Sleep in Social Cognition and Judgment

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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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