-adolescent relationship quality (i.e. openness in the relationship) was consistently associated with better sleep quality and less daytime sleepiness, especially in later adolescence. Better parent-adolescent relationship quality was also associated with earlier bedtimes and more time in bed, though this effect was not as strong as monitoring (Meijer et al., 2016). Parental monitoring and parent-set bedtimes were associated with longer sleep durations at ages 12 and 15. Findings were similar in a study of several hundred adolescents; those who reported that their parents set their bedtime had on average 19 more minutes of sleep compared to those who did not have a parent set bedtime. Although the difference in total sleep time appears underwhelming, adolescents with parent set bedtimes had less fatigue and experienced less difficulty maintaining wakefulness compared to adolescents without parent-set bedtimes (Short et al., 2011).

On the other hand, parenting styles that are inconsistent, overly harsh, and restrictive predict poor subjective sleep quality and longer sleep onset latencies (Brand, Hatzinger, Beck, & Holsboer-Trachsler, 2009). Negative parenting styles are also associated greater shifts in bed timing from weekday nights to weekend nights (Brand, Hatzinger, et al., 2009). Importantly, these shifts in sleep timing can lead to social jet lag, which is associated with poor health behaviors

(Roenneberg, Allebrandt, Merrow, & Vetter, 2012; Wittmann, Dinich, Merrow, & Roenneberg, 2006). Taken together, parental monitoring appears to facilitate adequate sleep due to earlier bedtimes, whereas positive parenting styles and better parent-adolescent relationship quality may facilitate better subjective sleep quality and shorter sleep onset latencies.

Some studies of parents and youth have gone beyond the parent-child dyad, and focused on interpersonal security among multiple family members. It appears that children's sleep is sensitive to familial conflict. Even in a normative sample, children (8–9 years) who reported more parental marital conflict had worse sleep efficiency and shorter sleep duration (El-Sheikh, Buckhalt, Mize, & Acebo, 2006). In a longitudinal study, greater distress in children about their parent's marital relationship predicted worse sleep problems and more sleepiness in third grade. Furthermore, greater distress about their parent's marital relationship in 3rd grade predicted an increase in sleep problems by 5th grade (Keller & El-Sheikh, 2011). This suggests that marital problems not only influence couple's sleep, but also interfere with the child's perception of felt security, and ultimately interferes with children's sleep.

Sleep coregulation As presented above, parent sleep behaviors may transmit to children, and transmission may depend on parent-youth relationship quality. For example, parents and youth had more concordant sleep durations (e.g. parent slept shorter or longer on days when their adolescent or parent slept shorter or longer) when adolescents reported high levels of support and understanding (Fuligni et al., 2015). There is some evidence that parent-youth dyads have physiological coregulation; mothers and adolescent's cortisol levels are synchronous throughout the day (Papp et al., 2009). However, to our knowledge sleep coregulation in parent-youth dyads has not been investigated beyond mother-infant paradigms.

Summary of parent-youth relationships and sleep The parent-youth relationship and sleep literature supports the notion that interpersonal security is necessary for sleep. As with couples, parent-youth relationships characterized as secure, open, supportive, and understanding are associated with better sleep outcomes for youth (Meijer et al., 2016). On the other hand, lack of interpersonal security appears to interfere with sleep. Inconsistent, restrictive, and harsh parenting and homes with high levels of conflict (either marital conflict or parent-youth conflict) are associated with worse sleep outcomes for youth (Brand, Hatzinger, et al., 2009). Structure and monitoring, which are aspects of social control and attachment are also relevant. Compared to their peers who are monitored less, adolescents that reported greater monitoring reported longer sleep durations (Adam et al., 2007; Meijer et al., 2016). There also appears to be a transmission of sleep behaviors between parents and adolescents. Parent and youth sleep duration is concordant on a daily level (Fuligni et al., 2015) and parental sleep quality is associated with their adolescent's sleep quality (Brand, Gerber, et al., 2009). This could be due to a shared living environment and heritable genetic traits. However, the quality of the sleep transmitted from parent to child and degree of similarity between parent-youth sleep may also be a function of attachment though this remains to be tested.

Gaps in Knowledge and Future Directions

Over the past 10–20 years, scientific findings have demonstrated significant associations between close relationships and sleep. However, there are several gaps in knowledge and attention to these can inform future directions in this field. With the exception of a few studies (e.g. El-Sheikh et al., 2015; Keller & El-Sheikh, 2011; Keller et al., 2014; Meijer et al., 2016) much of what we know about relationships and sleep is observed cross-sectionally. A small literature suggests that there are bi-directional associations between close relationships and sleep (Gordon & Chen, 2014; Hasler & Troxel, 2010; Kane et al., 2014); however, it is important to determine the strength and directionality as this will inform future research on possible interventions. To that end, we do not yet know whether improving proximal family processes improves sleep, or whether improving sleep improves proximal family processes. In the broader field of social relationships and health, there is strong evidence that relationships shape psychobiological processes that influence health (see Pietromonaco & Collins, 2017). However, a focus on sleep presents a unique opportunity for families to enhance interpersonal warmth and collaborative structure to increase overall interpersonal security. Furthermore, family members' may facilitate response to patient treatments. For example, spouses may bolster adherence to insomnia or other sleep-related treatment regimens (Rogojanski, Carney, & Monson, 2013). Observational and experimental studies that test directionality will help provide targets for future interventions.

Other proximal processes Much of this review, and most of the extant literature on relationships and sleep, focused on dyadic processes. To understand associations between family processes and sleep behaviors, it will be important to expand the focus to include other cohabitating relationships. Among the few studies focusing on sleep in multiple family members, the association between interpersonal relationships and sleep differs depending on the relationship and by gender. For example, interpersonal security between mother and child is linked to daytime sleepiness in boys and girls while interpersonal security between father and child is associated with sleep duration in girls only (Keller & El-Sheikh, 2011). Moreover, there are dynamic associations in sleep timing among family members. Youth sleep timing is similar to mothers, and fathers' sleep timing is associated with mothers' sleep timing (Kouros & El-Sheikh, 2017). This suggests that families have complex, interrelated sleep behaviors that are not observable when assessing sleep at the individual level.

It is also important to consider other types of cohabitating relationships (e.g., roommates). This may be particularly relevant for young adults transitioning into independence. For example, about 40% of college students have a roommate (Forquer, Camden, Gabriau, & Johnson, 2008) and about 40% of all adults aged 18–20 live with nonrelatives (Ingels, Glennie, Lauff, & Wirt, 2012). Social influences within the shared environment may contribute to insufficient and disturbed sleep, which are common in this age cohort (Lund, Reider, Whiting, & Prichard, 2010; Sexton-Radek & Hartley, 2013). However, few studies focus on the impact of roommates, or nonrelative cohabitating relationships on individual sleep.

In addition, few studies focus on sleep in the context of proximal processes outside the shared living environment (e.g., work relationships, peer relationships) whose reach likely extends to processes within the home. This could be especially relevant for youth, as peer relationships are proximal processes that influence youth development and sleep (Maume, 2013). Recent advances in technology make it increasingly common for peer relationships to be a virtual aspect of the household through social media and texting and chatting on technological devices (Rideout, 2015). In a study of over 900 teens, (Maume, 2013), demonstrated that positive peer relationships are associated with fewer sleep disruptions. Moreover, increases in positive peer relationships is associated with longer sleep and fewer sleep disruptions three years later (Maume, 2013). For employed family members, it is also likely that work-related interpersonal conflicts influence sleep processes. A daily diary study of over 100 employees demonstrated that conflict had work spillover into one's personal life (Martinez-Corts, Demerouti, Bakker, & Boz, 2015). Personality characteristics such as hostility mitigate the association between interpersonal conflict and sleep (Brissette & Cohen, 2002); however, a focused study on important proximal processes (in and outside the home) will increase our understanding of relationships and sleep processes.

Sleep measurement Sleep in the context of close relationships is most often studied using daily diaries and/or actigraphy to measure sleep behaviors. These are reliable, non-invasive tools that will continue to serve the field. To advance our understanding of proximal processes and sleep, however, it will be important to also include polysomnography (PSG)-assessed sleep processes. Technological advances in PSG now make it possible to observe sleep architecture in the home. This is particularly useful for capturing family-level sleep data. Troxel and colleagues recently found that couples' daily relationship characteristics were associated with a greater percentage of non-REM stage 3 sleep (Troxel, DeSantis, Germain, Buysse, & Matthews, 2017). The association between proximal processes and sleep appears to extend beyond self-reported and behaviorally observed sleep measurements. However, more data are needed to understand whether and how proximal processes influence sleep architecture.

In addition to more studies on sleep architecture, the field would benefit from more studies on circadian rhythms in the context of close relationships. Human life typically revolves around daily social rhythms, which likely keep the circadian system aligned (Monk, Kupfer, Frank, & Ritenour, 1991). Few studies have examined daily social rhythmicity and its interaction with family level processes; however, Monk and colleagues found that more daily social rhythmicity in infancy was associated with less anxiousness 10 years later (Monk et al., 2010). Their findings suggest that structuring children's daily rhythmicity may enhance early parent-child relationships (Monk et al., 2010). It is possible that this persists throughout one's childhood. Future studies would also benefit from measuring whether family members' rhythmicity is overlapping. Indeed, as previously mentioned, coordinated wake times (i.e., important components of daily rhythmicity) occurs within different family members (Kouros & El-Sheikh, 2017) and the coordination among family shifts during transitions. For example, husbands and wives have similar rhythmicity until childbirth when wives align more with their infant (Leonhard & Randler, 2009). It is likely that proximal processes, especially cohabitating relationships, influence daily rhythmicity, and ultimately circadian rhythms; however, there are very few studies that examine circadian rhythms in the context of close relationships. Given the coordination between circadian rhythms and sleep processes, measuring circadian rhythms (i.e., endogenous, chronotype preference, daily rhythmicity) is a critical next step in studying relationships and sleep.

Interpersonal processes measurement Social control may enhance interpersonal security, which in turn, could influence sleep. For example, men report greater relationship satisfaction when their partners engage in positive social control (de Montigny et al., 2017), and individuals show greater psychological well-being and positive affect when they report that their partners engage in positive health monitoring. On the other hand, individuals report greater negative affect and worse psychological well-being when their partners engage in negative social control (Craddock, vanDellen, Novak, & Ranby, 2015). This suggests that individuals may interpret positive social control as protective. Interpersonally secure family relationships likely involve some combination of warmth, social control, and moderate involvement. Multi-method assessment of interpersonal processes in future studies will help identify targets for intervention. For example, study protocols might include questionnaires, daily assessments of interpersonal processes, or laboratory engagement tasks.

Implications of focus on sleep in the context of close relationships Sleep may be one mechanism by which close relationships are linked to health. Relationships are strongly linked to long-term health and well-being (Kiecolt-Glaser & Newton, 2001; Pietromonaco & Collins, 2017). Sleep is strongly linked to health and well-being (Buysse, 2014; Gallicchio & Kalesan, 2009; McKnight-Eily et al., 2011). The lack of meaningful social relationships is associated with poor sleep quality (Cacioppo et al., 2002) and poor sleep efficiency (Cacioppo & Hawkley, 2003). Recently, Simon and Walker (2018) demonstrated that poor sleep quality leads to social withdrawal and loneliness. Bidirectional associations between sleep and connectedness will be important to explore in studies of couples' sleep and health. When assessing sleep at the dyadic level, Gunn and colleagues found that couples who were more concordant throughout the night also had lower C-reactive protein, which is a putative marker for cardiovascular disease (Gunn et al., 2017). Troxel and colleagues found that marital conflict was associated with nighttime blood pressure, which is also a putative marker of cardiovascular health (Troxel, DeSantis, et al., 2017). Many studies demonstrate associations between relationship characteristics and waking health behaviors and biological processes. Given that sleep is characterized by intimacy and vulnerability, and that it is highly predictive of short- and long-term health outcomes, it is important to consider how relationships influence psychophysiology at night and across the 24-hour day.

Conclusions

In summary, cohabitating close relationships appear to be powerfully linked to sleep parameters such as sleep quality, sleep duration, sleep efficiency, and sleep timing. Anthropological and attachment theories provide a guiding framework for understanding why and how relationships are associated with sleep. The literature provides strong supportive evidence for interpersonal security being necessary for good sleep and evidence for transmission of sleep behaviors within families, perhaps due in part due to the properties of attachment in close relationships. Most studies focus on cross-sectional associations; however, a few studies demonstrate bidirectional associations between relationship characteristics and sleep parameters. The broader field of the social environment and sleep would benefit from advancing research on controlled intervention studies, enhanced methodological considerations (e.g., daily observations, experimental designs) and greater attention to circadian rhythms in the context of families. Finally, it is likely that sleep characteristics are one way that relationships influence health. Studies examining relationship factors, sleep, and health outcomes will help identify targets for improving health by focusing on relationships and sleep.

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Sleep and Social Behavior in Organizations: Implications for Job Performance

Arielle P. Rogers, Christopher J. Budnick, and Larissa K. Barber

Employee behavior varies within organizations and job roles. Organizational behavior scientists have devoted significant effort toward understanding predictors of this variability—especially concerning job performance. Past research identified environmental (e.g., job characteristics, work conditions) and individual differences (e.g., employee knowledge, skills, abilities, and other characteristics) that facilitate or hinder performance, but recent research seeks to understand *within-person* performance fluctuations (e.g., Beal, Weiss, Barros, & MacDermid, 2005; Dalal, Lam, Weiss, Welch, & Hulin, 2009). One research avenue resulting from this shift is the influence of sleep on employee behavior and organizational functioning.

Recent research on sleep and workplace behavior treats sleep as an outcome variable by studying how work characteristics (e.g., work overload, shift work) harm sleep (e.g., Åkerstedt, 2003; Linton, Kecklund, Franklin, et al., 2015). Although decades of extant research examines sleep's influence on various cognitive tasks (e.g., Lim & Dinges, 2010; Harrison & Horne, 1999, 2000), organizational behavior scientists have only recently started investigating sleep's influence on performance within organizations. As poor sleep negatively influences cognitive (Harrison & Horne, 1999, 2000; Lim & Dinges, 2010), emotional (Kahn, Sheppes, & Sadeh, 2013), and social functioning (Beattie, Kyle, Espie, & Biello, 2015; Gordon,

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Mendes, & Prather, 2017) outside the work context, poor sleep should also affect behavior at work.

We focus on how sleep (i.e., quantity, quality, consistency, and sleepiness[1]) and social behavior intersect within organizations to influence job performance. Job performance encompasses multiple workplace behaviors. Therefore, we first define job performance and discuss how sleep relates to various job performance components. Then we highlight variables that could explain sleep and job performance relationships (i.e., mediators) while considering under what conditions (i.e., moderators) sleep is more (or less) likely to influence job performance. Last, we analyze current research methodologies, provide suggestions for improving future research designs, and identify novel research directions. Even though organizational sleep research is in nascent stages, we draw from the larger body of scientific research (i.e., occupational health psychology, clinical psychology, social psychology, biopsychology, management, neuroscience, sleep medicine) to inform critical inquiry into this topic. We hope this chapter sparks future interdisciplinary research on sleep and social behavior in organizations.

Job Performance: Definition and Relationship with Sleep

Job performance includes all workplace behaviors influencing organizational functioning and goal obtainment that are evaluated (positive or negative; Campbell, 1990; Motowidlo, Borman, & Schmidt, 1997; Viswesvaran & Ones, 2000). Consistent with past work, we conceptualize job performance as having three dimensions: task performance, organizational citizenship behaviors, and counterproductive work behaviors (Motowidlo et al., 1997). Task performance reflects the job role's core required behaviors (e.g., duties included in a job description) and thus operationalizations differ by role.

Organizational citizenship behaviors are voluntary behaviors that improve the organizational environment either socially or psychologically (e.g., helping a coworker with job-related tasks, teamwork; Organ, 1997). Organizational citizenship behaviors typically are not rewarded via formal compensation mechanisms but require employees to go above and beyond core duties (Organ, Podsakoff, & MacKenzie, 2006). Researchers generally propose two dimensions comprising organizational citizenship behavior: 1) helping individuals (Williams & Anderson, 1991) or helping behaviors (e.g., assisting others after absences; Smith, Organ, & Near, 1983; Organ et al., 2006), and 2) compliance (e.g., punctuality, regular

[1] Sleep is a multidimensional construct, so we often need to specify which type of sleep measurement was used for each study in our review. Quantity refers to the amount of sleep (usually measured in minutes or hours), whereas quality refers to whether someone feels restored after a sleep period. Sleep consistency refers to having regular bed and wake times. Sleep quality, quantity, and consistency are all potential precursors to the concept of sleepiness, which has a physiological basis in terms of the drive to want to fall asleep. For a thorough review of these distinctions related to work behavior, see Mullins et al. (2014).

attendance; Smith et al., 1983; Organ et al., 2006) or contributions to the broader organization (e.g., protecting organizational assets; Williams & Anderson, 1991).

Counterproductive work behaviors are behaviors that harm organizations and/or employees. Counterproductive work behaviors also are multidimensional with some suggesting five dimensions (i.e., abuse, production, sabotage, theft, and withdrawal; Spector et al., 2006), and others proposing a two-dimension model (i.e., interpersonal and organizational deviance; Sackett & DeVore, 2001). Interpersonal deviance refers to behaviors directed toward organizational *members* (e.g., gossiping or insults). Organizational deviance focuses on behaviors directed at the organization and include property deviance (e.g., theft or property damage) or production deviance (absences, tardiness, or intentional poor performance). Across models, counterproductive work behaviors are purposeful (i.e., volitional) and cause the organization or organizational stakeholders harm (Spector et al., 2006). Consistent with the three-dimension view of job performance, we next focus on how sleep influences task performance followed by a discussion of sleep's relationship with organizational citizenship and counterproductive work behaviors.

Task Performance and Sleep

Core job tasks, and thus task performance, differ by job type. Because our focus is on *social* behavior within organizations, we limit our discussion of task performance to two areas of social task performance relevant to various jobs: leadership and emotion performance. Although we focus on these, we acknowledge that they are not a complete "task performance" definition,[2] which also must account for non-social organizational objectives (e.g., individual productivity, safety). For example, sleep deficits increase task completion errors (Kribbs & Dinges, 1994; Van Dongen & Dinges, 2005) and workplace accidents (Barnes & Wagner, 2009). Still, leadership and emotion performance involve common workplace interpersonal interactions (e.g., leader-follower and employee-customer/client interactions), contribute to individual and organizational objectives, and therefore are important to overall employee and organizational functioning.

Leadership and Sleep Numerous conceptualizations of leadership make examining sleep and leadership complex. To date, organizational research has examined sleep in the context of three leadership theories: Transactional, Transformational-Charismatic, and Leader-Member Exchange theory. Transactional leaders use rewards and corrective feedback to motivate performance (Bass, 1985), whereas transformational leaders inspire and motivate followers through a strong vision,

[2] The organizational science literature does not typically classify emotion performance as a type of task performance. However, emotion performance often involves required behaviors that are central to one's job in service positions (e.g., displaying positive emotions toward customers, even when feeling negatively) and are rewarded via formal compensation mechanisms (e.g., exceptional customer service bonuses), consistent with the definition of task performance.

integrity, charisma, and communal follower-leader relationships (House, 1977; Weber, 1947). Alternatively, Leader-Member Exchange theory holds that leaders interact with followers differently based on in-group and out-group membership. In-group followers hold unique, high quality relationships with the leader, characterized by trust, respect, obligation, and mutual benefit; out-group followers often have low quality leader relationships (Dienesch & Liden, 1986; Graen & Scandura, 1987; Graen & Uhl-Bien, 1995).

Sleep loss hinders adaptive leadership performance including both decreased transactional and transformational leadership (Barnes, Guarana, Nauman, & Kong, 2016; Olsen, Pallesen, Torsheim, & Espevik, 2016). Additionally, inconsistent sleep (i.e., longer sleep durations on weekends compared to weeknights) has been associated with lower peer-rated leadership performance (Gaultney, 2014). Sleep issues also seem to influence leader-follower relationship quality. When lacking sleep, both leaders and followers report lower leader-follower relationship quality (Guarana & Barnes, 2017). Overall, the dearth of research in this area and the breadth of literature suggesting that leadership influences follower job performance (e.g., Martin, Guillaume, Thomas, Lee, & Epitropaki, 2016; Wang, Oh, Courtright, & Colbert, 2011) justifies more research examining sleep's relationship to different leadership components.

Emotion Performance and Sleep As a core job duty, customer service employees are often required to display positive emotions and hide negative emotions to achieve organizational objectives (i.e., 'service with a smile'; Hochschild, 1983; Grandey, 2000). Emotion performance reflects the extent that employees' expressed emotions align with rules dictating acceptable workplace emotional expression (emotional display rules; Grandey & Gabriel, 2015). Such emotion performance predicts customer satisfaction, loyalty, referrals, and service quality perceptions (Groth, Hennig-Thurau, & Walsh, 2009; Hennig-Thurau, Groth, Paul, & Gremler, 2006; Pugh, 2001).

Research has focused on two "emotional labor" strategies employees may use to achieve emotion performance: (1) surface acting – faking emotions by modifying displayed expressions, and (2) deep acting – using emotion regulation strategies to change *both* felt and expressed emotions. Deep acting involves the display of authentic emotions via methods such as cognitive reframing or attentional shifting, whereas an example of surface acting includes smiling while still feeling frustrated. Deep acting generally predicts more positive performance outcomes and fewer negative outcomes compared to surface acting (Groth et al., 2009; Hülsheger & Schewe, 2011; Totterdell & Holman, 2003). This strategy distinction is important because the *perceived authenticity* of emotional displays predicts positive customer service outcomes (Hennig-Thurau, Groth, & Gremler, 2006; Wang et al., 2017). As sleep loss and poor sleep quality are detrimental to adaptive emotion regulation (for reviews see Budnick & Barber, 2015; Kahn et al., 2013; Palmer & Alfano, 2017), sleep should influence employees' abilities to effectively deep act at work, in turn, influencing emotion performance and customer service. In fact, in one study, sleep deprivation predicted decreased deep acting for leaders; however, sleep loss did not predict surface acting (Barnes, Guarana, et al., 2016).

Moreover, emerging evidence indicates that sleep loss alters individuals' workplace social information interpretations, which could affect one's ability to evaluate—or re-evaluate-the situations. Sleepy individuals interpret ambiguous information more negatively than non-sleepy individuals (Barber & Budnick, 2015; Ree & Harvey, 2006), and poor sleep is associated with reduced cognitive reappraisal abilities (an emotional regulation strategy; Mauss, Troy, & LeBourgeois, 2013). Thus, sleep might alter how employees interpret interactions and their ability to adaptively respond. Yet, sleep and emotion performance outcomes are relatively unexamined even though many countries have predominantly service-based economies.

Organizational Citizenship Behaviors and Counterproductive Work Behaviors

We are aware of only one study to date that has directly examined sleep and Organizational Citizenship Behaviors—behaviors such as assisting others in the organization and showing enthusiasm in one's work and organizational goals. One night of objectively measured sleep quantity (via polysomnography) was associated with greater next-day organizational citizenship behaviors directed toward the organization, but not those directed toward *individuals* in the organization (Study 1; Barnes, Ghumman, & Scott, 2013). Self-reported sleep quantity across five workdays also positively predicted *both* organizational citizenship behaviors directed toward the organization and toward individual organizational members (Study 2).

Counterproductive work behaviors cover a range of negative workplace behaviors typically categorized as interpersonal or organizational deviance. Supervisors with poor self-reported sleep quality across 10 days displayed increased abusive supervisory behaviors (e.g., yelling or being rude to a subordinate) indirectly through lower self-reported self-regulation ability (i.e., ego depletion; Barnes, Lucianetti, Bhave, & Christian, 2015). Sleep issues also correlate with unethical counterproductive work behaviors (for a review see Barber & Budnick, 2016). For instance, in one study, higher objective sleep quantity and self-reported sleep quality predicted fewer unethical workplace behaviors like cheating and taking credit for another's work (Barnes, Schaubroeck, Huth, & Ghumman, 2011).

Intentionally withholding effort (work withdrawal) is another type of counterproductive work behavior. Employees can physically (e.g., lateness, absenteeism) or psychologically withdraw (e.g., presenteeism, cyberloafing; LeBlanc, Barling, & Turner, 2014; for a review on sleep and work withdrawal see Carleton & Barling, 2016). Concerning physical withdrawal, state sleepiness predicts partial (e.g., arriving late, leaving early; Swanson et al., 2011) and full absenteeism (Åkerstedt, Kecklund, Alfredsson, & Selen, 2007; Philip, Taillard, Niedhammer, Guilleminault, & Bioulac, 2001). Sleep deprivation also predicts psychological withdrawal, such as concentration and attention problems (Anderson & Horne, 2006; Chuah et al., 2010; Lim & Dinges, 2010; Swanson et al., 2011). Poor sleep additionally facilitates psychological withdrawal expressed as reduced work effort. For example, cyber-loafing – internet use at work for non-work purposes – is associated with poor objective sleep (Wagner, Barnes, Lim, & Ferris, 2012). On the Monday directly following Daylight Savings Time (a sleep loss proxy) employees increased cyberloafing relative to the week prior and two weeks after (Wagner et al., 2012). In sum, poor sleep quality and quantity generally predict less counterproductive work behaviors (e.g., Christian & Ellis, 2011; Mullins, Cortina, Drake, & Dalal, 2014) and sleep quantity predicted more organizational citizenship behaviors (Barnes et al., 2013), but less is understood about the causes or boundaries around those relationships. Therefore, we next discuss potential mediators and moderators of the sleep-performance relationship.

From Sleep to Performance: Mediators and Moderators

The reviewed literature demonstrates a link between better sleep and more desirable social behaviors in organizations. Yet our understanding of those relationships' causal explanations and boundary conditions remains limited. Integrating empirical evidence across disciplines (e.g., organizational behavior, social psychology, neuroscience, sleep medicine) suggests that three mediator "classes" help explain sleep and social behavior relationships: (1) social cognitive processes, (2) affective states, and (3) self-regulatory processes. Indeed, multiple related and interacting mechanisms likely explain the sleep-performance link (see Fig. 1). Although the mechanisms we propose certainly influence each other, in any situation, the most salient mechanism(s) may depend on both the focal performance component and context. For example, the mechanism explaining sleep's relationship to organizational citizenship behaviors might differ from that explaining sleep's relationship to counterproductive work behaviors, and whether those relationships even exist might be partially determined by the organizational context. Below, we discuss each separate—but highly interrelated—mediator class that might explain why sleep influences job performance, with the caveat that considerable work remains to confirm these proposed mechanisms.

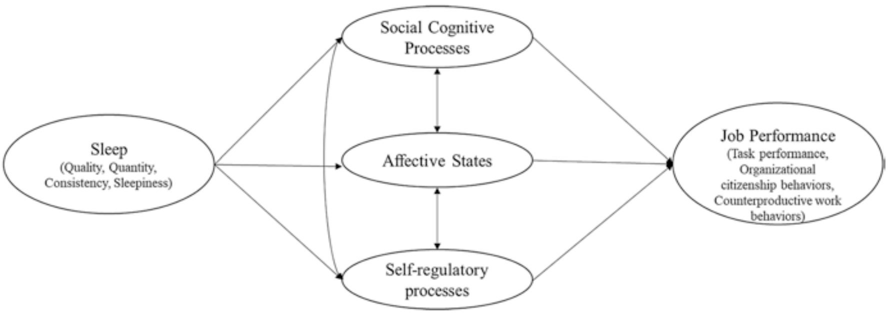

Fig. 1 Mediators of relations among sleep and job performance

Mediator Class 1: Social Cognitive Processes

A large body of research suggests sleep can influence various cognitive processes including attention, perception, memory, and decision-making (Alhola & Polo-Kantola, 2007; Harrison & Horne, 2000; Killgore, 2010). Growing evidence also suggests sleep influences *social* cognitive processes (Beattie et al., 2015; Gordon et al., 2017). Because organizational scientists already apply social cognitive principles to understanding leadership (e.g., leader-follower relations; Thomas, Martin, Epitropaki, Guillaume, & Lee, 2013; Implicit Leadership Theories; see Epitropaki, Sy, Martin, Tram-Quon, & Topakas, 2013; Lord & Maher, 1991), customer service interactions (e.g., Van Kleef, Homan, & Cheshin, 2012), and unethical work behaviors (Barber & Budnick, 2016), we suggest a similar approach to understanding relations among sleep and social-organizational behavior. We propose three social cognitive processes to help explain relations among sleep and social-organizational behavior: (1) attentional biases, (2) person perception, and (3) social judgment and decision-making processes.

Attentional and Memory Biases Sleepiness affects vigilance, in that important situation-relevant information can be overlooked (Budnick & Barber, 2015; Durmer & Dinges, 2005). This *attentional bias* can result in a failure to recognize the ethical implications of one's own or another's actions (Barber & Budnick, 2016). In fact, sleep loss is related to moral awareness (Barnes, Gunia, & Wagner, 2015); individuals are less likely to recognize that a situation holds moral implications when sleepy. Relatedly, poor sleep quality fosters a memory bias for negative information (Gobin, Banks, Fins, & Tartar, 2015). Employees could feel that aggressive responses toward the organization or others in the organization are justified when influenced by a sleepiness-induced negative attentional bias (i.e., only attending to and remembering supervisor, coworker, or customer negative behaviors). In other words, moral awareness might mediate a relationship between poor sleep and abusive supervision, as well as poor sleep and counterproductive work behaviors.

Person Perception Sleep also influences person perception (i.e., one's perception and impression of others; Gordon et al., 2017). For instance, sleep may influence emotion recognition which involves processing emotional stimuli, including identifying and interpreting others' emotions (Beattie et al., 2015; Killgore, Balkin, Yarnell, & Capaldi, 2017). Sleep deprivation decreases the speed and accuracy of facial expression recognition (positive, negative, or neutral) and ambiguous (neutral) expressions are especially subject to those deficits (Beattie et al., 2015; Maccari et al., 2014; van der Helm, Gujar, & Walker, 2010).[3] Outside of the organizational

[3] In a recent study, Holding et al. (2017) found no effect of self-reported sleep quality, quantity or manipulated sleep deprivation on emotion recognition accuracy using both video and audio-based stimuli. These authors suggest lack of replication may be due to use static stimuli and morphed images in prior research (versus multimodal stimuli) or publication bias. However, they also speculate sleep may influence recognition of emotion *intensity* (versus identification of the displayed emotion) which was not measured in their research.

literature, worse sleep in one partner predicted less empathic accuracy (i.e., identification of others' emotions) during conflict for *both* partners in the romantic relationship (Gordon & Chen, 2014). Additionally, one night of sleep deprivation led to decreased accuracy of identifying happiness and sadness, but not surprise, fear, disgust, or anger (Killgore et al., 2017). Killgore et al., concluded sleep deprivation may be less likely to influence reactions to urgent or threatening situations, but rather may impair social-affiliative processes and less urgent relationship processes—such as work-related social interactions.

From the Emotions as Social Information perspective (EASI; Van Kleef, 2009), affective displays influence perceivers' behaviors and social judgments by providing information about others' intentions and goals or by influencing perceiver affect via emotional contagion and/or increased interpersonal attraction (Van Kleef, 2009). For example, employees in service settings can use customers' positive or negative emotional displays as information indicating they should maintain or adjust behavior, respectively, in order to increase customer satisfaction (Mattila & Enz, 2002). Additionally, accurate emotion recognition appears critical for transformational leadership. Correctly identifying followers' emotions helps to effectively communicate and inspire, as well as develop high quality leader-follower relationships (Caruso, Mayer, & Salovey, 2002; Rubin, Munz, & Bommer, 2005). Further, follower sleep deprivation decreases perceptions of leader charisma (Barnes, Guarana, et al., 2016), which could reduce perceptions of leader effectiveness.

Social Judgment and Decision-making Sleep not only influences what social information individuals attend to and how they perceive this information, but also how they interpret/judge and make decisions regarding social information (see Harrison & Horne, 2000). The term "social decision-making" refers to decisions affecting both ourselves as well as others (Lee & Harris, 2013; Rilling & Sanfey, 2011). Such decisions involve both "non-social" processes (e.g., risk/reward processing) as well as social processes (e.g., inferring others' psychological states; Lee & Harris, 2013). Social processes also include decisions related to trusting others, helping others, following social norms, and fairness (Rilling & Sanfey, 2011), all of which are relevant to job performance.

For instance, poor sleepers use more heuristics or mental shortcuts, such as stereotyping, which can in turn lead to prejudice (Ghumman & Barnes, 2013). Sleepiness also fosters a negative interpretive bias; that is, when faced with ambiguous (or clearly) negative social information sleepy individuals provide especially negative interpretations relative to rested individuals (Barber, Barnes, & Carlson, 2013; Barber & Budnick, 2015; Ree & Harvey, 2006; Tempesta et al., 2010). Within the organizational context, increased sleepiness predicts heightened unfairness interpretations when exposed to ambiguous or clearly unfair workplace information (Barber & Budnick, 2015). Those findings align with research showing sleep deprivation leads to decreased trust and heightened unfairness sensitivity when interacting socially (Anderson & Dickinson, 2010). Further, sleep deprived individuals are more likely to place blame on others during frustrating situations and less likely to offer solutions or attempt to make amends with others

(Kahn-Greene, Lipizzi, Conrad, Kamimori, & Killgore, 2006). Finally, sleep deprivation can lead to deficits in moral decision-making (Olsen, Pallesen, & Eid, 2010; Tempesta, Couyoumdjian, Moroni, et al., 2011). As sleepier individuals tend to interpret ambiguous information as especially negative, those interpretations should influence their social behavior in organizational settings (Budnick & Barber, 2015). For instance, interpretive biases may be particularly relevant in mediating relations among sleep and non-task performance behaviors (Barber & Budnick, 2016) because perceptions of workplace fairness have been positively linked to organizational citizenship behaviors and negatively linked to counterproductive work behaviors (Colquitt et al., 2013; Dalal, 2005). However, there is currently no direct evidence empirically supporting the link between sleep, fairness perceptions, and job performance outcomes.

Finally, given attention, perception, judgment, and decision-making are interrelated, sleep may simultaneously influence these processes. For example, attentional biases might contribute to faulty decision-making (e.g., as neutral/negative information is more heavily weighted) and negative judgments toward others (e.g., subordinate perceptions of leaders). In the workplace, sleepy leaders that engage in more abusive supervisory behaviors (Barnes, Gunia, et al., 2015) might do so because they attend to, remember, and more heavily weight followers' actions that are negative or are ambiguously negative (Barber & Budnick, 2015; Budnick & Barber, 2015).

Mediator Class 2: Affective States

Social Task Performance Much research examines affective states' and related processes' (e.g., display of affect; see discussion on self-regulatory processes below) influence on work behaviors (e.g., Beal et al., 2005; Dalal et al., 2009; Weiss & Cropanzano, 1996), in particular, social performance behaviors (Barsade & Gibson, 2007; Van Knippenberg, Van Knippenberg, Van Kleef, & Damen, 2008). Sleep's importance for mood/emotional states is well-documented (e.g., Beattie et al., 2015; Fairholme & Manber, 2015; Kahn et al., 2013; Pilcher & Huffcutt, 1996). When individuals sleep poorly they experience more negative (Dinges et al., 1997; Drake et al., 2001; Križan & Hisler, 2019) and less positive affect (Bower, Bylsma, Morris, & Rottenberg, 2010; Talbot, McGlinchey, Kaplan, Dahl, & Harvey, 2010).

Direct evidence links sleep to leadership via negative affective states. Specifically, rested leaders display less hostility which improves leader-follower relationship quality (Guarana & Barnes, 2017). Sleep deprivation decreases follower positive affect and perceptions of charismatic leadership (Barnes, Guarana, et al., 2016). Regarding customer service performance, poor sleep that increases employees' negative affect could disrupt attempts to bridge gaps between experienced and displayed emotions (Gish & Wagner, 2016). Sleepy employees might have difficulty meeting social performance expectations (e.g., to express friendliness toward customers), because of increased negative affect combined with more emotion regulation difficulties.

Organizational Citizenship Behaviors Research suggests job satisfaction mediates the sleep to organizational citizenship behavior relationship (Barnes et al., 2013). Job satisfaction is an attitudinal construct comprised of both affective (i.e., positive mood) and cognitive components (Judge & Kammeyer-Mueller, 2012). Evidence suggesting positive affect is associated with organizational citizenship behaviors (Dalal et al., 2009; Fisher, 2002; Miles, Borman, Spector & Fox, 2002) might indicate that positive affective states also mediate relations between sleep and organizational citizenship behaviors. Still another plausible mediator of relations among sleep and organizational citizenship behaviors is work engagement, which is a positive affective-motivational state characterized by vigor, dedication, and absorption (Schaufeli, Salanova, Gonzalez-Romá, & Bakker, 2002). Work engagement increases organizational citizenship behaviors (Rich, LePine, & Crawford, 2010), but sleep problems predict decreased work engagement (Hallberg & Schaufeli, 2006) and better sleep hygiene and sleep quality predict more work engagement (Barber, Grawitch, & Munz, 2013; Kühnel, Zacher, de Bloom, & Bledow, 2017). Furthermore, *supervisor* sleep quality correlates with decreased *employee* work unit engagement (Barnes, Lucianetti, et al., 2015) suggesting supervisor sleep may also influence employee organizational citizenship behaviors, although this is not yet empirically confirmed.

Counterproductive Work Behaviors Regarding counterproductive work behaviors, empirical evidence suggests hostility mediates the relationship between sleep and counterproductive work behaviors (Christian & Ellis, 2011). Another potential negative affective state that may mediate relations among sleep and counterproductive work behaviors includes anxiety, which correlates with both sleep problems (Swanson et al., 2011) and counterproductive work behaviors (Fox, Spector, & Miles, 2001). However, an empirical test of this has yet to emerge. A different alternative mechanism might relate to affective functioning; when sleepy, individuals might have greater difficulty interpreting the cause of their own affective states—for example, they might attribute negative emotions to an aspect of the organizational environment instead of to poor sleep (Barnes, Guarana, et al., 2016). If sleepiness is the cause of negative affect, but employees misattribute it to the organizational environment, sleepy individuals might engage in counterproductive work behaviors.

Mediator Class 3: Self-Regulatory Processes

Self-regulation Definition and Relationship to Job Performance Self-regulation is a broad construct referring to effortful goal-focused control over cognition, affect, and/or behaviors. Sleep has a well-established influence on higher-order executive self-regulatory functions (e.g., working memory, attention, inhibition; Chuah, Venkatraman, Dinges, & Chee, 2006; Killgore, 2010; Lim & Dinges, 2010). Although listed separately, self-regulatory processes are intertwined tightly with the affective and social cognitive processes discussed previously. We discuss self-regulatory processes separately because they are integral to job performance (Beal et al., 2005; Porath & Bateman, 2006) and are commonly discussed as a potential mediator of sleep and workplace outcomes (e.g., Barnes, 2012).

Effective behaviors in each component of job performance involve self-regulation as they require motivating goal-directed and inhibiting non-goal-directed behaviors. For example, social task performance (e.g., leadership and emotion performance) necessitates emotion regulation – controlling emotional experiences and displays. Effective emotion regulation should also predict high emotion performance. Given customer and leader perceptions of employees are critical to successful social task performance, much research examines the association between affective *displays* (as opposed to affective experiences) and leadership (e.g., Trichas, Schyns, Lord, & Hall, 2017). Effective social task performance also involves other aspects of self-regulation such as goal-monitoring and inhibitory control. For example, emotion performance requires monitoring the discrepancy between affective experiences and display rules (i.e., goal monitoring). If a discrepancy occurs, emotion regulation strategies (e.g., deep or surface acting) are key to inhibiting maladaptive responses (e.g., yelling at a customer/employee). Thus, sleep issues can interfere with multiple self-regulatory aspects key to social task performance including goal monitoring, emotion regulation, and inhibitory control (e.g., Križan & Hisler, 2016).

Self-regulation Theories Although multiple self-regulatory theories exist, two seem to be relevant contenders; the self-regulatory depletion model (i.e., strength model) and shifting priorities models (Križan & Hisler, 2016; Pilcher, Morris, Donnelly, & Feigl, 2015). The depletion model proposes that individuals' self-regulatory *ability* or energy is limited; adequate sleep replenishes self-regulatory resources (e.g., Barnes, 2012). When employees "deplete" resources via effortful work activities, they must sleep to restore resources required for subsequent self-regulation. The proposition that employees cannot self-regulate for effective job performance without sleep is characteristic of a self-regulation depletion approach (e.g., Baumeister, Vohs, & Tice, 2007). To date, most organizational behavior research has adopted the self-regulatory depletion model by suggesting performance results from employees' self-regulatory *ability*. For instance, counterproductive work behaviors result from self-regulatory failure due to depletion (e.g., Barnes, Gunia, et al., 2015; Christian & Ellis, 2011).

Yet, rather than being *unable* to self-regulate, employees might just be *unwilling*. The shifting priorities model of self-regulation proposes that employees can adaptively self-regulate but choose not to. Evidence contradictory to the strength model suggests that incentives override ego depletion (Vohs, Baumeister, & Schmeichel, 2012) and sleep-related vigilance deficits (Horne & Pettitt, 1985). Moreover, ego depletion *perceptions* influence performance, regardless of actual depletion (Clarkson, Hirt, Jia, & Alexander, 2010; Draganich & Erdal, 2014). Because organizational behavior research typically collects self-reports of ego depletion, some performance results might be attributed to sleep-related motivation variations. When experiencing sleepiness, employees might think that they are unable to self-regulate and that could provide a "self-license" for negative behavior (e.g., counterproductive work behaviors, violating display rules; e.g., Križan & Hisler, 2016). Finally, researchers also have been unable to provide evidence for what "resource" is being depleted (see Inzlicht & Berkman, 2015), especially given central claims of an energy mechanism have been undermined by later research (i.e., glucose; Dang, 2016). Other studies even question the robustness of the central depletion behavioral effect observed in past research (Carter, Kofler, Forster, & McCullough, 2015; Carter & McCullough, 2014; Hagger et al., 2016).

Alternatively, sleepy employees might reprioritize focal goals and recruit compensatory mechanisms to motivate goal pursuit, an assertion consistent with work showing fewer performance decrements on complex compared to simple tasks when sleepy (Harrison & Horne, 2000; Hockey, 2013; Križan & Hisler, 2016). Stated differently, sleepy employees might identify and focus efforts on achieving the most critical goals and withhold citizenship effort for sustained task performance despite sleep problems (Križan & Hisler, 2016). This discussion presents at least two potential self-regulatory mediators between sleep and job performance. Sleepiness might predict increased task performance (but decreased organizational citizenship behaviors) indirectly via self-regulatory beliefs (i.e., limited or not) and/or ego-depletion perceptions.

Moderators of the Sleep-Job Performance Relationship

Caffeine Intake Caffeine mitigates attention and vigilance deficits after poor sleep (Lorist, Snel, Kok, & Mulder, 1994; Patat et al., 2000; Reyner & Horne, 1997; Van Dongen et al., 2001; Wright, Badia, Myers, & Plenzler, 1997) and could buffer job performance against sleep loss—at least on some tasks. Although caffeine seems to consistently provide benefits for simple attention and vigilance tasks, caffeine's relationship with sleep and social behavior appears more nuanced. In social contexts, caffeine may enhance sleep deprived participants' differentiation of complex emotional expressions' subtleties (Huck, McBride, Kendall, Grugle, & Killgore, 2008). Caffeine also improves mood following sleep loss (e.g., reduced fatigue and irritability; Grant et al., 2018; Lieberman, Tharion, Shukitt-Hale, Speckman, & Tulley, 2002; Penetar, McCann, & Thorne, 1993) and reduces depletion to influence social performance (e.g., counterproductive work behaviors such as deception; Welsh, Ellis, Mai, & Christian, 2014). Further, caffeine use leads to less risky-decision making and impulsivity following sleep deprivation (Killgore, Kamimori, & Balkin, 2011). However, some studies find no effect of caffeine on some executive functions (Killgore, Kahn-Greene, Grugle, Killgore, & Balkin, 2009), or moral decision-making speed (Killgore et al., 2007) following sleep deprivation. Further, others report that caffeine increases anxiety and social threat sensitivity (Smith, Lawrence, Diukova, Wise, & Rogers, 2012). Those results hold implications for different dimensions of job performance as caffeine could attenuate sleep-related deficits at work, or potentially even enhance negative attentional or interpretive biases by increasing anxiety and threat sensitivity. Importantly, both the dose of caffeine as well as the amount of sleep loss may also influence whether and how caffeine affects performance (e.g., Bonnet et al., 2005; Roehrs & Roth, 2008). Thus, various factors (e.g., task type, caffeine dose, amount of sleep loss) may interact with caffeine use to influence social-organizational behavior.

Task Type and Job Position Sleep research emphasizes the differential effects of poor sleep on various cognitive and emotional functions (e.g., Harrison & Horne, 2000; Killgore, 2010; Lim & Dinges, 2010; Nilsson et al., 2005; Pilcher & Huffcutt, 1996; Tucker, Whitney, Belenky, Hinson, & Van Dongen, 2010). Given different cognitive functions underlie different tasks, sleep and job performance relationships should differ by task type (e.g., Mullins et al., 2014; Pilcher & Huffcutt, 1996). For example, poor sleep heavily influences creative thinking and problem-solving tasks via reduced prefrontal cortex functioning (Barnes & Hollenbeck, 2009; Durmer & Dinges, 2005). That influence is even greater for novel or difficult tasks relative to well-learned, routine tasks (Bonnet, 2011; Mullins et al., 2014).

In team contexts, task interdependency might alter the relationship between sleep and team performance. Interdependent tasks require unique contributions from team members toward a superordinate goal. By contrast, independent or additive team tasks are ones in which each member contributes to an overall team output and no member's contribution is identifiable. Preliminary research suggests that interdependent tasks mitigate the influence of poor sleep on task performance. When identifiable and responsible for a unique contribution, individuals appear to increase performance motivation since low effort is easily noticed by others (Baranski et al., 2007). Alternatively, if a sleepy employee is under-performing, non-sleepy team members might increase effort to compensate and safeguard performance levels (Barnes & Hollenbeck, 2009). However, in an independent team task context (i.e., all employees complete identical tasks), poor sleep increases social loafing (i.e., lower effort when working in a group versus alone; Hoeksema-van Orden, Gaillard, & Buunk, 1998). Because individual contributions are unidentifiable for independent team tasks, individuals can reduce efforts without fear of potential social consequences. In fact, providing individual performance feedback mitigates poor sleep's negative influence on both task and team performance (Hoeksema-van Orden et al., 1998).

Perhaps particularly socially relevant, sleep deprivation's negative mood induction seems even stronger than its detrimental influence on cognitive and motor performance (Pilcher & Huffcutt, 1996). Therefore, poor sleep may be more strongly related to job performance for employees working in jobs characterized by high levels of emotional labor (e.g., customer service and client-facing employees). Additionally, effective leadership also heavily relies on adaptive emotional functioning (e.g., inspiring and motivating), which poor sleep might influence more heavily than non-social job performance components (e.g., individual productivity).

Chronotype Misalignment Individuals typically self-identify as a morning or night person, which is one chronotype indicator. Chronotype refers to a biologically-based (circadian) rhythm toward morning/evening alertness. A mismatch between one's chronotype and work schedule should exacerbate sleep loss' negative effects on social cognitive, affective, and self-regulatory processes. Research suggests circadian processes (which determine chronotype) influence affect (Boivin, 2000; Murray et al., 2009), alertness (Dijk, Duffy, & Czeisler, 1992) and cognitive performance (Dijk et al., 1992). Regarding social behavior, the *morning morality effect* (Kouchaki & Smith, 2014) suggests ethical behavior is more likely in the morning than evening; however, one's chronotype qualifies that effect. Although morning types exhibit the morning morality effect, evening types are most ethical in the evening (Gunia, Barnes, & Sah, 2014). Thus chronotype-schedule fit might moderate relationships between sleep and unethical (Barber & Budnick, 2016) or counterproductive work behaviors (see also Randler, chapter "Chronotype and Social Behavior", this volume).

Closely related to the above, many employees' work schedules disrupt their normal circadian rhythm resulting in lost sleep on work days (i.e., sleep debt), which is recuperated by sleeping longer on non-work days. The degree to which one's work schedule is chronically misaligned with one's circadian rhythm is called *social jetlag*, and is commonly observed in evening types (Wittmann, Dinich, Merrow, & Roenneberg, 2006) and/or shift workers (Juda, Vetter, & Roenneberg, 2013). For instance, emerging work suggests circadian misalignment in shift workers is associated with increased procrastination (Kühnel, Sonnentag, Bledow, & Melchers, 2018). Further, social jetlag moderates a sleep quality and procrastination relationship; poor sleep quality predicts procrastination for socially jetlagged employees (Kühnel, Bledow, & Feuerhahn, 2016). Research has yet to examine if sleep quality (or quantity) and social jetlag interact to predict social performance behaviors like leadership effectiveness, emotion performance, or citizenship behaviors.

Personality In addition to external influences, stable individual differences (e.g., personality) likely render individuals more or less vulnerable to poor sleep's negative outcomes. For instance, sleep deprivation harms extraverts' cognitive and psychomotor functioning on vigilance tasks relative to introverts (Killgore et al., 2007; Taylor & McFatter, 2003). However, that effect is only observed during daytime social interactions; when socially isolated, no differences emerged between introverts and extraverts on vigilance performance (Rupp, Killgore, & Balkin, 2010). In team settings (or highly socially interactive jobs) extraverts might actually be at a greater performance disadvantage following sleep loss than introverts, at least concerning vigilance tasks (e.g., TSA agents scanning airport luggage together). Alternatively, sleep-deprived extraverts in socially-enriched environments might perform worse on vigilance tasks but better on social interaction tasks (e.g., customer service, sales performance) than introverts. As extraverts may be energized by social interaction (Cunningham, 1988), interacting when sleepy might exhibit similar effects on social tasks as those observed for caffeine on vigilance tasks. Given that some individual differences (e.g., trait negative/positive affectivity, self-control) directly influence organizational citizenship behaviors and counterproductive work behaviors (Kaplan, Bradley, Luchman, & Haynes, 2009), examination of personality's influence on the sleep and social performance relationship is warranted.

Dyad Tenure For some employees, high performance means developing high-quality relationships with relevant colleagues and stakeholders (e.g., followers in leader-follower relationships, customers, clients). As Leader-Member Exchange theory suggests, the dyadic relationship among a leader and follower develops over-time and eventually stabilizes once individuals learn more about each other. In the beginning of the relationship, however, individuals may rely heavily on social and environmental cues (e.g., emotional expressions; Guarana & Barnes, 2017) in understanding the other person and the quality of their relationship. Further, in forming impressions, individuals tend to attribute others' behaviors to personality or stable characteristics instead of situational factors (i.e., the fundamental attribution error). Because of this, sleep may be more likely to influence relationship quality early in the relationship versus once the relationship is stabilized (e.g., attributing a leader's negative expressions to internal characteristics versus poor sleep). Testing this specific question, Guarana and Barnes (2017) found dyad tenure moderated the relationship between *follower* sleep quantity and leader perceptions of relationship quality, such that there was a positive relationship *only* for newer dyads. However, tenure did not influence the positive relationship between *leader* sleep quantity and follower perceptions of relationship quality. Whether such findings may extend to the customer service context is a relevant question not yet empirically examined.

Organizational Norms Organizations, leaders, and/or jobs requiring or rewarding long working hours and constant connectivity (e.g., via e-mail or messaging platforms) contribute to employees' poor sleep (Barber & Jenkins, 2014; Barnes, Jiang, & Lepak, 2016; Lanaj, Johnson, & Barnes, 2014; van der Hulst, 2003). Under those conditions, employees might expend compensatory effort to perform for *short-term* productivity (e.g., vigilance tasks; Doran, Van Dongen, & Dinges, 2001) at the expense of long-term sustainable performance. In fact, immediate productivity *increases* may result when employees restrict sleep to work more (Barnes, Jiang, et al., 2016). Yet a point exists at which such behavior becomes unsustainable and compensatory efforts fail to buffer poor sleep's influence on performance (Doran et al., 2001; Meijman, 1997). Thus, employees adhering strictly to norms for long work hours and constant connectivity paradoxically facilitate further performance decrements as poor sleep's negative effects accumulate and worsen with time (Hursh et al., 2004). Moreover, as sleep debt increases recovery time to return to baseline performance also increases (Barnes, Jiang, et al., 2016; Rupp, Wesensten, & Balkin, 2010) likely leading to decreasing performance across workdays.

Perhaps even more concerning, chronically sleepy employees have greater negative health risks, such as burnout (Armon, Shirom, Shapira, & Melamed, 2008; Söderström, Jeding, Ekstedt, Perski, & Åkerstedt, 2012), further costing the organization through absenteeism and/or turnover (e.g., Swider & Zimmerman, 2010). Even though organizational norms prioritizing work over sleep initially buffer sleep loss' negative performance influence, over time those norms exacerbate the relationship between poor sleep and performance decrements (Barnes, Jiang, et al., 2016).

Future Directions: Understudied Topics and Methodologies

The above discussions on mediators and moderators suggest several gaps in the literature and questions for future research. Below we review five broad areas in need of further investigation in terms of both understudied topics and methodological approaches. Although there are many possible avenues for research in this area, we believe these five will most critically advance the literature on sleep and social behavior in organizations.

Multilevel Approaches Beyond the Individual

The topic of sleep and social behavior in organizations is inherently multilevel as it involves biological and psychological processes nested within individuals, who may be nested within dyads (i.e., supervisor-employees), which are also nested within both teams and organizations. Although our review highlighted some multilevel research designs addressing sleep and organizational behavior questions, they tend to be limited to within-person approaches using daily diary or experience sampling designs (e.g. Barnes, Gunia, et al., 2015; Barnes, Lucianetti, et al., 2015; Kühnel et al., 2016) or dyadic designs (e.g., lead-follower relations, employee-customer relations; for a review and examples of approaches applied to organizationally-relevant dyads see Krasikova & LeBreton, 2012). Following others' suggestions (Faber, Häusser, & Kerr, 2017; Gordon et al., 2017), depending on one's research question, research examining sleep in the context of teams and organizations would benefit from social network methodology (for a review see Brass, Galaskiewicz, Greve, & Tsai, 2004) and/or the use of data analytic techniques such as multilevel modeling that make maximal use of group level data. Though multilevel research is difficult and time-consuming to conduct (for resources see Kerr & Tindale, 2004; Kozlowski & Klein, 2000), such designs are crucial given the importance of both team and organizational factors on behavior. We highlight a few examples of each of these below.

Team Performance Team-based work is ubiquitous in organizations; yet, there is little empirical research to date on the effects of poor sleep on team performance (for theoretical reviews on sleep and team performance see Barnes & Hollenbeck, 2009 and Faber et al., 2017). A key takeaway from the small body of literature is that the impact of poor sleep on team performance will differ depending on various aspects of the team and aspects of the task. For example, Barnes and Hollenbeck (2009) propose the link between sleep deprivation and team performance will depend on the number of rested vs. sleep deprived team members, the task type (e.g., decision-making versus problem solving), the team composition and structure (e.g., diversity of the members in terms of areas of expertise or level), and social characteristics (e.g., trust among team members). Analogous to the effects on individual performance, a single team member's poor sleep can contribute to decreased individual productivity, increased errors, poor communication of important information, or increased interpersonal conflict. However, non-sleepy team members could compensate for the poor performance of sleepy team members, mitigating the effects of poor sleep on team performance. In other cases, non-sleepy team members may purposefully withhold effort so as not to encourage free-riding and be taken advantage of by a sleepy member (i.e., the *sucker effect*; Barnes, 2011; Faber et al., 2017; Kerr, 1983), thereby exacerbating the effects of poor sleep on team performance. Furthermore, if that sleepy team member happens to be the team leader, the influence of their errors or poor decision-making may be much greater than if that team member is more peripheral (i.e., less impactful) to the group. Clearly this topic is complex, and research is needed to test these and other propositions on the topic of sleep and team performance (see Barnes & Hollenbeck, 2009).

Organizational-Level Factors Ironically, the body of empirical research on relations among sleep and social behavior in organizations is largely missing examinations of how organizational-level variables influence these relations. Features unique to organizational settings are likely to have a direct influence on sleep, such as work-family balance policies (e.g., Crain, Brossoit, & Fisher, 2018) and policies regarding payment reductions (e.g., Greenberg, 2006). Organizational factors may also buffer or exacerbate relations among sleep and social behavior. As discussed previously, it is possible aspects of the organizational environment may motivate employees to exert extra effort to perform well despite poor sleep, temporarily reducing negative relationships between sleep and social-organizational behavior (e.g., organizational norms prioritizing work over sleep; Barnes, Jiang, et al., 2016). One example not previously considered is workplace formality. For instance, the influence of poor sleep on social behavior may be more pronounced in organizations that have an "informality climate" as individuals feel less pressure to conform to strict behavioral rules and thus, are less motivated to act in an appropriate way when sleepy (for an analogous hypothesis see Andersson and Pearson (1999) on the incivility spiral). In formal workplaces, sleepy employees may exert extra effort to display acceptable behaviors, in turn mitigating the effects of sleep on social behavior—at least in the case of minor sleep deficiency. In the case of severe sleep deficiency, it is possible deviation from organizational norms will be most relevant in formal workplace climates, and in turn, *more* disruptive to performance.

Experimental Designs Focused on Interventions

As demonstrated throughout our review, research to date on sleep and social-organizational behavior generally converges on the finding that poor sleep is associated with fewer positive outcomes and more negative outcomes. Much of this work relies on cross-sectional data or longitudinal designs not assessing directional relationships, as experimentally manipulating sleep deprivation (i.e., negative sleep interventions) in organizations is fraught with ethical considerations (Barber, 2017).

We suggest experiments can be used in several other ways to advance the literature on sleep and social-organizational behavior. First, as manipulation of work-related variables (e.g., culture, policies, job characteristics) in an organizational setting is often unfeasible and/or unethical, experimental designs using laboratory simulations can be used to examine the interactive effect of organizational-level factors on relations among sleep and social-organizational behavior. This research can aid in the identification of variables that can mitigate the negative impact of sleep. Second, increased use of experiments will help identify mechanisms explaining relations among sleep and social-organizational behavior (i.e., mediators). The majority of research in this area measures mediators via self-report questionnaires (e.g., self-reported depletion, self-reported affect). Using an experimental procedure to manipulate a proposed mechanism provides a stronger test of the mediating process (similar to the *moderation-of-process* design; see Spencer, Zanna, & Fong, 2005). Such designs can aid in theory-building by clarifying *why* sleep contributes to certain social-organizational outcomes. Finally, whereas research has successfully identified a multitude of negative outcomes associated with poor sleep, research on positive sleep interventions (i.e., interventions aiming to improve sleep; Barber, 2017) is lacking. However, authors have identified several promising intervention targets via research on antecedents of poor sleep (e.g., organizational norms, late-night technology use, emotional labor; Barnes, 2011; Lanaj et al., 2014; Wagner, Barnes, & Scott, 2014).

Although few studies have actually tested the effectiveness of sleep interventions in organizational settings, sleep interventions have been examined in populations outside the workplace (e.g., students, Barber & Cucalon, 2017; Brown, Buboltz, & Soper, 2006; individuals with insomnia; Seyffert et al., 2016; van Straten et al., 2018; adults without sleep disorders; Murawski, Wade, Plotnikoff, Lubans, & Duncan, 2018). As such, this area is particularly suitable for cross-discipline collaboration. Below we discuss the limited intervention research that exists in the organizational behavior literature organizing our discussion into two sections (per Barber, 2017): interventions that directly target sleep processes and interventions indirectly targeting sleep.

Interventions Directly Targeting Sleep In some instances, sleep interventions developed for clinical populations outside of the workplace may be feasibly and effectively implemented in organizational settings. For instance, Barnes, Miller, and Bostock (2017) examined the effects of the internet-based version of cognitive-behavioral therapy for insomnia (CBT-I) which has been successfully employed in clinical populations (Ritterband, Thorndike, Ingersoll, et al., 2017; Seyffert et al., 2016; van Straten et al., 2018). CBT-I involves reframing maladaptive thoughts regarding sleep as well as changing unhealthy sleep-related behaviors. In an employee sample, the ten-week intervention increased organizational citizenship behaviors and job satisfaction and decreased interpersonal deviance via decreased insomnia and increased self-control (Barnes et al., 2017). Burton et al. (2016) tested a five-month web-based sleep hygiene education intervention (called *Healthy Sleep for Healthy Living*) in a sample of employees and found improved self-reported sleep quality and quantity and fewer self-reported workplace limitations (i.e., time management difficulties, mental/interpersonal limitations, productivity limitations) due to emotional or physical problems. Similar sleep hygiene education interventions that researchers may consider adapting and testing in organizational settings include the Sleep Treatment and Education Program for Students (STEPS; Brown et al., 2006) and the modified STEPS intervention (STEPS-TECH; Barber & Cucalon, 2017) which includes a component addressing sleep-disruptive technology use.

Interventions Indirectly Targeting Sleep Other research has tested interventions indirectly targeting sleep through other work- and health-related factors. One way to intervene on employee sleep is through supervisor behavior. Greenberg (2006) tested the effects of an interactional justice training (IJT; i.e., training in the fair interpersonal treatment of employees) in nurses' supervisors on insomnia in underpaid nurses. Nurses whose supervisors received the training reported fewer insomnia symptoms compared to nurses whose supervisors did not receive the training. As IJT has also been associated with social behavior in organizations (i.e., increased organizational citizenship behaviors; Skarlicki & Jones, 2002; decreased counterproductive work behaviors; Greenberg, 1990), such interventions may be dually effective in improving both sleep and performance.

A second intervention indirectly targeting sleep through both employees and their managers includes the STAR (Support, Transform, Achieve, Results) intervention which is aimed at improving workplace culture by increasing employees' control over their time and family supportive supervisor behaviors (i.e., behaviors supporting the effective management of employees' family and home lives). The STAR intervention improved actigraphy-assessed sleep quantity and self-reported perceptions of sleep insufficiency (but not actigraphy-assessed sleep quality or insomnia symptoms) in a sample of IT employees (Olson et al., 2015). However, there were no effects of the STAR intervention on sleep outcomes in a sample of extended-care, home nursing employees (Marino et al., 2016). Future research might consider examining an intervention directly targeting organizational norms surrounding sleep or supervisor support of healthy sleep practices (termed "sleep leadership"; Gunia, Sipos, LoPresti, & Adler, 2015), and how these influence employee sleep and in turn, social behavior. Indeed, one study found sleep leadership is associated with improved sleep among deployed soldiers and in turn, improved unit climate (i.e., unit morale and cohesion; Gunia et al., 2015).

Outside the organizational behavior literature, interventions targeting other health behaviors such as exercise and nutrition have been shown to improve sleep (e.g., Banno et al., 2018; Peuhkuri, Sihvola, & Korpela, 2012). Such interventions could also be feasibly integrated into workplace wellness programs or implemented on their own to improve employee sleep in a workplace setting (for an example see de Vries, van Hooff, Geurts, & Kompier, 2017). Another example is workplace mindfulness training (WMT). Mindfulness interventions have gained popularity in the organizational behavior literature over the past decade given mindfulness is associated with a host of positive outcomes including improved job performance

(Dane & Brummel, 2013), self-regulation (Howell, Digdon, & Buro, 2010), and improved sleep (Allen & Kiburz, 2012; Hülsheger et al., 2014). In a sample of employees from various industries self-reported sleep quality and quantity increased as a result of daily mindfulness practice over a ten-day period (Hülsheger, Feinholdt, & Nübold, 2015). Furthermore, a randomized waitlist-controlled trial examining an 8-week WMT in a sample of teachers found that the WMT improved self-reported sleep quantity, insomnia symptoms and sleepiness at post-intervention, and self-reported sleep quality and quantity at a three-month follow up (Crain, Schonert-Reichl, & Roeser, 2017). Future research is needed to examine whether WMTs can influence social behavior in organizations via improved sleep.

Multimethod Approaches to Sleep Measurement

Multimethod Approaches To date, research typically centers on examining sleep quality (i.e., how well one slept), sleep quantity (i.e., how long one slept), sleep consistency (i.e., consistency of bed and wake times), or state sleepiness (i.e., the experienced drive to seek sleep). Each of these constructs might exhibit unique effects on performance and require unique intervention components to address. For instance, one intervention might promote sleep consistency but not sleep quality which can be influenced by a host of factors (e.g., prescribed medication, drug/alcohol consumption prior to sleeping); however, increasing sleep consistency might simultaneously increase sleep quality. Therefore, the careful and precise specification (e.g., quality, quantity, consistency) of sleep remains critical.

Throughout our literature review, we specified whether sleep quality and quantity were measured objectively (e.g., actigraphy, polysomnography) or subjectively (i.e., self-report measures). This is in part because research has generally shown differential effects of sleep depending on the measurement method (see Litwiller, Snyder, Taylor, & Steele, 2017 for meta-analytic findings). Currently, the dominant approach to measuring sleep constructs in the organizational behavior literature is via self-report; however, more and more organizational behavior research is assessing sleep quality and quantity via actigraphy. Consistent with other authors (e.g., Crain et al., 2018), we suggest a multimethod approach given each method has unique limitations, and confidence in an effect is higher with corroboration of findings across multiple methods.

Ability/Motivational Mechanisms Researchers have also considered that differential findings across measurement approaches may be due to different constructs being assessed. For instance, our discussion on mediators highlighted how sleep can influence self-regulation (and in turn, social behavior in organizations), through both ability and motivational mechanisms. Barber, Taylor, Burton, and Bailey (2017) found that only *subjective* sleep quality was associated with failure in self-regulation, whereas actigraphy-assessed sleep was not. These authors speculated that self-reported sleep quality may relate to self-regulation *motivation*, whereas objective sleep quality may better predict self-regulatory *ability*.

An important question may concern the conditions under which sleep makes an individual *unable* to perform well (i.e., declines in ability) versus *unwilling* to perform well (i.e., declines in motivation). For example, much of the literature on sleep and counterproductive work behaviors is approached from the perspective of the limited resource or ego-depletion model of self-regulation (Muraven & Baumeister, 2000), which suggests self-regulation is a limited resource which must be replenished via sleep or an individual will be *unable* to self-regulate. Recent work has challenged the limited resource model on the basis of several conceptual and methodological arguments (see Carter et al., 2015; Inzlicht & Berkman, 2015; Schimmack, 2012; Vadillo, Gold, & Osman, 2016). Some arguments point to research demonstrating that motivational incentives can reverse depletion effects (Masicampo, Martin, & Anderson, 2014), similar to the buffering effects of monetary incentives or feedback on performance following sleep deprivation (Steyvers & Gaillard, 1993). Other research challenging the limited resource model has shown how *perceptions* of being less depleted or less fatigued can improve performance (Clarkson et al., 2010; Draganich & Erdal, 2014).

We agree with other authors (e.g., Kühnel et al., 2018) who point out it is likely not the case sleep influences self-regulation through *either* ability *or* motivational mechanisms. However, when considering social behavior in organizations, it still may be the case that motivation is the dominant mechanism under certain conditions whereas changes in ability explain these relations under other conditions. Such notions raise important questions such as: Up to what point (e.g., for what degree of sleep loss), can motivational aspects of the workplace setting (e.g., performance evaluations, potential consequences of good and poor performance) offset negative effects of poor sleep by motivating employees to exert compensatory effort to sustain performance? In what situations does poor sleep lead to declines in ability that cannot be compensated for by exertion of extra effort?

Underlying Physiological Processes Employee performance and organizational outcomes also might be influenced by two separate physiological processes related to regulating the sleep-wake cycle, which might explain some inconsistent findings. Sleep researchers propose that the two-process model of sleep-wake regulation influences daytime sleepiness levels via both the: (1) homeostatic sleep drive (Process S), and (2) circadian cycle/pacemaker (Process C; discussed in the Chronotype Misalignment section; Schmidt, Collette, Cajochen, & Peigneux, 2007). The homeostatic sleep drive (Process S) accumulates linearly with time awake and reflects the proximal state of sleep need or pressure. Adequate quality sleep resets the sleep drive, whereas sleep issues result in a failure to return to baseline levels upon awakening. Alternatively, the circadian cycle influences individuals through non-linear daily patterns related to alertness, attention, and cognitive functioning. The circadian cycle fluctuates throughout the day, resulting in multiple highs and lows in alertness (Schmidt et al., 2007; Tutek et al., chapter "Daily Rhythmicity in Social Activity", this volume). A better understanding of which measures better capture homeostatic sleep drive-related variables versus circadian process-related variables would be a valuable addition to the literature.

The Oura ring (https://ouraring.com/#unique-quidance) is a new product marketed as a wearable sleep-tracker designed to improve employee sleep. Advertisements for this product suggest it assesses sleep stages, heart rate, heart rate variability, and body temperature—key variables typically not assessable outside laboratory settings. Empirical tests confirming the accuracy of such products will likely prove highly valuable to future research. For example, body temperature (especially core body temperature) is a strong indicator of one's position in their circadian cycle (Khalsa, Jewett, Duffy, & Czeisler, 2000; Smith, Reilly, & Midkiff, 1989); however, it is difficult to collect multiple reliable daily body temperature assessments. Pending evidence of reliability and validity in an organizational setting, the Oura ring or similar technology might be able to overcome measurement challenges such as these.

Changes in Sleep-Performance Links Over Time

The above discussions highlight the importance of considering time and patterns of sleep behavior when examining the effects of sleep on social behavior in organizations (see also Barnes, Jiang, et al., 2016). Along these lines, researchers have typically measured within-person variability in performance via experience-sampling methodology, similar to the approach taken by researchers who study emotions in organizations (e.g., Beal et al., 2005; Beal & Weiss, 2003; Weiss & Cropanzano, 1996). In other words, daily variations in sleep quality and quantity are likely to influence daily variations in job performance (e.g., via variations in affect, self-regulation, and cognitive processes), which would not otherwise be captured by assessing "general" sleep quality or overall performance in the aggregate (for examples specific to sleep see Pilcher, Vander Wood, & O'Connell, 2011; Zohar, Tzischinsky, Epstein, & Lavie, 2005). Given there can be substantial within-person variation in both job performance and sleep (e.g., Knutson, Rathouz, Yan, Liu, & Lauderdale, 2007), and that sleep (in)consistency also influences performance-related outcomes (Barber & Munz, 2011), it will be important for future research to continue to use longitudinal, within-person approaches.

Chronic vs. Short-Term Sleep Deficiency Along these lines, research should consider whether accumulation of sleep dept overtime (i.e., chronic sleep deficiency) and shorter-term sleep deficiency differentially influences components of social behavior and whether these effects occur via different mediating mechanisms. For instance, it is possible short-term sleep deficiency is more likely to lead to decreases in job performance components such as organizational citizenship behaviors via a conscious process to withdraw effort from tasks that are not absolutely essential, whereas chronic sleep deficiency may influence all areas of performance (albeit through different mechanisms).

Circadian Processes Within-person approaches should also be used to look at performance episodes in shorter intervals (i.e., within a single day). As discussed previously, employee performance might be influenced by two separate physiological processes (Process S and Process C; Schmidt et al., 2007). Depending on one's position in the circadian cycle (Process C), circadian peaks (i.e., daily periods of high cognitive alertness) might foster stable vigilance levels even when sleep drive is elevated thus masking actual sleep loss or poor sleep quality effects (i.e., Type II error). During circadian dips (i.e., daily periods of reduced cognitive alertness), the effects of heightened sleep drive resulting from sleep loss might be exacerbated, artificially inflating observed effects. A better understanding of how circadian alertness peaks influence performance following employee sleep loss would further our understanding of sleep's organizational influence and could help integrate empirical inconsistencies.

Bi-directional Relationships The focus of this chapter was on sleep as an antecedent of social performance outcomes. Research suggests relations are bi-directional—social behavior in organizations such as emotional labor (Wagner, Barnes, & Scott, 2014), leadership (Munir & Nielsen, 2009), and counterproductive work behaviors (Yuan, Barnes, & Li, 2018), including interpersonal stressors and workplace bullying (Niedhammer, David, Degioanni, Drummond, & Philip, 2009) can also undermine sleep quality and quantity. More longitudinal research is needed to understand the cyclical and bidirectional relationship between sleep and organizational behavior. For instance, interventions targeting potential mediators (e.g., emotion regulation at work, late-night smartphone use, ICT boundary crossing), may contribute to healthy sleep patterns, in turn contributing to effective social behavior and vice versa.

Technological Advances and Positive Social Performance Outcomes

Similar to a lack of sufficient research on positive sleep interventions, researchers have also tended to overlook positive social behavior outcomes in organizations. This disproportionate focus on negative performance outcomes, such as counterproductive work behaviors, has limited our understanding of how sleep might influence organizational citizenship behaviors and other positive experiences in the workplace. We suggest the field of positive psychology offers both relevant theory and methodology that can translate to and advance research on sleep and social-organizational behavior.

One exemplar methodological advancement is the sociometric badge. Sociometric badges appear as typical name badges or tags but contain instruments designed to assess face-to-face interaction and physical activities amongst others (Chancellor, Layous, & Lyubomirsky, 2015; Yano, Lyubomirsky, & Chancellor, 2012). Such instruments could be used, for example, in conjunction with subjective measures to examine associations between sleep and workplace relationships. Quality relationships at work (e.g., High Quality Connections; Stephens, Heaphy, & Dutton, 2011) may have motivational properties (e.g., increased feelings of energy) that could potentially buffer relations among poor sleep and job performance. Relatedly, workplace humor—another positive psychology topic—has been shown to contribute to important outcomes, including task persistence (Cheng & Wang, 2015) and organizational citizenship behaviors (Cooper, Kong, & Crossley, 2018). From an intervention perspective, quality workplace relationships and/or humor may contribute to improved sleep, given positive affect and social support predict better sleep outcomes (Kent, Uchino, Cribbet, Bowen, & Smith, 2015; Steptoe, O'Donnell, Marmot, & Wardle, 2008; Wood, Joseph, Lloyd, & Atkins, 2009).

Along these lines, sleep, as it relates to social-organizational behavior, can be examined in the context of innate needs as proposed by Self-Determination Theory (needs for social relatedness, autonomy, and competence; Gagné & Deci, 2005; Ryan & Deci, 2000). For instance, the need for autonomy is the most influential of the three needs, and refers to an individual's freedom to direct their behavior in the manner they determine best (Gagné & Deci, 2005; Ryan & Deci, 2000). Employees in autonomy-supportive work environments report increased persistence, performance (especially on creative tasks), job satisfaction, work attitudes, organizational citizenship behaviors, and personal wellbeing (Gagné & Deci, 2005). Individuals with high levels of autonomy might be able to better negotiate their daily fluctuations in alertness due to circadian rhythms, as they have the freedom to take short breaks when needed. Having autonomy to arrange their work processes (e.g., via job crafting, schedule flexibility) is another method that might assist employees with combatting the effects of circadian rhythm on their performance. For example, an employee could choose to complete attention-demanding work tasks (e.g., reviewing documents for errors) early in the day when they are the most cognitively alert and save menial tasks (e.g., email) for the afternoon when alertness typically declines. Highly autonomous employees might even shift the start of their work day to later hours after sleeping poorly or to make up for missed sleep. Alternatively, workplace need fulfillment might predict better quality sleep that evening because need fulfillment reduces stress (Weinstein & Ryan, 2011)—a known sleep disruptor (Åkerstedt, Kecklund, & Axelsson, 2007; Hisler, Krizan, & DeHart, 2018). This interplay between need fulfillment and sleep on employee performance has yet to be examined.

Conclusion

Knowledge and understanding of the relationship between sleep and social behavior in organizations will grow as researchers approach questions from varied perspectives, draw from fields outside their own, and partner with diverse scholars. Advancing the science and practice surrounding sleep and social-organizational behavior will involve using methodologies that align with the multifaceted constructs we examine and the multilevel questions we ask. It is our hope we have both demonstrated the importance of sleep to social behavior in organizations and recognized the nuances in this relationship. We further hope that while outlining the limitations and presenting current challenges, we have highlighted the vast and exciting opportunities in this research area. Finally, this topic is one of widespread applicability; the positive impact of this work can be maximally realized to the extent scientists and practitioners communicate and collaborate with the common goal of improving employee and organizational wellbeing.

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Part V
Personality

Sleep and Temperament in Early Childhood

Kate E. Williams

The topics of sleep and infant behavior tend to consume parents' thoughts in the first years of a baby's life, and generate much discussion, debate, and advice-giving in both private and public arenas. Not only do both topics have immediate in-the-moment impacts on the daily lives of children, parents, and educators, but there is a widespread sense that these early constitutional tendencies have longer term implications for lifecourse development. While sleep and temperament have each been an important focus of research for some time, recent developments in measurement and the integration of different disciplinary perspectives are shedding new light on their association with each other, and with genetic and parenting contexts. As with any area of human development research, the picture that is building through these strands of research is complex, involving dynamic processes across a number of individual and environmental factors. Figure 1 summarizes key ones discussed in this chapter.

The focus of the chapter is on night-time sleep behaviours and temperament across the first 5 years of life, with the initial sections of the chapter providing an overview of temperament as a construct, and then its known relations with early sleep behaviours. Because infant development in these areas cannot be considered without reference to the parenting environment, a brief section outlines known relations among sleep, temperament, and early parenting. While there are many challenges that persist in this field of research, two key areas of challenge will then be explored in further detail: increasing understanding about *why* early sleep and temperament are linked; and, understanding mechanisms involved in the transactional developmental system depicted in Fig. 1. The final section provides suggestions for how to move theory and research forward in this field, including pressing research

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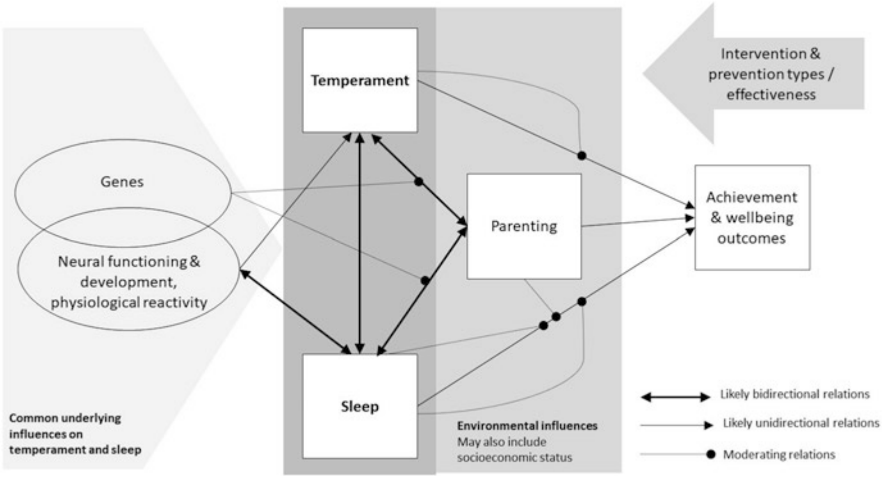

Fig. 1 Summary of temperament and sleep and their relations with other important constructs

questions and novel analytic approaches. A key message in this section is the need for multidisciplinary study designs where findings are translated to support successful identification, prevention, and intervention approaches for children and families early in life.

Early Childhood Temperament: Definition, History, Measurement, and Related Concepts

Temperament refers to “constitutionally based individual differences in *reactivity* and *self-regulation* in the domains of affect, activity, and attention” (Rothbart, Sheese, Rueda, & Posner, 2011, p. 207) and is considered to be influenced by both genetic and environmental factors (Zentner & Shiner, 2015). *Reactivity* refers to “responses to change in the external and internal environment, measured in terms of the latency, duration and intensity of emotional, orienting and motor reactions” (Rothbart, Sheese et al., 2011, p. 207), and is considered to be largely biologically driven. *Regulation* refers to the processes that serve to modulate this reactivity. Compared to reactivity, regulation is thought to involve more learned behaviours and be driven by experience and, as such, is considered more amenable to change primarily through early experiences with caregivers. Beyond infancy, self-regulation is considered a separate dimension of behavior (vs reactivity) that is the focus of a large body of work, discussed later in this section.

Measuring Temperament

Various measures of early temperament reflect the two-factor super structure of reactivity and regulation described in this definition. Parent report measures tend to yield a three-factor structure with two dimensions reflecting reactivity: surgency/extraversion which refers to levels of motor activity excitement, impulsivity, and vocal reactivity; and, negative affectivity reflecting levels of fear, frustration, sadness, and sensory discomfort (Putnam, Rothbart, & Gartstein, 2008). The third factor reflects the regulatory dimension and is defined as attentional orienting in infancy (capacity to sustain attention on an object), and effortful control in older children (referring to sustained attention to task, suppression of inappropriate actions or responses, and attentional shifting) (Casalin, Luyten, Vliegen, & Meurs, 2012; Putnam et al., 2008). A recent observational measure has further delimitated the negative affectivity construct into separate factors of fear reactivity and anger reactivity (Willoughby, Stifter, Gottfredson, & the Family Life Project Investigators, 2015).

The pioneering temperament work of Thomas and Chess beginning in the 1950s as part of the New York Longitudinal Study (Thomas & Chess, 1977), was the first systematic effort to measure and categorize early infant behavior as reflective of underlying temperament and formed the basis upon which temperament research began in earnest. At this time parent report and observational measures were used to identify clusters of infants with more 'difficult' or 'easy' temperamental profiles. Advances since then have included thorough development and testing of parent report measures, and theories and measures for physiological indicators of temperament. Two groups of caregiver-report measures of early childhood temperament behaviours have dominated research. The first group includes the *Infant*, *Early Childhood*, and *Child Behaviour Questionnaires* (IBQ, ECBQ, and CBQ, respectively) by leading temperament researcher Mary Rothbart and colleagues (Rothbart, 1981; Rothbart, Ahadi, Hershey, & Fisher, 2001). The second group includes the *Revised Infant Temperament Questionnaire* (RITQ) (Carey & McDevitt, 1978), and *Toddler Temperament Scale* (Fullard, McDevitt, & Carey, 1978) by Carey, McDevitt and colleagues. Several laboratory-based measures of early temperament have also been developed (e.g., *Kochanska Behavioural battery*; Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996; *Laboratory Temperament Assessment Battery – Locomotor Version;* Gagne & Goldsmith, 2011) along with observational approaches (Willoughby et al., 2015). Physiological measures of temperament in early childhood have been developed on the basis of Porges' polyvagal theory which describes the maturation of the parasympathetic nervous system, and its key role in the regulation of state, motor activity, attention, and emotion (Dale, O'Hara, Keen, & Porges, 2011; Porges, 2011). These indicators tap activity in the parasympathetic branch of the autonomic nervous system, measuring respiratory sinus arrhythmia (RSA) reflecting reactivity, and vagal withdrawal, reflecting regulation.

Temperament, Self-Regulation, and Behavioural Problems

The study of temperament has significant overlap with at least two other important and neighbouring bodies of work in early childhood. First, the acknowledgement that temperament includes both a reactivity *and* regulatory aspect has led to an important body of research specifically on *early childhood self-regulation*, which has grown exponentially over the last two decades alongside and intertwined with temperament and cognitive science research. Temperament researchers tend to consider self-regulation to be highly important in mediating between biological constitution and positive developmental outcomes (Sanson et al., 2009) and have commented that self-regulation is a "major contributor to the organization of temperament" (Rothbart, Ellis, & Posner, 2011, p. 441). Self-regulation is an umbrella term that encompasses both "bottom-up" or more automatic regulatory processes involving emotion and attention and "top-down", more voluntary processes that serve to control emotions, behaviour, and cognition, including the executive functions (Blair & Raver, 2015). The conceptual overlap across temperament and self-regulation research is most readily exemplified by the positioning of effortful control, which is variously considered a temperament construct (Casalin et al., 2012) and a construct tapping cognitive self-regulation (Lipsey et al., 2017).

Second, temperament research shows conceptual overlap with the study of behavioural and emotional problems in very early childhood. These problems are of significant concern to psychopathology researchers, epidemiologists, and clinicians who seek to understand, prevent, diagnose, and treat behaviour problems as early as possible. In very early life, the line between temperament and behavioural/emotional problems might be difficult to draw given the developmental appropriateness of a degree of reactive and dysregulated emotion and behavior (Bagner, Rodriguez, Blake, Linares, & Carter, 2012; Derauf et al., 2011). However, extremes of early temperament or behaviour are considered to constitute disordered behaviour or regulation as early as infancy (Schmid, Schreier, Meyer, & Wolke, 2010). Various temperamental features are also known risk factors for later behavioural problems (Bagner et al., 2012). These conceptual overlaps can result in specification difficulty in relation to temperament, self-regulation, and behavioural problems in very early childhood. This chapter considers research primarily from the temperament field but necessarily also alludes to self-regulatory research and epidemiological studies of infant regulatory disorders.

Relations Among Early Sleep Behaviours and Temperament

Sleep and temperament have been theoretically and empirically linked from the earliest studies of temperament beginning in the 1950s. Infant temperament pioneers Thomas and Chess (Goldsmith et al., 1987) proposed the dimension of *rhythmicity*, which included constructs of sleep, hunger cycles, and bowel movements.

Sleep behaviours were a key indicator in the development of profiles of 'easy' infants (less reactive, more positive affect, more easily socialized, higher rhythmicity – *more regular sleep*) and 'difficult' infants (highly reactive, more negative affect, difficulties with socialization, lower rhythmicity – *more irregular sleep*).[1] While the rhythmicity scale was dropped by Rothbart and colleagues in the *IBQ* group of measures following early evidence of unsatisfactory internal reliability (Rothbart, 1981), it has been maintained in the *RITQ* group of measures (Carey & McDevitt, 1978). Further, scales of falling reactivity/rate of recovery from distress in the IBQ have included an item on sleep onset behaviours – how easily infants fall asleep; and the irritability subscale of the RITQ includes irritability upon falling asleep or waking up. Taken together it appears that temperament researchers have an inherent understanding of sleep as a context in which young children's temperament is often displayed.

This linking of early sleep behaviours and temperament as indicators of overall infant adjustment is also reflected in contemporary clinical practice and research regarding infant regulatory disorders (National Center for Infants, Toddlers, and Families, 1994). The infants that Thomas and Chess might have identified as extremely 'difficult' are now considered to experience regulatory disorders characterized by a constellation of fussy eating, excessive crying (negative affectivity), hypersensitivity, and behavioural *sleep* problems, all which negatively impact on the child's functioning (DeGangi, 2000; National Center for Infants, Toddlers, and Families, 1994). This group of symptoms can occur independently or as a cluster, may be transient or more ongoing, and have been linked with risk for later behavioural and emotional problems (Schmid et al., 2010).

Beyond intra-individual profiles of early behavior that link sleep and temperament as constitutional constructs, a range of developmental research has demonstrated correlations among the two constructs. Daytime levels of negative emotionality and dysregulation have been correlated with night waking (DeLeon & Karraker, 2007; Ednick et al., 2009 for a review), and decreased nocturnal sleep hours (Molfese et al., 2015; Spruyt et al., 2008) across infancy and toddlerhood. Preschool children (aged 3–5 years) with temperaments characterized by high reactivity and negative emotionality have been documented as having higher bedtime resistance and poorer sleep hygiene practices[2] (Wilson et al., 2015). However, other studies have found no relations among temperament and sleep (Hayes, McCoy, Fukumizu, Wellman, & DiPietro, 2011; Jian & Teti, 2016) and, overall, correlational studies do not allow for causal inference across the two constructs. In longitudinal studies, sleep has predicted later temperament (Judge, Chang, & Lammi-Keefe, 2015; Van den Bergh & Mulder, 2012), and early temperament has predicted later sleep (Gartstein, Potapova, & Hsu, 2014; Sorondo & Reeb-Sutherland, 2015). In still other studies, sleep and temperament have been shown to

[1] A third category of slow-to-warm-up infants includes those who are difficult at first but become easier over time.

[2] Sleep hygiene refers to the practices and routines leading up to bed time that promote optimal sleep quality.

be independent across infancy to toddlerhood (Hayes et al., 2011). Overall, in the limited number of longitudinal studies conducted, findings about the relation between sleep and temperament appear to vary according to measures used and age investigated.

Bidirectional and Shared Developmental Pathways

However, there is an emerging agreement in the field that pathways among sleep and temperament are likely to be bidirectional in nature across early childhood (Molfese, Rudasill, & Molfese, 2013; Williams, Berthelsen, Walker, & Nicholson, 2017), but few empirical studies have documented this in detail. In our recent large multi-cultural population study of Australian children (N = 4109), we examined the longitudinal and reciprocal relations among sleep problems, emotional dysregulation (akin to temperamental negative emotionality), and attentional regulation in a developmental model spanning from infancy to 9 years. We found that behavioural sleep problems generally predicted emotional dysregulation measures 2 years later, which in turn predicted attentional regulation 2 years later again (Williams et al., 2017). Emotional dysregulation also predicted sleep problems 2 years later, but these paths were slightly weaker than the sleep-driven paths, suggesting sleep as the more important antecedent. Similar bidirectional paths have also been noted by our group in children with Attention Deficit Hyperactivty Disorder (ADHD) (Williams & Sciberras, 2016), and in examination of sleep problems and behavioural problems across preschool to adolescence (Quach, Nguyen, Williams, & Sciberras, 2018).

Early sleep problems and temperament also appear to share other commonalities, including developmental progression, and associated sequelae. At a cohort level, both sleep and temperament show less longitudinal stability very early in life, with increasing stability over time (Casalin et al., 2012; Neppl et al., 2010; Pedlow, Sanson, Prior, & Oberklaid, 1993; Wake et al., 2006; Williams et al., 2017). Both early sleep problems and more highly reactive and dysregulated temperaments have been independently associated with similar developmental sequelae including behavior problems (Astill, Van der Heijden, Van Ijzendoorn, & Van Someren, 2012; Hemmi, Wolke, & Schneider, 2011; Honomichl & Donnellan, 2012; Keefe-Cooperman & Brady-Amoon, 2014), symptoms of ADHD (Hemmi et al., 2011 Willoughby, Gottfredson, & Stifter, 2017), poorer social skills (Sanson et al., 2009; Schmid et al., 2010), and poorer academic achievement (Astill et al., 2012; Rudasill, Gallagher, & White, 2010). Importantly, *change* in both sleep and regulation dimensions appears to be particularly important during early childhood in stimulating positive developmental trajectories. For example, resolution of behavioural sleep problems across birth to 5 years has been associated with improved adjustment to school (Williams, Nicholson, Walker, & Berthelsen, 2016). Increases in self-regulation from 4 to 6 years have been documented to reduce adolescent risk taking and mental health difficulties 10 years later (Howard & Williams, 2018). Finally, both early childhood sleep (Nicholson, Lucas, Berthelsen, & Wake, 2012) and temperament (Jansen et al., 2009) show socioeconomic inequality, with children from the poorest households at the highest risk of poor outcomes in these areas. These shared features suggest that a focus on sleep and temperament in the early years, both clinically and empirically, is highly warranted.

The Role of Parenting in Early Sleep and Temperament

No discussion focussing on early childhood sleep and temperament would be complete without at least a brief exploration of the role of the parenting environment. Both sleep behaviours and the behaviours associated with infant temperament develop within the context of the parenting and home environment. In fact, some suggest that infant sleep and regulatory disorders can be best understood as a reflection of the parent-child system, rather than reflective of infant characteristics alone (Martini et al., 2017). A range of parenting and family functioning constructs have been documented as antecedents or risk factors related to children's sleep or temperament behaviours (see Tikotzky, 2017 for a review regarding sleep and Kiff, Lengua, & Zalewski, 2011 for a review regarding temperament). While the bulk of the research has focused on mothers, recent research has provided valuable and much-needed insights on fathers' role in children's sleep (Bernier, Tétreault, Bélanger, & Carrier, 2017) and temperament (Potapova, Gartstein, & Bridgett, 2014).

In general, parenting approaches are related to both sleep and temperament in intuitive ways such that aggressive, highly controlling parenting is associated with poorer regulatory development (Graziano, Calkins, & Keane, 2011; Nelson et al., 2012; Olson, Lopez-Duran, Lunkenheimer, Chang, & Sameroff, 2011; Spinrad et al., 2012) and less optimal child sleep quality (Kelly, Marks, & El-Sheikh, 2014). More warm, sensitive, emotionally available and consistent parenting is generally linked with enhanced infant sleep (Jian & Teti, 2016; Staples, Bates, & Petersen, 2015) and increased regulatory behaviours in young children (Graziano et al., 2011). Other aspects of family functioning including parent-child attachment style (Belanger, Bernier, Simard, Bordeleau, & Carrier, 2015), marital satisfaction (Bernier, Belanger, Bordeleau, & Carrier, 2013), relaxing bedtime routines (Mindell, Telofski, Wiegand, & Kurtz, 2009), and lower parental intervention at bedtime (Philbrook & Teti, 2016) have also been linked with more positive sleep behaviours in young children.

Parental mental health has been a key focus in the literature linking the parenting environment to early childhood sleep and temperament. Maternal depressive, anxiety, and stress symptoms have been linked with infant sleep problems (Martini et al., 2017; Sinai & Tikotzky, 2012) and more negative infant temperament behaviours including negative affectivity, lower soothability, and poorer attentional focussing (Field, 2011; Pesonen et al., 2008). Mothers with poorer mental health report their infants to have more night waking and night time distress, and are more bothered by these behaviours (Goldberg et al., 2013). Fathers' parenting stress has also been linked with children's sleep problems (Bernier et al., 2013) and more difficult temperament (Potapova et al., 2014).

Many of these relations among the parenting environment, infant temperament and sleep behaviours stem from as early as the prenatal period, suggesting fetal programming, genetic, and/or social modelling pathways. For example, high levels of stress experienced by mothers during pregnancy has been associated with greater crying and fussing, or more 'difficult' temperaments, in their six-week-old infants (Bolten, Fink, & Stadler, 2012). This fetal programming mechanism is thought to relate to the presence of maternal stress hormones during pregnancy, and their effects on the developing fetus and infant's subsequent regulatory capacity (Sandman, Davis, Buss, & Glynn, 2012). Postnatally, maternal effortful control has been linked with toddler effortful control (Bridgett et al., 2011) and fathers' personality traits have been linked with infant temperament (Potapova et al., 2014).

The Transactional Model

Importantly, since the beginnings of temperament research, transactional models of temperament-sleep-parenting have been widely acknowledged. Within the early temperament studies, what was of most concern was the extent to which infants with certain temperaments had a 'goodness of fit' in relation to the parenting environment they found themselves in (Thomas & Chess, 1977). That is, 'difficult' infants were considered most at risk when matched with parents that did not have the psychological resources to sensitively manage infants perceived as 'fussy' and high maintenance, with low rhythmicity in daily routines (including sleep). More recently, it has been acknowledged that child-driven effects which position parenting as the consequence of child behaviours are also likely (Sameroff, 2009).

While these interactional and transactional pathways are highly relevant to the study of parenting, sleep, and temperament, few studies have operationalized these to a detailed extent. In relation to child-driven effects, early sleep problems have been linked with parental sleep disruption (McDaniel & Teti, 2012), parenting stress (Meltzer & Mindell, 2007), poor parental physical health (Martin, Hiscock, Hardy, Davey, & Wake, 2007), and more maladaptive sleep hygiene management by parents (Simard, Nielsen, Tremblay, Boivin, & Montplaisir, 2008). Reciprocal relations have been found between maternal emotional availability at bedtime and night-time distress in infants across the first six months of life (Philbrook & Teti, 2016), and also among toddler sleep and maternal relationship satisfaction and coparental cooperation (Peltz, Rogge, Sturge-Apple, O'Connor, & Pigeon, 2016). Regarding temperament, children's regulatory behaviours during toddlerhood have predicted later parental teaching (Eisenberg et al., 2010) and punishment strategies (Barnes, Boutwell, Beaver, & Gibson, 2013). Toddler negative emotionality has also predicted lower maternal support behaviours (Scaramella, Sohr-Preston, Mirabile, Robison, & Callahan, 2008). Taken together it is clear that the parenting environment and child characteristics exert influence on each other across early childhood with likely impacts on observed temperament, children's sleep behaviours, and parenting approaches and mental health.

Key Challenge 1: Understanding *Why* Sleep and Temperament Are Linked

A key challenge within the field of sleep and temperament research is that there are at least two potential mechanisms through which relations among sleep problems and children's temperamentally-based behaviours in early childhood might be explained, and these are not likely to operate independently. The first theory suggests that early sleep behaviours and temperament are linked because they share an underlying biological or genetic basis related to neural functioning. For example, fetuses in the third trimester who exhibited more smooth transitions between active and passive sleep have been found to have higher levels of mother-reported effortful control at 8–9 years and 14–15 years of age (Van den Bergh & Mulder, 2012). It is suggested that near-term fetal sleep regulation is indicative of central nervous system maturity and degree of neural plasticity, leading to more positive adaptation to the fetal environment, and to later gene-environment contexts, leading to higher self-regulatory capacity (or expressed temperament) (Van den Bergh & Mulder, 2012). Related to this biological explanation is the suggestion that regulatory difficulties including ADHD symptoms and sleep problems later in childhood might be related due to shared neurotransmitter dysfunction (specifically dopamine and serotonin) (Kirov & Brand, 2014) with temperament an intermediate endophenotype underlying the associations among sleep and ADHD (Melegari et al., 2018).

In line with this theory, sleep behaviours in infants in the first 48 hours of life (Judge et al., 2015) are also thought to be an indication of neurobehavioural functioning or organization, central nervous system maturity, and general neural plasticity (Ednick et al., 2009; Van den Bergh & Mulder, 2012), with these same underlying neural and biological functions also expressed as temperament behaviours. However, early sleep behaviours (Philbrook & Teti, 2016), expressed temperament (particularly the regulatory aspect) (Montroy, Bowles, Skibbe, McClelland, & Morrison, 2016) and even physiological reactivity in children (Berry, Blair, Willoughby, Granger, & Mills-Koonce, 2017) are quickly and substantially modified by the parenting environment making it difficult to disentangle indicators of biologically-based neuroplasticity in the rapidly developing infant, at least through observational measures. The self-regulatory aspect of temperament provides a key example here as these skills develop rapidly from birth in the context of co-regulatory relationships with caregivers. Thus, self-regulation very quickly acts to mask or behaviourally control underlying temperamental reactivity in individuals. Are behavioural or observational assessments of temperament conducted following infancy adequately tapping biologically based temperament or only the self-regulatory control since developed? In reality, not all young children with regulatory dysfunction will exhibit sleep problems and not all children with sleep problems exhibit regulatory dysfunction (Williams & Sciberras, 2016) suggesting that the shared neural basis hypothesis may be only partly accurate or the early behavioural evidence supporting it is quickly altered by the environment. It is likely that sleep measures taken following infancy tap adaption to the parenting environment and parent sleep management practices, as well as a degree of neurobehavioural organization but this is yet to be researched in detail.

The second explanatory mechanism relates to a neurological and developmental cascade effect, or a mutual exacerbation process. Early sleep problems that do not resolve may result in sub-optimal neurological responses which, over time, may exhibit as reactivity and regulation behaviours in children. For instance, disrupted sleep may result in sleep deprivation which has been shown to affect neural connectivity between the prefrontal cortex and the limbic system, resulting in increased reactivity (Gujar, Yoo, Hu, & Walker, 2011). This pathway may manifest as difficult temperament in children during the day. In turn, children experiencing high reactivity and poor regulation may find the task of falling asleep independently and remaining in bed all night challenging, creating a mutually exacerbating system. Our studies have shown that behavioural sleep problems predict emotional dysregulation 2 years later, suggesting a sustained and cumulative effect of sleep problems (Williams et al., 2017; Williams & Sciberras, 2016). Of note, the mutual exacerbation process is likely also relevant to a transactional developmental model involving the parenting environment reflecting the second key challenge in the field.

Key Challenge 2: Understanding a Transactional System: Sleep, Temperament, Genes, and the Parenting Environment

A second key, but related, challenge is the fact that sleep, temperament, parenting, and genotypes are likely all part of a dynamic transactional system that is difficult to operationalize in any single study (see Fig. 1). Within this system, these four factors have the potential to act as a mediator or moderator, or in some instances both. Each might also act as a susceptibility or sensitivity factor meaning individuals that differ in genes, sleep, or temperament are more susceptible than others to either: (a) the negative impact of other factors in the system (diathesis stress/dual risk model); (b) the positive impact of other factors in the system (protection model/vantage sensitivity) (Pluess & Belsky, 2013); or (c) both the risk-promoting *and* development-enhancing impacts of other factors in the system (differential susceptibility) (Ellis, Boyce, Belsky, Bakermans-Kranenburg, & Van Ijzendoorn, 2011). A range of studies have begun to explore these models and are briefly described here, with further research clearly needed.

Sleep, Temperament, and Parenting Within the System

More or less optimal sleep might present a context in which effects of the parental environment are amplified. For example, more optimal sleep in children, in combination with high levels of maternal sensitivity, has been linked with enhanced attachment security and executive functioning, and lower levels of problem behaviours (dual protection) (Bordeleau, Bernier, & Carrier, 2012). Poorer sleep in children has also moderated relations between attachment status and children's academic performance, with attachment insecurity associated with lower academic test scores only for children with less optimal sleep (diathesis-stress/dual risk) (Keller, El-Sheikh, & Buckhalt, 2008). Less is known about the extent to which sleep acts as a sensitivity factor aligned with the differential susceptibility framework. While it does not seem conceivable that children with optimal sleep behaviours would be more sensitive to both negative and positive parenting, it is feasible that those with poor sleep behaviours could exhibit this pattern. Further research is required in this area.

It is relatively well established that children with more difficult temperaments are likely to respond for-better-and-for-worse in terms of the impact of the parenting environment on longer term problem behaviours and mental health (differential susceptibility) (Slagt, Dubas, Dekovic, & van Aken, 2016), although there are mixed findings across studies and analytic approaches (Stoltz, Beijers, Smeekens, & Dekovic, 2017). In relation to sleep in particular, different temperamental profiles might respond differentially to the parental environment and parents' management of sleep. For example, infants with more highly surgent temperaments appear to particularly benefit from maternal emotional availability at bedtime in terms of increasing sleep consolidation across the first six months (vantage sensitivity) (Jian & Teti, 2016). Children with higher levels of physiological reactivity measured through RSA appear to be more susceptible to parenting stress in terms of its impact on sleep problems (diathesis-stress) (Davis et al., 2017). Boys with more reactive temperaments have been shown to be more highly susceptible to prenatal maternal depression, showing more night wakings during toddlerhood than girls or boys with less reactive temperaments (diathesis stress) (Netsi et al., 2015). Temperament may also represent a context in which sleep problems are more or less detrimental to children. For example, sleep problems have been associated with more negative sequelae (behavior problems) when present in the context of negative emotionality (temperament) and less secure toddler-mother attachment (diathesis stress) (Troxel, Trentacosta, Forbes, & Campbell, 2013). Taken together it is clear that temperament plays an important role in understanding relations among parenting, sleep, and longer term outcomes, and future work should carefully investigate alternate models related to risk, protection, and differential susceptibility.

The Role of Genes in the System

Both temperament and sleep behaviours are considered to have a genetic basis. Behavioural genetic studies aim to examine the variance accounted for by genetics, shared environment (e.g. parenting approaches, the home learning environment), and individual environmental factors using cohorts of twins (known as ACE models). Recent heritability estimates for various sleep behaviours have been reported as 62% to 89% in school-aged children (Madrid-Valero, Ordonana, Klump, & Burt, 2019) and 48% to 90% in adolescents. However, early childhood studies suggest lower heritability estimates of 35% for sleep behaviours (Brescianini et al., 2011) with shared environmental factors accounting for 60% to 81% in sleep behaviours across 1–5 years of age (Breitenstein, Doane, Clifford, & Lemery-Chalfant, 2018).

In relation to temperament, recent heritability estimates in 2-year-olds for difficult temperament have been 54%, with 33% of variance accounted for by shared environmental factors (Micalizzi, Wang, & Saudino, 2017). Another study found that degree of heritability vs shared environment influence may depend on the profile of temperament. Scott et al., (2016) found in 7-year-old children that temperament profiles characterized by strong regulation combined with surgent or positive reactivity were highly heritable (up to 91%) with no environmental effects detected. However, the most common profile which included typical levels of reactivity and regulation, and the dysregulated profile had much stronger environmental influences (44%–71%). Findings such as these provide evidence for moderated heritability where the home and parenting environment moderates the expression of genetic influences on behavior.

The field of behavioural genetics is becoming increasingly interested in these gene-environment interactions. In these interactions, genomes, which may be expressed as temperamental traits, moderate the effect of environmental experiences (e.g. parenting) on child behavior or outcomes; or the environment may act as a moderator of a broader genetic influence as suggested above. For example, for children with one or two copies of the short (s) allele of the 5-HTTLPR gene, shorter sleep duration has been associated with higher negative emotionality and behavioural dysregulation (Bouvette-Turcot et al., 2015). Children with this genotype had the highest emotionality and dysregulation scores at short sleep durations, but also the lowest scores at longer sleep duration. There was no main effect of the gene on sleep or temperament suggesting that the gene reflects plasticity to the environmental influences of sleep duration (differential susceptibility), rather than an underlying cause of sleep problems (Bouvette-Turcot et al., 2015). The same genetic variation has been associated with stronger effects from maternal parenting stress to sleep problems, with sleep problems in children with this genome significantly lower at low levels of parenting stress, and significantly higher at high rates of parenting stress (differential susceptibility) (Davis et al., 2017). This genome has also been associated with diminished self-regulatory capacity from the ages of two to four and half years for children, but only for children with poor attachment to their mothers (Kochanska, Philibert, & Barry, 2009).

Dopamine receptors (DRD2, DRD4) and transporters (DAT1) have also been a key area of research. Infants carrying the 7-repeat allele of the DRD4 VNTR have been found to have higher levels of negative affectivity than those not carrying the allele, with those also carrying the 5-HTTLPR genotype having the highest levels of negative affectivity (Holmboe et al., 2011). Dopamine receptors and transporters are also implicated as plasticity alleles in relation to infant temperament and risk for later disorder (Becker et al., 2010) and susceptibility to parenting environments (Davies, Cicchetti, & Hentges, 2015), with less research in the area of sleep.

Key Directions for Sleep and Temperament Research

Given the complexity of the gene, environment, sleep, and temperament interactions briefly summarized above, as well as the many other systems that influence these including parent and child education, and socio-economic environments, there is still much work to be done in the field. This section provides a suggested, but not exhaustive, list of research questions and approaches that will be needed to address these. What is important here is that if the aim of developmental science is not just to advance knowledge for its own sake but for the benefit of society, then there must also be more attention paid to knowledge translation in this field. This is reflected in ideas below about research with practical implications for screening, prevention, and intervention approaches.

Although dynamic and transactional models of sleep, temperament, and parenting are not new, few studies have operationalized multiple aspects of the model, even though modern modelling techniques provide the opportunity to do so. While there have been some advances in bidirectional modelling among sleep problems and behaviour problems and social-emotional adjustment (Foley & Weinraub, 2017; Quach et al., 2018) much of this work begins in preschool with limited bidirectional work from birth to 4 years. Rather, bidirectional models in this very young age group have rightly so focussed primarily on transactional processes of sleep and parenting (Jian & Teti, 2016). Our recent work examining bidirectional relations among sleep, emotional and attentional regulation from infancy has gone some way to addressing this (Williams et al., 2017). However, this study was limited by the measures being 2 years apart and the model did not include transactions with the parenting environment.

Study Designs and Analysis

Overall, pathways of effects across time involving family functioning, parenting, children's sleep, and temperament *together* are rarely addressed (El-Sheikh & Kelly, 2017). Future work that endeavours to do this should consider: longitudinal studies with more frequent measurement time points from the *prenatal* period through to 5 years because of the rapid changes in all constructs that occur during this time period; inclusion of fathers in terms of the parenting environment and as informants; and, use of techniques within the structural equation modelling framework that can test strengths of reciprocal paths among constructs at different time points (e.g., is sleep or temperament the stronger predictor of the other?) and for different groups (e.g., boys vs girls, mothers vs fathers, clinical vs typically developing populations). Finally, diathesis stress/dual risk models and protection/vantage sensitivity models appear generally well understood in this field, but there is less evidence for differential susceptibility, particularly in relation to sleep. Future studies should seek to carefully explicate these models and the interpretation of their findings.

As well as these variable-centred modelling approaches that assume associations found hold for each individual within the population, this field should make further use of person-centred approaches such as latent class/latent profile analyses.[3] These are semi-parametric group-based approaches that allow for the estimation of qualitatively different groups when group membership cannot be observed *a priori* (Collins & Lanza, 2010). These may allow for enhanced capturing of the heterogeneity of sleep and temperament development, along with parenting environments. These approaches can also be particularly useful when measures necessarily change across time to reflect development, with longitudinal measurement invariance not holding, thus precluding growth curve and other variable-centred approaches. Recent examples from sleep and temperament include: profiles of 'normal' and 'troubled' sleepers from 5 years to adolescence with profile membership linked to attention and behaviour (Wang et al., 2016); and, profiles of temperamental reactivity and regulation from six to 36 months linked with first grade ADHD behaviours (Willoughby et al., 2017). Latent profiling techniques that examine sleep and temperament together are rare. Our recent work has used this approach to document a 30% prevalence rate of escalating behavioural sleep problems along with poorer emotional and attentional regulation across infancy to 5 years in Australian children (Williams et al., 2016). Membership of this profile was associated with teacher-reported hyperactivity and emotional problems, and poorer classroom self-regulation and prosocial skills following transition to school (Williams et al., 2016). Future research can do more with these person-centred approaches which may help to circumvent some of the measurement and analytic challenges in this field in very early childhood.

Identification and Intervention

Research with strong practical applications will be required to develop risk prediction tools to identify those most at need of early support in relation to sleep and temperament, and to continue to inform intervention work. For example, it is well known that children with ADHD have poorer early effortful control (Einziger et al., 2018) and higher rates of sleep problems than their typically developing peers, emerging as early as 2 years (Williams & Sciberras, 2016). Could early behavioural sleep problems, which are relatively simple to measure, be a useful indicator of liability to future disorder? While there is potential here, most children with ADHD will not exhibit early sleep problems and most children with early sleep problems will not go on to have ADHD (Williams & Sciberras, 2016). Therefore, research should focus on developing risk prediction tools sensitive enough to determine which children presenting with early markers of sleep or temperamental difficulties

[3] Latent class is the term used when variables are categorical; latent profile is the term used when variables are continuous.

are most at risk of going on to meet criteria for ADHD and/or other developmental or mental health conditions later in childhood. Indeed, it has been argued that early sleep behaviours are a useful indicator of overall regulatory capacity (Williams et al., 2016) and a barometer for children at risk of later behavioural problems, sooner than behavioural problems are evident (Keefe-Cooperman & Brady-Amoon, 2014). Future research is needed to establish how well sleep information about children gathered by health and early education professionals helps to identify children in need of additional support and whether the field is, or should, be using sleep indicators in this way.

Intervening on behavioural sleep problems is generally effective and associated with improvements in psychosocial functioning for many children (Price, Wake, Ukoumunne, & Hiscock, 2012; Quach, Hiscock, Ukoumunne, & Wake, 2011). However, the clinical application of the transactional models discussed in the previous section have not yet been fully realized in practice. It is feasible that interventions designed to improve sleep or self-regulatory behaviours might be differentially effective within various systems that are characterized by differences in parenting environment, genes, sleep, and temperament. Is a different approach to managing sleep problems required for children with various temperamental profiles, or for families with different profiles of parental mental health, parent sleep, and parenting behaviours? How can sleep interventions be tailored to family systems with various combinations of child and parental characteristics and what is the effectiveness of doing so? Future research might focus on a more nuanced and tailored approach to designing and evaluating sleep interventions in light of temperamental characteristics.

There have been numerous calls to address early childhood self-regulatory skills as a means to stimulating positive learning and wellbeing trajectories (Blair & Raver, 2015), and a number of groups are working on these interventions (Barnett et al., 2008; Howard, Powell, Vasseleu, Johnstone, & Melhuish, 2017; Schmitt, McClelland, Tominey, & Acock, 2015). However, no known interventions have simultaneously addressed early childhood self-regulation and behavioural sleep problems. Are the efforts of interventionists targeting self-regulatory development being undermined for some children by pervasive behavioural sleep problems? Could children with various sleep problem profiles be differentially susceptible to particular self-regulation intervention strategies? Do gains made in self-regulation through intervention support more positive sleep behaviours as would be suggested by developmental cascade models (Williams et al., 2017)?

Many of these future-focussed research questions will be best addressed with multi-disciplinary approaches that can adequately explore both the transactional model of development and meet the need for multi-pronged measurement of constructs. The issue of valid measurement of both sleep problems (Simard, Bernier, Bélanger, & Carrier, 2013) and temperament (McClelland & Cameron, 2012) has long vexed the field but it is beyond the scope of this chapter to delve into these complex measurement issues. Multi and transdisciplinary studies that combine measures including brain structure and function, genetics and neurotransmitters, and behavioural, observational, and physiological measures across home and early education settings will help to move the field forward. In this vein, the field can move beyond debates about measurement issues, perhaps taking a post-positivist view. This would see the field accept that all measures are ultimately flawed but taking enough flawed measures from different disciplinary perspectives, and at different points in the lifespan, will best build the required evidence base. A complementary approach would also include the use of more standardized measures across multiple replication studies allowing for better aggregation of results.

Conclusion

In conclusion, the fields of early sleep and temperament have benefited from a strong tradition of high quality research and theoretical underpinnings. These two constructs together appear to open unique and important windows into very early child development and family dynamics, and might offer pathways of prevention for some of the most prevalent psychosocial and behavioural disorders and dysfunction. There are a range of exciting opportunities for future research that bring together disciplinary understandings and methodologies and better translate these to practice. Our growing understanding of these two important constructs, along with their interactions with the parenting environment and genetic factors, should aim to both contribute to developmental science and to have a positive impact on educators, health professionals, children, and parents. To achieve this, creative multidisciplinary approaches and strong engagement with early education and family health settings will be required. Only in this way will knowledge translation contribute to improved support and outcomes for the most vulnerable groups of children and parents.

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Personality Processes and Sleep: An Overview and a Leitmotif for a Research Agenda

Katherine A. Duggan and Zlatan Križan

Personality Traits and Processes are Relevant to Understanding Sleep and Social Behavior

Social psychology and social processes are traditionally concerned with whether, when, how, and why individuals are shaped by their real, perceived, and imagined social environments (that is, by the presence of others). However, an account of how individuals interact with their social worlds is not complete without an understanding of whether, when, how and why individuals behave consistently or similarly *across* situations and time, and in turn, how they select into, shape, and reinforce their social environments. Insights into these enduring patterns of thoughts, feelings, and behaviors that make people uniquely themselves across situations require an appreciation of personality and personality processes.

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Personality Traits and States

These relatively enduring patterns of thoughts, feelings, and behaviors (or traits) are hierarchically-organized, with the focus typically on the Five Factor Model (John, Naumann, & Soto, 2008), which includes five personality traits: conscientiousness, agreeableness, neuroticism, openness, and extraversion (though see the HEXACO model for an alternative; Ashton & Lee, 2007). Each of these traits is in turn made up of hierarchically-organized facets (or components of each trait). For example, trait conscientiousness is defined by facets or collections of items which tap persistence, planfulness, organization, and self-control *in general* (i.e., across long periods of time; Roberts, Lejuez, Krueger, Richards, & Hill, 2014). Agreeableness taps facets of altruism, trust, compliance, and straightforwardness; neuroticism taps facets of anxiety, hostility, depression, and emotional lability; openness taps facets of curiosity, imagination, and the preference for novel activities; and extraversion taps facets sociability, dominance, activity, and positive emotions (John & Srivastava, 1999). These same traits can also be organized hierarchically at the higher level into meta-traits, with meta-trait stability (conscientiousness, agreeableness, and low neuroticism) and plasticity (openness and extraversion) forming one replicable higher-order structure with relevance to sleep and health (Dermody et al., 2016; DeYoung, Hasher, Djikic, Criger, & Peterson, 2007; Wilmot, DeYoung, Stillwell, & Kosinski, 2015).

Each of these facets within traits can be further differentiated by specific sets of thoughts, feelings, and behaviors which indeed fluctuate across situations and time, partially due to changes in the features of the situation (Rauthmann, Horstmann, & Sherman, 2018), changes in affect (Wilson, Thompson, & Vazire, 2017), and changes in goal pursuit (McCabe & Fleeson, 2016). This within-person variability in particular thoughts, feelings, and behaviors corresponds to personality *states*, which vary around a stable mean tendency reflecting the higher order trait (Fleeson, 2001). Considering personality traits as amalgamations of personality states across time is useful for (1) reflecting variability in individual behavior across time and situations (i.e., social processes; Fleeson, 2004; Funder, 2006); (2) linking personality traits with consequential outcomes via personality processes (Hampson, 2012); and (3) understanding factors that shape personality stability and change across time (Wrzus & Roberts, 2017).

Personality Processes

Broadly, personality processes describe *how* traits manifest in real, observable behavior (Hampson, 2012; Wrzus & Mehl, 2015), ultimately shaping important outcomes. These processes are thought to occur once a situation triggers a particular expectancy (or goal), leading to a state-like expression of personality, followed by the individual reacting to their own behaviors or interpreting the reactions of others in their social environments (Wrzus & Roberts, 2017). For example, if a woman has a goal of getting a raise or promotion at work, this may translate to specific conscientiousness-like behaviors: using planners to schedule her day, showing up early, systematically organizing her work files and materials, setting timelines for getting projects done, and persisting at tasks after meeting setbacks or failures (Jackson et al., 2010). In the long-term, as her colleagues and supervisors notice her efforts, they may perceive her as more organized, planful, punctual, and persistent, which may result in the pay raise or promotion she desired. In this way, her goals shaped her behavior (*states*) in ways that were consistent with her personality (i.e., her high *trait* conscientiousness), leading to a meaningful outcome (i.e., raise or promotion) in her life. The interpersonal and social rewards for behaving in this way may also reinforce her high trait conscientiousness, ultimately making her more likely to think, feel, and behave in ways consistent with high conscientiousness in the future (DeYoung, 2015).

As these transactions can repeatedly occur over time, personality processes therefore tell us about both stability and change in behavior—which, given amalgamations of personality states into traits, describes how personality stability is maintained and suggests mechanisms which may lead to lasting personality change. To the extent that individuals repeatedly select into situations consistent with their personalities (or are reinforced for their behaviors), personality should become more stable (as similar levels of that particular trait will be reinforced). On the other hand, if people are repeatedly exposed to novel situations or are not reinforced for their behaviors, their personality is more likely to change.

These processes are important features of theories emerging from both personality and developmental psychology. Situational selection (sometimes called cumulative continuity in the developmental literature; Caspi, Bem, & Elder, 1989; Hampson, 2012; Scarr & McCartney, 1983) is a process of niche-picking (Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007) through which people select into environments or may be recruited into environments. They can also alter their social milieu through person-situation transactions or situation evocation (termed interactional continuity in the developmental literature). People attend to and learn from the evoked reactions in and features of these environments (Buss, 1987; Funder, 2008), and sometimes are removed from (or selected out of) certain environments through attrition. Environments that are repeatedly selected into are often consistent with and reinforce the person's existing personality traits, while simultaneously promoting trait-outcome associations (such as in the work example above; Roberts, Caspi, & Moffitt, 2003) across long periods of time. In other words, person-situation transactions produce personality stability and change, and behavioral stability and change produce long-term consequential outcomes. In this way, personality processes impact personality development (stability and change) as well as consequential outcomes (Deary, Weiss, & Batty, 2010), including health behaviors and longevity (Strickhouser, Zell, & Krizan, 2017). Thus, personality traits and processes are relevant to understanding how healthy sleep is promoted and sustained over time.

Personality and Sleep are Associated with Each Other

Because both personality and sleep are associated with consequential outcomes (e.g., occupational success, relationship satisfaction, psychological well-being, and physical health; Barrick & Mount, 1991; DeNeve & Cooper, 1998; Friedman & Kern, 2014; Litwiller, Snyder, Taylor, & Steele, 2016; Luyster, Strollo, Zee, & Walsh, 2012; Malouff, Thorsteinsson, Schutte, Bhullar, & Rooke, 2009; Slavish et al., 2018; Troxel, Robles, Hall, & Buysse, 2007), it is surprising that research on personality and multiple dimensions of subjectively-, behaviorally-, and objectively-assessed sleep is still relatively nascent. Historically, there has been relatively little overlap or cross-talk between researchers interested in personality or sleep, likely due to differences in publication outlets (personality, social psychology, and developmental journals versus medical, psychiatric, neuroscience, and public health journals). Some differences may also emerge due to training. For example, personality psychologists may not be aware of multidimensional, reliable, and valid self-reports of sleep (as they are often published in specialized sleep journals), or may not have the training, funding, or personnel required for the collection, interpretation, and analysis of behavioral (actigraphy) and physiological (polysomnographic) sleep data (Hall, 2010). Similarly, sleep researchers may lack awareness of hierarchical models of personality and individual differences which may subsume some of the measures they are often interested in (e.g., positive and negative affect, impulsivity, motivation, and creativity), or they may not collect the large sample sizes that are more typical in personality psychology and necessary for precise analyses of individual differences. Despite this, sleep researchers are beginning to recognize that in intervention studies focused on improving consequential outcomes such as mental and physical health, personality traits may help identify individuals at-risk for poor sleep and individuals more or less amenable to intervention. Similarly, personality researchers are beginning to recognize that sleep may be a missing psychological, behavioral, and physiological mechanism implicated in personality processes across the lifespan. Thus, research at the intersection of sleep and personality is exponentially increasing (see Fig. 1).

Circadian Preference and Chronotype

Personality and chronotype is the most well-established and most frequently-researched area in personality and sleep (see Randler, chapter "Chronotype and Social Behavior", this volume, for review of chronotype research). Because chronotype is conceptualized as a relatively stable (trait-like) individual differences measure of sleep timing and preferences for activity during different times of day

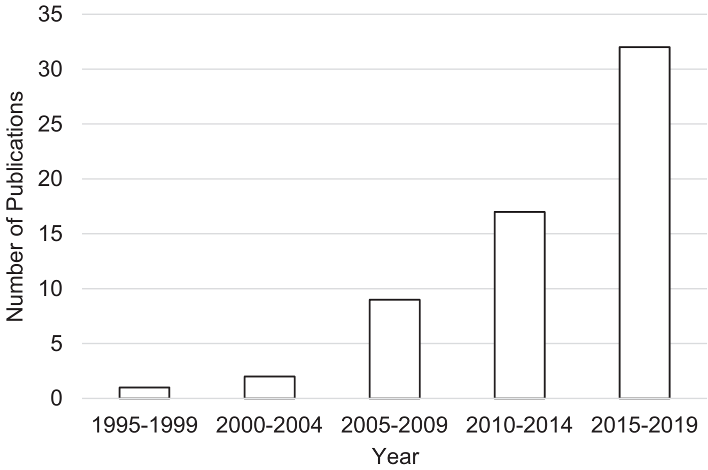

Fig. 1 Number of publications in SCOPUS with "Big Five" and sleep or circadian listed in the title, abstract, or keywords. We believe this to be an underestimate of the total published literature

(Randler, Schredl, & Göritz, 2017), there has been a rich tradition of distinguishing it from other individual difference characteristics (such as personality), and researchers interested in chronotype often publish in personality journals. A recent meta-analysis of the work in this area demonstrates conscientiousness is robustly correlated with chronotype, regardless of whether it is assessed by separate types (i.e., morningness or eveningness) or continuously (Lipnevich et al., 2017). Extraversion, openness, and low neuroticism also correlate with morningness, though to less of an extent than conscientiousness (Adan et al., 2012; DeYoung et al., 2007; Lipnevich et al., 2017; Randler, 2008). Part of the reason for overlap between personality and chronotype may be due to common genetic bases (Duggan, Friedman, McDevitt, & Mednick, 2014), including CLOCK and PER3 (Jiménez, Pereira-Morales, & Forero, 2017; Terracciano et al., 2010).

The majority of research in this area has used self-report measures of circadian preference and has not included behavioral or physiologic indices of the circadian system, such as circadian phase angles, dim light melatonin onset, or the timing and periodicity of biological rhythms (e.g., temperature, Frank et al., 2013; Skene & Arendt, 2006, though see Hasler, Buysse, Kupfer, & Germain, 2010 and Terracciano et al., 2014, for exceptions). Associations between personality and behavioral or physiologic measures of circadian rhythms are a ripe area for future research. It will also be important to disentangle biological (genetic) contributions to both personality and chronotype, relative to daily behaviors linking stable individual differences (i.e., personality traits) to chronotype and circadian preference across development (see also Tutek et al., chapter "Daily Rhythmicity in Social Activity", this volume).

Sleep Quality, Sleep Complaints, and Insomnia

Following chronotype, self-reports of poor sleep quality, sleep complaints, daytime sleepiness, and insomnia are the most commonly investigated. Sleep quality (e.g., Buysse et al., 2017; Buysse, Reynolds III, Monk, Berman, & Kupfer, 1989; Hays, Martin, Sesti, & Spritzer, 2005; Yu et al., 2011) includes not just self-reported global assessments, but also multidimensional indices tapping trouble falling asleep and staying asleep, the restorativeness and length of sleep, and daytime dysfunction and sleepiness. Self-report measures of insomnia (e.g., Levine et al., 2003; Morin, Belleville, Bélanger, & Ivers, 2011; Soldatos, Dikeos, & Paparrigopoulos, 2000) also capture several of these dimensions. Thus, measures of poor sleep quality and insomnia are highly correlated as they tap similar complaints. However, *clinical diagnoses* of insomnia are more than just reports of poor sleep quality: insomnia diagnoses require complaints about sleep quality *or* duration, with difficulties falling asleep or maintaining sleep *despite adequate opportunity for sleep*, resulting in clinically-significant daytime distress or impairment for at least three nights per week for over 3 months. These complaints must not be better explained by other health behaviors (substance use), medications, or other physical and mental health problems (Buysse, Rush, & Reynolds, 2017; Morin et al., 2015). Thus, although personality correlates of poor sleep quality and insomnia are similar due to their high conceptual overlap, it is important to note mechanisms linking personality and each of these dimensions of sleep may vary.

Personality traits are robustly correlated with self-reported poor sleep quality and insomnia symptoms. The strongest and most consistent associations are for high neuroticism, followed by low conscientiousness, low extraversion, and then agreeableness. Openness is not consistently associated with better sleep quality (Bertelson & Monroe, 1979; Calkins, Hearon, Capozzoli, & Otto, 2013; Duggan et al., 2014; Hintsanen et al., 2014; Križan & Hisler, 2019; Stephan, Sutin, Bayard, Križan, & Terracciano, 2018; van de Laar, Verbeek, Pevernagie, Aldenkamp, & Overeem, 2010). While there is no "objective" physiological or biological test for insomnia (it is completely dependent on self-reports), some research in insomnia has focused on sleep-state misperceptions (Vela-Bueno et al., 2010) or differences between perceived sleep and objective sleep on polysomnographic indicators (Dorsey & Bootzin, 1997). These differences may be linked to neuroticism (Costa & McCrae, 1987; Watson & Pennebaker, 1989). That is, in addition to functioning as a predictor or correlate of sleep quality, personality traits (particularly neuroticism and negative affectivity) may also moderate associations between subjective and behavioral or objective indices of sleep (as subjective reports are influenced by negative response styles; Watson & Pennebaker, 1989).

Though this area of research is smaller than that of personality and chronotype, more work has been done to disentangle pathways linking personality and sleep quality. Neuroticism may be a particularly important correlate of poor sleep quality because it is associated with stress (Williams & Moroz, 2009), poorer emotion regulation (Mauss, Troy, & LeBourgeois, 2012; Vantieghem, Marcoen, Mairesse, &

Vandekerckhove, 2016), problematic internet use (Herlache, Lang, & Krizan, 2018), and hyperarousal and rumination before bed (Cellini, Duggan, & Sarlo, 2017). On the other hand, conscientiousness likely promotes better sleep quality indirectly through better health behaviors related to sleep (i.e., sleep hygiene) as well as maintaining a more consistent bedtime routine and schedule (Duggan et al., 2014; Križan & Hisler, 2019). Extraversion may play a role via positive affectivity and sociability (Stephan et al., 2018), and agreeableness may promote sleep via feelings of trust and safety, as well as reduced interpersonal distress (Dahl & Lewin, 2002; Gunn, Troxel, Hall, & Buysse, 2014). Yet bidirectional associations are also possible, and poor sleep quality may also reliably predict personality change over time. One analysis of both Japanese and United States participants found poor sleep quality to be prospectively related to decreases in conscientiousness, agreeableness, and extraversion, and increases in neuroticism (Stephan et al., 2018), perhaps because chronically-poor sleep quality may deplete the psychosocial and physiological resources required for maintaining motivation, self-control, trust, positive affect, and emotion regulation. Genetic influences may also play an important role for tying personality traits to sleep quality. Both personality and sleep quality show substantive heritability (Bleidorn, Kandler, & Caspi, 2014; Lind & Gehrman, 2016), so it is important to evaluate whether shared genetic influences contribute to their phenotypic links. To this end, Krizan, Hisler, Krueger, and McGue (2019), estimated genetic correlations between sleep quality and personality traits in a large sample of twins, finding strong genetic overlap with neuroticism, extraversion, and aggression. Multivariate analyses indicated that unique genetic influences shape the overlap of sleep quality with different traits.

Finally, recent work has focused on sleep quality as an intervening variable linking personality and consequential health outcomes. One study found sleep latency, disturbance, and quality mediated associations between neuroticism and depressive symptoms, and sleep latency and daytime dysfunction mediated associations between conscientiousness and depressive symptoms. Although data were cross-sectional, alternative models exploring depression as a mediator of personality-sleep associations were not supported (Huang, Peck, Mallya, Lupien, & Fiocco, 2016). In another cross-sectional study, associations between neuroticism (the only trait measured) and depressive symptoms were mediated by daytime dysfunction and alertness upon waking (i.e., sleep inertia; Wong, Zhang, Wing, & Lau, 2017). In the first study to examine sleep as a potential reasons that personality traits predict mortality, recent work using a large longitudinal sample found that self-reported daytime dysfunction (rather than sleep problems) mediated the personality-mortality association, with higher neuroticism, lower conscientiousness, and lower extraversion predicting increased mortality risk via daytime dysfunction (Spears, Montgomery-Downs, Steinman, Duggan, & Turiano, 2019). Together, these three studies suggest the daytime consequences of poor nocturnal sleep may be especially important to understanding links between personality and health outcomes.

Like work on personality and chronotype, work on personality and sleep quality could profitably incorporate multiple methods, including partner-ratings of personality and dimensions of sleep quality to test actor-partner (i.e., participant and spouse) effects on sleep and personality dynamics. Additionally, studies incorporating physiological measures of sleep and laboratory-based correlates of poor sleep quality and daytime dysfunction (e.g., the Psychomotor Vigilance Test; Killgore, Richards, Killgore, Kamimori, & Balkin, 2007) would be useful for testing sleep state misperception hypotheses, which may be particularly relevant to neuroticism. Additional work should delve into associations at the facet level, which may provide finer-grained insight into psychosocial mechanisms linking personality and sleep quality, and thus, targets for intervention.

Sleep Duration

The majority of research on associations between personality and sleep duration finds null associations (Calkins et al., 2013; Duggan et al., 2014; Gray & Watson, 2002; Randler, 2009; Soehner, Kennedy, & Monk, 2007), though there is scattered evidence for weak correlations between short sleep duration and neuroticism (Gau, 2000; Vincent, Cox, & Clara, 2009), impulsivity (Grano et al., 2007), effortful control (Diaz et al., 2017), conscientiousness (Randler, 2008), extraversion (Randler et al., 2017), openness (Križan & Hisler, 2019), and agreeableness (Hintsanen et al., 2014; Randler, 2008). Furthermore, neuroticism and low extraversion may predispose individuals to the negative sequelae associated with acute sleep deprivation (i.e., they may function as moderators; Mastin, Peszka, Poling, Phillips, & Duke, 2005).

It is possible that associations between personality and sleep duration are truly trivial. However, there are several limitations in this area that are critical to address. First, most studies are cross-sectional in nature and utilize self-reports of both personality and sleep, often testing only one or a few traits. Additionally, secondary data analyses relying on single-item questions assessing sleep duration are common, with questionable reliability and validity relative to questions tapping sleep schedules, daily diary measures, or behavioral or physiologic measures of sleep duration (Hall, 2010; Matthews et al., 2018). This makes small associations across traits difficult to interpret. Second, given the importance of both short *and* long sleep durations to physical health (Cappuccio, D'Elia, Strazzullo, & Miller, 2010; Gallicchio & Kalesan, 2009), it may be that absence of linear associations masks curvilinear patterns between personality and sleep duration. In support of this, one study examining U-shaped associations between personality and sleep duration found neuroticism was associated with both short and long sleep durations (Allen, Magee, & Vella, 2016), and recent work in a large, longitudinal sample found associations between low conscientiousness, high neuroticism, and mortality risk were mediated by both short and long sleep durations (Spears et al., 2019). Third, associations may vary across developmental stage, but most research has been conducted on adult samples. Sleep duration may be more robustly associated with temperament—the developmental precursor to personality—in children (Moore, Slane, Mindell, Burt, & Klump, 2011; Sadeh, 2007; see Williams, chapter "Sleep and Temperament in

Early Childhood", this volume, for review). Fourth, personality and sleep duration may be more intricately linked at the *state* level, with acute bouts of sleep deprivation depleting resources required for emotion regulation, self-control, social competence, and activity (see Engle-Friedmann, chapter "Sleep's Role in Effortful Performance and Sociability", this volume; Goldschmied, chapter "How Sleep Shapes Emotion Regulation", this volume; Hisler & Križan, "Dynamics between Sleep and Self-Control", this volume). Similarly, days characterized by reduced self-control, inactivity, difficulties in emotion regulation, and increases in negative affect may lead to nights of shorter sleep (Slavish et al., 2018). Additional multimethod research on personality and sleep duration is required before firm conclusions can be drawn.

Sleep Regularity, Variability, and Social Jetlag A final possibility for research on sleep duration and personality may be to focus on sleep *deficiency* (the difference between typical and preferred sleep duration), which is sometimes indexed using sleep *variability,* or differences in weekday and weekend sleep duration. In a large analysis of Australians and Finns, neuroticism, extraversion, low agreeableness, and low conscientiousness were related to more sleep deficiency (the difference between typical and preferred sleep duration). Thus, in terms of sleep length, personality traits may more correlate more robustly with (at least perceived) *discrepancies* between preferred and usual sleep (and associated daytime consequences) rather than actual sleep duration or length.

It will also be important to examine associations between personality and social jetlag, which indexes the misalignment between biological and social timing (Wittmann, Dinich, Merrow, & Roenneberg, 2006). To the extent that individuals are consistently unable to meet their sleep need (voluntarily or otherwise) and occasionally engage in attempts to "catch up" on sleep on free days or weekends, this mismatch may be indexed both by sleep variability (i.e., low stability) or social jetlag (undersleeping on weekdays and oversleeping on weekends). Additionally, individuals advance or delay their preferred (biological) sleep schedules due to school and work schedules, as well as social engagements. Personality may be related to social jetlag or variability because personality processes link traits to selection into these educational, occupational, and social environments.

Three cross-sectional studies speak to this possibility. One found agreeableness and low conscientiousness are related to oversleeping on weekends, and extraversion, low agreeableness, and low conscientiousness are related to misalignment and social jetlag (Randler, 2008). A second found delayed sleep-wake phase disorder patients (characterized by delayed timing of circadian rhythms) were characterized high agreeableness, conscientiousness, and extraversion, and low neuroticism relative to controls, although samples were very small (Micic, Lovato, Gradisar, & Lack, 2017). Finally, recent work in the a large, longitudinal cohort also found that variability in sleep duration was related to neuroticism; variability in sleep continuity (latency, fragmentation, and wake after sleep onset as indexed using actigraphy) was related to low conscientiousness and high neuroticism; and variability in sleep quality was related to neuroticism and low extraversion (Križan & Hisler, 2019).

Thus, future research should continue to examine associations between personality and social jetlag as well as sleep variability, using both self-reported and behavioral measures of sleep. Because sleep variability and social jetlag are of increasing interest as predictors of cardiometabolic risk, particularly fasting glucose and insulin resistance (Scheer, Hilton, Mantzoros, & Shea, 2009; Wong, Hasler, Kamarck, Muldoon, & Manuck, 2015), personality traits may provide a unique window towards identifying individuals who might be well-suited for behavioral sleep interventions focused on reducing social jetlag, sleep variability, or circadian misalignment (see Tutek et al., chapter "Daily Rhythmicity in Social Activity", this volume).

Research on Sleep Hygiene, Behaviorally-Assessed Sleep, and Objectively-Assessed Sleep Is Ripe for Future Personality Research

Though personality traits have been extensively linked to *daytime* health behaviors (Turiano, Chapman, Gruenewald, & Mroczek, 2015), it is surprising that little research has examined links between personality and health behaviors that promote sleep. Poor sleep hygiene involves long daytime naps; irregular wake schedules; doing cognitively- or emotionally-stimulating activities, exercising, or using tobacco, alcohol, or caffeine before going to bed; sleeping in an uncomfortable bedroom; and thinking, planning, or worrying before bed (Mastin, Bryson, & Corwyn, 2006). To our knowledge, only one study (Duggan et al., 2014) has examined associations between personality and sleep hygiene, with conscientiousness, agreeableness and low neuroticism emerging as predictors. Another did not look at sleep hygiene per se but found that non-restorative daytime nap habits were related to low conscientiousness and high neuroticism (Duggan, McDevitt, Whitehurst, & Mednick, 2018), and a third found more conscientious individuals are less likely to procrastinate their bed time, which should improve sleep (Kroese, De Ridder, Evers, & Adriaanse, 2014). Given that a portion of the association between personality and mortality risk is unexplained by daytime health behaviors (Booth et al., 2014; Hagger-Johnson et al., 2012; Hampson, Goldberg, Vogt, & Dubanoski, 2006), sleep hygiene (as well as the other characteristics of sleep described above) may be a missing link in models of personality and health.

There is also very little research on behaviorally-assessed sleep using actigraphy. One notable exception in adults (Križan & Hisler, 2019) found conscientiousness and low neuroticism were associated with lower actigraphically-assessed sleep latency, lower wake after sleep onset, and lower fragmentation indices, as well as reduced variability in these variables. In children, Diaz et al. (2017) found actigraphically-assessed longer sleep duration (but not variability in sleep duration, sleep onset, sleep latency, or sleep efficiency) was associated with more effortful control in children. Other analyses in children have linked less actigraphy-assessed sleep duration with greater depression, anxiety, and externalizing symptoms (Kelly

& El-Sheikh, 2014), and better sleep efficiency to lower behavioral dysregulation and emotional arousal (El-Sheikh, Buckhalt, Cummings, & Keller, 2007), though another analysis found null results (El-Sheikh, Kelly, Buckhalt, & Benjamin Hinnant, 2010). These results are promising and suggest that personality (and temperament) may be associated with behaviorally-assessed sleep throughout the lifespan (see Williams, chapter "Sleep and Temperament in Early Childhood", this volume). We encourage researchers to continue to examine sleep using actigraphy, focusing on both long-term (trait-like) and short-term (daily, state-like) associations.

At the time of publication of this chapter, there are (to our knowledge) no published reports on personality and objectively-assessed sleep using polysomnography (PSG). While both actigraphy and PSG provide estimates of total sleep time and sleep continuity, only PSG can generate measures of sleep architecture and depth. Additionally, while actigraphy relies solely on movements (and sometimes light) in its scoring, PSG is a more comprehensive record of the physiological changes that occur during sleep, including electrical activity in the brain (electroencephalography; EEG), eye movements (electrooculography; EOG), muscle movements (electromyography; EMG), heart rate (electrocardiography; EKG), respiration, and airflow. PSG is therefore the gold standard for assessment of sleep (Hall, 2010). While studies using PSG could determine whether personality is related to objectively-assessed sleep duration, continuity, timing, and regularity, they importantly might also provide a window linking personality and physiological functioning in the brain using sleep architecture, staging, and depth using EEG. Studies of this type could allow comparison of self-reported sleep against objective measures, to examine the role of personality in sleep-state misperception. Although polysomnography studies are time-consuming, expensive, and require specialized training, we hope that researchers will soon begin work of this type. Even small pilot studies would be informative for securing grant funding to examine personality and polysomnographically-assessed sleep using the sample sizes typical of personality research. Moreover, advances in at-home EEG assessment could provide less costly, yet more naturalistic measures of sleep behavior and architecture relative to laboratory-based PSG assessments (e.g., Wang, Loparo, Kelly, & Kaplan, 2015).

Future Research on Personality and Sleep Should Focus on Interactions Among Sleep and Personality Traits, States, and Processes Across Time

In addition to the suggestions noted above for specific dimensions of sleep, there are also several areas of research that could profitably integrate or translate across multiple dimensions of sleep. First, future research should determine why conscientiousness and neuroticism are particularly important to sleep. Duggan et al. (2014)

proposed that conscientiousness likely promotes healthy sleep through habitual sleep behaviors, such as an earlier sleep timing and waking routines, a regular sleep schedule, and salubrious sleep hygiene. On the other hand, low neuroticism might promote healthy sleep via positive emotions and reduced hyperarousal (Cellini et al., 2017) which ultimately promote better subjective sleep experiences, including perceptions of better sleep quality and reduced daytime sleepiness. The extent to which these associations are direct or bidirectional (via a possible feedback loop or *personality process* through which personality stability is achieved via sleep habits) may vary across development and nature of phenomena (e.g., the trait versus state level). Longitudinal research with multiple assessments of personality and sleep are required to disentangle these pathways. Second, additional work using observer reports of personality and behavioral or objective assessments of sleep will be necessary to determine to what extent are personality and sleep are correlated due to common method bias, and whether personality is also associated with *behavioral* or *physiologic* indices of sleep. Finally, more research is needed on habitual sleep behaviors (e.g., sleep regularity and sleep hygiene) as well as subjective sleep experiences (e.g., sleep quality, sleepiness, and daytime dysfunction) for adequate comparison of the strength of conscientiousness and neuroticism with each sleep domain, ideally via meta-analysis or meta-regression.

A second open question involves the directionality of trait-like versus state-like measures of personality and sleep. Is personality *causally* associated with healthy sleep? Can sleep reliably *change* personality? Answers to these questions likely vary by age. Trait-dependent processes for sleep assume the individual has some *direct, volitional control* over their sleep hygiene, timing, and length which is relatively stable and enduring (see Conceptual Fig. 2 for a hypothetical model). In young children, temperament is more plastic and biologically-determined (Rothbart,

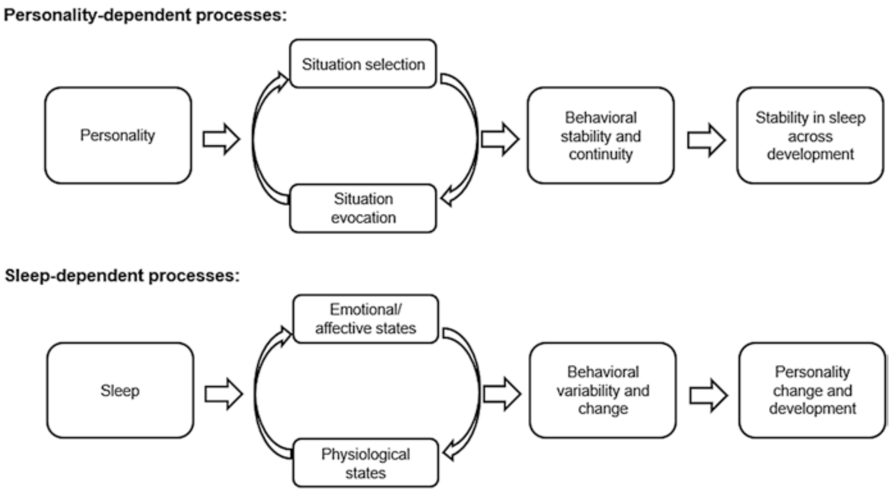

Fig. 2 A conceptual figure illustrating models linking personality and sleep at different levels of measurement across the lifespan

Ahadi, & Evans, 2000; Shiner & Caspi, 2003), and sleep is somewhat more variable and determined largely by family socioeconomic status, parent personality and behaviors, family conflict, parental sleep schedules (and occupations), school schedules, and culture (Adam, Snell, & Pendry, 2007; El-Sheikh, Buckhalt, Mize, Acebo, & El-sheikh, 2006; Jenni & LeBourgeois, 2006; Jenni & O'Connor, 2005; Owens, 2004; Zhang, Li, Fok, & Wing, 2010; see Williams, chapter "Sleep and Temperament in Early Childhood", this volume for review). For example, children whose sleep is relatively short, of variable timing and length, and frequently interrupted (perhaps due to family or neighborhood stress) may feel angry, frustrated, impulsive, or sad; to the extent that this process is repeated across development, these children may experience increases in neuroticism and decreases in conscientiousness, extraversion, and agreeableness. Infancy, childhood, and adolescence may therefore be a sensitive period in which sleep may influence temperament and thus, later personality. However, in adulthood personality is relatively enduring and sleep is more variable (Knutson, Rathouz, Yan, Liu, & Lauderdale, 2006; Roberts, Walton, & Viechtbauer, 2006), and individuals have more personal control over their sleep schedules and timing. For example, adults who have salubrious sleep hygiene and daytime health behaviors (i.e., they regularly exercise; avoid alcohol, tobacco, and drug use; and get in and out of bed at the same time each day), who also experience more stability and positivity in their emotions and interpersonal interactions, may report better sleep quality, less social jetlag, and better sleep continuity. Thus, adulthood may be a window of time when personality may be more likely to influence sleep.

A third substantial open question is the extent to which results vary by time span or developmental period. In experimental, daily dairy, or actigraphy studies, sleep *states* may impact affect and cognition, therefore changing personality *states* (e.g., impulsivity, Hisler & Krizan, 2017), assuming little underlying trait change. In contrast, studies using trait-like measures (or averages) collected prospectively years or decades apart may find that personality *traits* may be more likely to prospectively predict *trait-like* or averaged measures of sleep (including within-person variability), although this is an open question (Duggan et al., 2014; Križan & Hisler, 2019). We see possibly conflicting results at different units of analysis as mutually supportive rather than exclusive, since results cannot be extrapolated from the trait level to the state level and vice versa (ecological fallacy; Wilson et al. 2017). In other words, when changing units of analysis, associations may be absent or even in the opposite direction, because different phenomena are at play. Work integrating sleep and personality at multiple levels of measurement (e.g., integrating state and trait across days and across years via burst designs; Sliwinski, 2008) using multiple methods of personality and sleep (e.g., self-reports, observer reports, actigraphy, and polysomnography), will all be important. Such studies will be informative for understanding the role of personality *processes* in sleep as well as considering *variability* in both personality and sleep states. Additional experimental manipulations of personality and sleep could provide causal evidence of associations, and also inform intervention development aimed at improving sleep and public health.

Finally, given the importance of sleep for public health (Luyster et al., 2012), a fourth need includes applied mediational research on personality and health in service of public health interventions. For example, personality could be used to (1) identify individuals in the population who may have the greatest need for sleep interventions; (2) develop personality-informed interventions targeted to work synergistically with their personality profile; and (3) to use sleep interventions to shift problematic personality expressions, ultimately producing better health. Importantly, experimental research in this area would provide support for or against hypothetical causal models linking personality traits to future sleep, and sleep to changing personality traits.

The depth and breadth of associations between personality and sleep with consequential outcomes like health suggests the need for development and refinement of the theoretically-plausible causal models noted in the four substantial open questions above. For example, does personality lead to these consequential outcomes via sleep? Does sleep promote these consequential outcomes via personality development and change? To what extent are associations bidirectional? How and why do associations vary across different dimensions of personality and sleep, and across development? These questions still await answers, and we hope that researchers will continue to leverage increasingly sophisticated measurement tools to tackle them.

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Personality Disorders, Maladaptive Personality Traits, and Sleep Problems: Findings and Future Directions

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Personality disorder is defined in the American Psychiatric Association's (APA) *Diagnostic and Statistical Manual of Mental Disorders-5* (APA, 2013) as, "an enduring pattern of inner experience and behavior that deviates markedly from the expectations of the individuals' culture, is pervasive and inflexible, has an onset in adolescence or early adulthood, is stable over time, and leads to distress or impairment." (p. 645). Personality disorders involve maladaptive patterns of thinking, feeling, and behaving that cause distress or impairment. It is thus understandable that personality disorders would be associated with sleep problems such as insomnia, which is defined as a disorder involving trouble falling asleep, staying asleep, and/or waking too early, any of which results in daytime impairment (APA, 2013). Enduring patterns of maladaptive thoughts, feelings, and behaviors affect sleep habits (e.g., Harvey, 2002; Winsper et al., 2017). However, the research literature on personality disorder and sleep is surprisingly sparse, focuses primarily on insomnia, and has inconsistent findings. This is perhaps due to small sample sizes used in prior research, inconsistent assessments of personality disorder, and high co-occurrences of sleep problems with many forms of psychopathology (Lichstein, 2000). The present chapter will review what has been found previously, consider ways in which we might make findings in this area more coherent and systematic, and present possibilities for future research.

A large research literature indicates that the DSM symptoms for personality disorders can be thought of analogously as maladaptive personality traits (Samuel & Widiger, 2008), and the two will be discussed as two sides of the same coin in this chapter. There are many reasons why maladaptive personality traits might affect sleep quality. The maladaptive trait of affective instability (i.e., being unstable emotionally)—which is characteristic of borderline personality disorder (BPD)—could make it difficult to fall asleep at night, difficult to stay asleep, and easy to wake up too early (and not be able to fall back asleep). Intense emotions are not conducive to

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a calming environment in which to fall and stay asleep. Likewise, if one is high in maladaptive worry, for example about social interactions (as in avoidant personality disorder), or about being taken advantage of by others (as in paranoid personality disorder), or about odd or unusual experiences (as in schizotypal personality disorder), one may have difficulty sleeping well (Harvey, 2002; Watson, Stasik, Ellickson-Larew, & Stanton, 2015). Research to date demonstrates that these maladaptive traits (or symptoms of personality disorder) are often associated with sleep problems. However, differences in methodology have led to inconsistent findings.

Although it is possible that personality disorders are related to all sleep disorders, the large majority of studies investigating this topic have focused on polysomnographic recordings or self-reported insomnia symptoms. There are some references to other sleep disorders in this chapter; however, most discussion here revolves around differences in polysomnographic recordings between people with personality disorders and healthy controls, and findings using self-reports of insomnia symptoms. More research is needed on personality disorders and other sleep disorders such as hypersomnolence, narcolepsy, and sleep apnea.

Polysomnography of Sleep Differences in Personality Disorders

Polysomnography (PSG) is the method used to objectively record key sleep parameters such as duration, continuity, and stages of sleep for an individual—typically during an in-laboratory overnight sleep study (although ambulatory PSG technologies also exist). PSG studies include overnight examination of physiologically-measured (often through electroencephalography) sleep parameters such as sleep onset latency (the amount of time spent in bed trying to fall asleep before sleep), wake after sleep onset (the amount of time awake after initially falling asleep), sleep efficiency (the amount of time in bed spent asleep versus awake), and total sleep time (the total amount of sleep in the night). PSG studies also measure percentages of stage I, II, III, and IV sleep (stages III and IV are combined as "slow wave sleep"), as well as delta and theta power of sleep (measurements of the sine waves in the electroencephalography recordings), rapid eye movement (REM) sleep parameters such as the percentage of sleep spent in REM stages versus non-REM, REM latency (time spent in other stages until REM), density and duration of REM sleep in the first stage of REM, and overall REM density and number of REM periods during the night.

Differences between patients with personality disorders and controls have been found in each of the sleep parameters mentioned above. BPD has the largest research literature, compared to other personality disorders (Winsper et al., 2017). Early studies found polysomnographic differences between borderline patients and controls such as less total sleep time, sleep efficiency, and REM latency (Akiskal, Yerevanian, Davis, King, & Lemmi, 1985; McNamara et al., 1984; Reynolds III et al., 1985). However, even in these early studies, there are frequent contradictory results (e.g., both positive and null findings in REM density and sleep onset latency in patients with BPD versus controls). Across more than ten further studies using PSG recordings to compare patients with BPD to controls, findings have been inconsistent. No single finding has replicated in every study, and some sleep parameters have produced opposite findings between studies (Oltmanns & Oltmanns, 2015). The only consistency in these findings is that patients with BPD appear to have worse sleep functioning than control subjects, with a lack of specificity beyond that. Methodological limitations of these studies, such as low statistical power, may have led to the inconsistencies that will be discussed later in the chapter.

Fewer PSG studies have been conducted on the sleep quality of patients with other personality disorders. Patients with antisocial personality disorder (ASPD) were found to have lower sleep efficiency, more awakenings, less stage II and slow wave sleep, and greater delta power in slow wave sleep than controls (Lindberg et al., 2003; Lindberg et al., 2006). Adolescents with conduct disorder, however, did not show differences in PSG sleep parameters compared to controls, with the exception of somewhat longer sleep time (Lindberg et al., 2008). The authors attributed the lack of replication in adolescents with conduct disorder perhaps to a lower symptom severity or age differences in sleep architecture (Lindberg et al., 2008). With regard to obsessive-compulsive personality disorder (OCPD) symptoms, OCPD patients with insomnia have shown less total sleep time, lower sleep efficiency, and greater wake after sleep onset than non-OCPD patients 1 year after completing behavior therapy for insomnia (Petrov, Emert, & Lichstein, 2018). Petrov et al.'s (2018) study is important because of the longitudinal design, which added information to the literature about the efficacy of sleep treatment in these patients across time. Schizotypal personality disorder has been associated with lower sleep spindle density in adults (Lustenberger et al., 2014), and shorter sleep spindles and extended REM sleep in adolescents (Kuula et al., 2017). In sum, there are few studies on sleep and personality disorders other than BPD, but they do provide evidence that patients with other personality disorders also display sleep abnormalities.

Limitations

PSG studies on personality disorder have been limited by small sample sizes, inconsistent personality assessment, varying gender distributions and research settings, and different clinical characteristics of the samples. Of 13 PSG studies on BPD reviewed by Oltmanns and Oltmanns (2015), the median sample size was $N = 12$, ranging from $N = 6$ to $N = 27$. In PSG studies, personality disorder criteria have been assessed with semi-structured interview, self-report questionnaire, or informant-report questionnaire, with differences found between methods. Although multi-method assessment would represent a strength if the methods are used in combination, inconsistent findings may be a result of using different methods of assessment on their own across studies. Samples of PSG studies have consisted of inpatients, outpatients, inmates, and community adults. Some samples have been all-male, some all-female, and some mixed-gender. Likewise, some studies have attempted to control for co-occurring psychopathology, such as major depression, while others have not. Some have controlled for a lifetime history of depression but not current depression, and vice versa. Some studies have averaged PSG recordings across multiple nights, while some have relied on only one night. All of these differences may be collectively to blame for the varied results. Nevertheless, the primary limitation of PSG studies of personality disorder and sleep has been the small sample sizes, which have not been adequate enough to capture reliable differences in PSG sleep parameters between people with personality disorders and controls (see Simmons, Nelson, & Simonsohn, 2011). This problem must be addressed in future studies. The small sample sizes likely reflect the cost in conducting PSG studies, but they contribute to the reduced reliability of the findings (Tackett et al., 2017). The other differences amongst studies (such as assessment methods, sample settings, and gender distributions) are problematic in that it is difficult to compare findings. Larger sample sizes would enable investigators to evaluate the generalizability of findings across relevant demographic characteristics, methods employed to measure personality characteristics, and severity of personality disturbance, as well as the possible impact of co-occurring forms of other health problems.

Self-Reported Sleep Problems in Personality Disorders

Two sleep assessment methods have been used in studies of personality disorder and sleep problems: most have been laboratory-based PSG studies while others have relied on self-report questionnaires. Because of reduced burden and costs, studies using self-report questionnaires to assess sleep problems have benefitted from the ability to recruit larger sample sizes, and sometimes been able to follow associations between personality and sleep across time. In a review of seven self-report studies of BPD and sleep, the median sample size was $N = 327$, with a maximum $N = 5692$ (Oltmanns & Oltmanns, 2015).

As in the PSG studies, most self-report studies of personality disorder and sleep problems focus on BPD. It has been found that adult patients with BPD are more likely than patients with other personality disorders to use sedative-hypnotic medications for sleep aid (Plante, Zanarini, Frankenburg, & Fitzmaurice, 2009), BPD symptoms are associated with sleep disturbance even when controlling for depressive symptoms (Harty, Forkner, Thompson, Stuewig, & Tangney, 2010; Oltmanns, Weinstein, & Oltmanns, 2014), BPD symptoms interact with sleep problems to predict socioemotional, cognitive, and self-care impairment (Selby, 2013), BPD patients have greater dysfunctional beliefs and attitudes about sleep (Plante, Frankenburg, Fitzmaurice, & Zanarini, 2013b), reduced daytime alertness and variability in sleep-wake cycles (Bromundt et al., 2013), worse sleep quality and daytime dysfunction (Plante, Frankenburg, Fitzmaurice, & Zanarini, 2013a), and more frequent nightmares (Schredl et al., 2012; Semiz, Basoglu, Ebrinc, & Cetin, 2008). BPD symptoms can increase the risk for suicide through insomnia symptoms (Deshong & Tucker, 2019). Lereya, Winsper, Tang, and Wolke (2017) examined data from 6050 children and found that nightmares were longitudinally predictive of BPD symptoms in early adolescence. Together these studies indicate that BPD is associated with significant self-reported perceptions of problems across many areas of sleep.

With regard to other personality disorders and sleep, Ruiter, Lichstein, Nau, and Geyer (2012) found that avoidant, obsessive-compulsive, dependent, schizotypal, and schizoid personality disorder symptoms, as measured by the SCID-II-Personality Questionnaire, were significantly correlated with total scores on the Insomnia Severity Index (ISI: Bastien, Vallières, & Morin, 2001), higher impact of insomnia on daytime functioning, and daytime fatigue (with the exception of schizotypal, which was not significantly associated with daytime fatigue) in a sample of 84 adults with insomnia. Kamphuis, Karsten, de Weerd, and Lancel (2013) found that forensic psychiatric hospital patients with ASPD symptoms were more dissatisfied with their sleep than other patients. Zhang and Lu (2013) found that paranoid, schizoid, antisocial, histrionic, impulsive, anxious, obsessive-compulsive, and dependent personality disorders were associated with trouble falling asleep, early waking, and restless sleep in a sample of 615 college students. Oltmanns et al. (2014) found that all DSM-IV personality disorders were significantly correlated with insomnia symptoms in a sample of 633 community older adults. Schizotypal personality disorder has been associated with nightmares and narcolepsy in adults (Hartmann, Russ, Oldfield, Sivan, & Cooper, 1987; Levin & Raulin, 1991; Wilcox, 1985). These self-report studies also suggest that personality disorders other than BPD are associated with sleep problems—particularly insomnia; however, this literature is sparse (van de Laar, Verbeek, Pevernagie, Aldenkamp, & Overeem, 2010).

Limitations

While self-report studies have been useful for improving sample size and examining questions regarding development and bi-directional relationships, they also have their own limitations with regard to the measurement of sleep problems. First, self-perceptions of sleep continuity may be inaccurate (e.g., because of the impact of stress or individual differences in reporting). Self-reports of sleep in BPD patients have been found not to align with PSG sleep continuity parameters (Philipsen et al., 2005). On the other hand, Bastien, Guimond, St-Jean, and Lemelin (2008) found that BPD patients were actually more accurate in their self-reports of sleep quality than insomnia patients and controls. They suggested, interestingly, that sleep may actually improve in patients with BPD when they are brought into the sleep laboratory overnight, as a consequence of feeling less lonely while surrounded by researchers in the laboratory (Bastien et al., 2008). This improved sleep in the lab may cause discrepancies between PSG recordings and self-reports of sleep continuity. However, this theory and finding need to be replicated. Further, in other personality disorders, self-reports have generally been in agreement with PSG recordings (Ruiter et al., 2012).

A second limitation of self-report studies is that self-reports of sleep quality cannot tell us about sleep continuity and architecture (i.e., stages of sleep, REM sleep), which are important biological indices of sleep. Sleep stages and latencies have specific connections with psychopathology, for example, shortened REM latency in major depressive disorder (Benca et al., 1997) and reduced sleep spindle activity in schizophrenia (Ferrarelli et al., 2007). Third, as in PSG studies, self-report studies have been limited by the use of varied personality disorder assessments which may range from a few screening items to a full semi-structured interview. Finally, PSG studies have been conducted in varied research settings (i.e., clinical, community, forensic), with a variety of gender distributions, and include varied mixtures of co-occurring psychopathology. Nevertheless, self-report studies have been able to increase the sample sizes of these studies, and that has been the largest limitation of PSG studies to date. With larger sample sizes, some of these limitations can be addressed. For example, gender distributions can more easily be improved and co-occurring psychopathology or other risk factors for sleep problems may be controlled statistically.

Problems with the Categorical Assessment of Personality Disorder

In the research reviewed above, personality disorder was assessed and conceptualized using the DSM system for the diagnosis of personality disorders. Although the development of specific criterion sets for each personality disorder in DSM-III (APA, 1980) was a monumental advance in the classification of mental disorders, personality disorder as defined by the categorical DSM model is problematic (Widiger & Trull, 2007). The DSM criteria for personality disorders were largely written by experts on an anecdotal, unscientific, basis. The DSM model also assumes that discrete personality disorder categories exist in nature, while empirical evidence suggests that they do not exist as categories, but as constellations of maladaptive personality traits (Clark, 2007; Widiger & Trull, 2007). As a result, the criteria for the personality disorders overlap significantly across personality disorders, people with the same personality disorder may have entirely different symptoms, and the threshold between personality disorder and no personality disorder is marked by an arbitrary diagnostic line. These problems have several negative implications for practice such as excessive diagnostic co-occurrence of personality disorders and the constructs being changed over the years with diagnoses being dropped and added along the way. The arbitrary diagnostic threshold for each DSM personality disorder indicates that, for example in BPD, a person who exhibits five of the criteria for BPD is qualitatively different from a person who meets only four BPD criteria. The heterogeneity within personality disorder diagnostic criteria affects study results because symptoms are often not shared by the patients within the studies (although they may share the same DSM personality disorder diagnosis). Indeed, the DSM method of conceptualizing and diagnosing personality disorder is likely a major contributor to the heterogeneous results of studies investigating personality disorders and sleep.

The twenty-first century is witnessing a paradigm shift in the classification of personality disorder (Hopwood et al., 2018; Tyrer, Mulder, Kim, & Crawford, 2019). This process is the result of aligning the assessment of personality disorder with the assessment of normal personality, which has been developed over the past century (John, Naumann, & Soto, 2008). The five-factor model (FFM) of personality was developed from scientific examination of language based on the "lexical hypothesis," or the compelling premise that personality trait names and adjectives that are more important to humans are represented more frequently in language (Goldberg, 1993). If one wants to know the basic domains of personality, one can study language. The FFM has an extensive amount of research support as a normative model of personality (John et al., 2008). A large body of emerging empirical evidence suggests that the DSM personality disorders can be conceptualized as maladaptive variants of the facet traits of the FFM (e.g., Samuel & Widiger, 2008; Widiger, Gore, Crego, Rojas, & Oltmanns, 2017). Conceptualizing personality disorder as "constellations" of maladaptive personality traits from the FFM can resolve many of the most important problems of the DSM system of personality disorder classification. Following early calls for a dimensional model of personality disorder (e.g., Presley & Walton, 1973; Tyrer & Alexander, 1979), innovative dimensional models of personality disorder based on maladaptive personality traits have been validated and widely embraced (APA, 2013; Krueger, Derringer, Markon, Watson, & Skodol, 2012; Livesley, 1985; Widiger, Lynam, Miller, & Oltmanns, 2012).

The development of a dimensional trait model of personality disorder is important to understanding the relationship between personality disorder and sleep in large part because maladaptive personality traits are more specific and homogenous than the traditional DSM personality disorder constructs. Homogeneous constructs provide clarity in predictive relationships; that is, homogeneity of the construct of interest ensures that it is this construct (and not another construct hidden within the measure) that is driving the predictive relationship (Smith, McCarthy, & Zapolski, 2009). Within total scores of heterogeneous DSM personality disorders, several different symptoms or traits may have competing relationships with sleep quality. Using a total score of a DSM personality disorder to predict an outcome such as sleep is then problematic. Not all symptoms in a DSM personality disorder score may have the same relationship with sleep, and vice versa; trivial relationships between symptoms within a given DSM personality disorder score and sleep may obfuscate significant relationships between other symptoms and sleep. As a result, if a predictive relationship is not significant, a researcher may conclude that there is no relationship between the personality disorder at hand and sleep, when in fact one symptom of the personality disorder may have an important relationship with sleep that is obfuscated by the other symptoms that do not have relationships with sleep. Symptom-level analyses using DSM personality disorder measures could help surpass this problem; however, this lower-order approach would also be problematic psychometrically because DSM personality disorder criteria are usually assessed by only one item. One-item measures do not provide a reliable measurement of the personality disorder symptom/trait. In addition, some of the individual personality disorder diagnostic criteria still fail to be homogeneous. In contrast, the homogeneity of multi-item maladaptive personality trait scales from dimensional trait models of personality disorder (i.e., that include multiple items that have high mean inter-item correlations and increase the reliability of the measurement) will allow researchers to more easily find which traits are related to sleep. It could provide a much clearer picture of the relations between personality disorder and sleep and create a direct bridge to findings on sleep and 'normal' personality traits (see Duggan & Križan, chapter "Personality Processes and Sleep: An Overview and a Leitmotif for a Research Agenda", this volume, for review).

Sleep Problems and Dimensional Maladaptive Personality Traits

There has been a growing research literature on maladaptive personality traits and sleep—separate from DSM personality disorders—that will be important to continue. The studies reviewed here examined specific homogeneous maladaptive traits (or "facets" of maladaptive traits domains) as opposed to trait domains or compound dimensional psychopathology measures, which are much broader and heterogeneous measures that would suffer from a similar heterogeneity problem as assessments of the DSM personality disorders. Although few in number, there have been important studies that have used rigorous methodologies that are more likely to be replicable; for example, using longitudinal designs or recruitment of large sample sizes. Studies on maladaptive traits and sleep have found associations between sleep and emotion dysregulation, alexithymia, worry and rumination, anxiety, traits of schizotypy, paranoia, anger, impulsivity, and depressiveness. While it should be noted that studying these traits on their own is more specific than DSM personality disorder constructs, it is noteworthy these traits may be further subdivided into more specific facets or "nuances" (e.g., Mõttus, Kandler, Bleidorn, Riemann, & McCrae, 2017; Oltmanns & Widiger, in press). However, studying the relations between more homogeneous traits at this level, and their relations with sleep, is likely to be a more fruitful line than the DSM personality disorder constructs; it is a step in the right direction towards having a more specific understanding of the relationship between personality disorders and sleep problems.

There is a growing number of studies on emotion dysregulation, specifically, and sleep (see Goldschmied, chapter "How Sleep Shapes Emotion Regulation", this volume). Interestingly, emotion dysregulation is a hallmark feature of BPD, and it is possible that emotion dysregulation is an important contributor to the significant associations that have been found previously between BPD and sleep problems. The following studies illustrate this possibility: A longitudinal investigation of 1132 college students in Canada found that emotion dysregulation was associated with insomnia symptoms (bi-directionally) across 5 years, a relationship that was mediated by depressive symptoms (Semplonius & Willoughby, 2018). Another longitudinal study of 2333 community adults in Sweden found that emotion dysregulation on its own did not significantly predict insomnia symptoms. However, *changes* in emotion dysregulation (increases in emotion dysregulation, specifically) across time did predict insomnia symptoms prospectively across 18 months (Jansson-Fröjmark, Norell-Clarke, & Linton, 2016). These longitudinal studies provide convincing evidence of the association, and more studies examining other maladaptive traits and sleep longitudinally in this fashion would be helpful. There are yet other studies indicating an association between emotion dysregulation and sleep problems with cross-sectional correlations (e.g., Brand et al., 2016; Palagini et al., 2018; Hisler & Krizan, 2017).

More longitudinal studies are needed investigating the temporal relationships between maladaptive traits and sleep problems. However, a relatively large number of cross-sectional studies with extensive samples have identified significant connections between maladaptive traits and sleep, including: Machiavellianism and psychopathy (but not narcissism; Akram et al., 2018, $N = 475$; Sabouri et al., 2016, $N = 341$), alexithymia (Kronholm, Partonen, Salminen, Mattila, & Joukamaa, 2008; $N = 5388$), perfectionism related to concern over mistakes, doubts about actions, and parental expectations and criticism (Lombardo, Mallia, Battagliese, Grano, & Violani, 2013; $N = 819$), paranoia (Rehman, Gumley, & Biello, 2018, $N = 401$ and 402; Scott, Rowse, & Webb, 2017, $N = 348$), rumination (Palmer, Oosterhoff, Bower, Kaplow, & Alfano, 2018, $N = 10{,}148$), and anger (Hisler & Krizan, 2017, $N = 436$; Ottoni, Lorenzi, & Lara, 2011, $N = 5129$; Shin et al., 2005, $N = 4695$). Traits related to schizotypy have also been linked to sleep problems in several cross-sectional studies (e.g., Watson et al., 2015, $N = 438$), but most have employed relatively smaller samples, including studies linking magical ideation (Lustenberger et al., 2014, $N = 20$), dissociation, amnesia, absorption, and derealization/depersonalization (Vannikov-Lugassi & Soffer-Dudek, 2017, $N = 93$ and $N = 218$) with sleep. Impulsive traits have been linked to sleep problems, but in smaller cross-sectional samples, with further investigation needed (e.g., Schmidt & Van der Linden, 2009, $N = 112$; Van Veen, Karsten, & Lancel, 2017, $N = 101$). These studies are preliminary, but important, and need follow-up longitudinal replications.

There are, of course, studies to find null effects for associations between maladaptive traits and sleep problems, including: rumination (Slavish et al., 2018), repetitiveness (Vannikov-Lugassi & Soffer-Dudek, 2017), sensation-seeking (Schmidt & Van der Linden, 2009), perfectionism related to personal standards or organization (Lombardo et al., 2013), and angry irritability (Tavernier, Choo, Grant, & Adam, 2016). However, these are most often the exceptions. Given methodological limitations across studies, it should be expected that not all studies will agree. Therefore, conclusions about relationships between specific maladaptive traits and sleep problems should be based on robust findings that are consistent across many studies. Individual studies with null results should not be used to draw conclusions about these relationships.

Future Directions

Recent advances in the conceptualization and classification of personality disorders as well as research practices in psychology will improve future research on personality disorders and sleep. The dimensional assessment of personality disorders improves problems of the DSM-based categorical approach. Further, recent advances in psychological methods via the credibility revolution in psychology will improve the confidence we can have in findings on personality disorders and sleep (Nelson, Simmons, & Simonsohn, 2018; Vazire, 2018).

Improvements in Measurement of Maladaptive Personality

Several problems are inherent in the categorical DSM model of personality disorder, including excessive diagnostic co-occurrence, heterogeneity in criteria across personality disorder constructs, inadequate coverage of maladaptive personality traits, and inadequate scientific base for the categorical types (Widiger & Trull, 2007). Recent years have seen the development and validation of dimensional personality disorder models and measures (Krueger et al., 2012; Widiger et al., 2012). Criterion B of the DSM-5's alternative model of personality disorders (AMPD) consists of five maladaptive personality trait domains that were based on the empirical support of the FFM of personality. As stated in the DSM-5 AMPD, "these five broad domains are maladaptive variants of the five domains of the extensively validated and replicated personality model known as the 'Big Five' or Five Factor Model of personality (FFM)" (APA, 2013, p. 773). The AMPD's Criterion B includes 25 more specific maladaptive facets of personality and even more scales have been developed for a broader FFM conceptualization of personality disorder (see Crego, Oltmanns, & Widiger, 2018). It is in the relationships of the specific maladaptive traits with sleep that we will improve our understanding of personality disorder and sleep; not in the relations between DSM personality disorder measures and sleep. Examining a heterogeneous DSM-based score's association with sleep is not useful because we do not know what drives the relationship; using homogeneous maladaptive trait scores is useful because the precise nature of the relationship can become more specifically clear (Smith et al., 2009). Future research can use dimensional maladaptive trait models and measures such as the FFM of personality disorder scales (Widiger et al., 2012) or the DSM AMPD traits (APA, 2013) to uncover relationships between personality disorders and sleep that will be more specific and replicable. For example, knowing that an emotion dysregulation facet of borderline personality leads to sleep problems is more useful to us than knowing that the DSM construct of BPD is related to sleep problems.

Open Science and Improvements in Research Design

The past 10 years have seen the rise of a scientific credibility revolution in psychological science in response to the findings that many psychological research findings do not replicate (Tackett et al., 2017; Vazire, 2018). Pillars of the revolution include transparency and reproducible methodology that will make psychological research more meaningful through replicability. In addition, opening research materials for closer scrutiny by different researchers will allow greater coherence of studies on personality disorder and sleep. With open data and materials, scientists will be motivated to be more careful in presentations of results and can hold each other accountable. The credibility revolution emphasizes the use of larger samples because of the statistical power it provides. Larger samples will afford more power to avoid false positive results, more power to detect robust yet smaller differences, and afford overall more precision when estimating relations between personality disorders and sleep. The use of preregistered hypotheses will help us clarify what we expect to find and then be more confident in our findings. The use of registered reports will perhaps be especially imperative in this line of research because null results will not preclude studies from being published, and will reduce the motivation for *p*-hacking, which "has long been the biggest threat to the integrity of our discipline" (Nelson et al., 2018, p. 517). Using smaller *p*-values and, in particular, relying more on effect sizes rather than statistical significance will also help us be sure that we are detecting true effects, rather than spurious ones. And finally, with the rise of interest in and publication of direct replications, we can cement our findings. For a review of the history and important pillars of the credibility revolution in psychology see Nelson et al. (2018) and Vazire (2018).

It should finally be noted that small samples have understandably been the norm in PSG studies because they are expensive and difficult to conduct. Unfortunately, small samples can lead to inaccurate and inconsistent results (Simmons et al., 2011). Our prior reliance on results from small samples are likely a reason for the disagreement among the findings; we have little specificity in our understanding of exactly how people with personality disorders differ in their sleep from those without personality disorders. But PSG studies are imperative because they connect biological sleep parameters to symptoms and traits. More effort should be used to recruit larger samples, however, and when large exploratory longitudinal studies using self-reports provide evidence of an effect, these effects can then be tested in smaller, confirmatory, PSG studies with preregistered hypotheses, giving us more confidence in the results. Registered reports may be especially useful in these cases. Finally, with new technologies such as actigraphy and mobile PSG methods, future research might be able to reduce costs while at the same time collecting information on sleep parameters measured by PSG.

Conclusions

A small and slowly emerging literature on personality disorder and sleep problems has become a more rapidly growing field. Early studies using DSM PD constructs and small sample sizes are now being replaced with large samples sometimes including ambulatory and longitudinal methodologies that provide higher-powered answers to research questions. The developments in this line of research, such as the consideration of more specific maladaptive personality traits as opposed to categorical personality disorder diagnoses, ambulatory and longitudinal sleep research methodologies, and transparent research practices aimed at increasing the reproducibility of results, it appears that our understanding of sleep and personality disorder will improve. There are many exciting questions to be answered that will ultimately have the ability to improve lives.

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