SLEEP, 2022, 1–3

https://doi.org/10.1093/sleep/zsac177
Advance Access Publication Date: 23 July 2022
Editorial

EDITORIAL

# To minimize loss or maximize gain? That depends on sleep and gender

Suzanne H. Mitchell[1,2,*] and Steven A. Shea[2]

[1]Departments of Behavioral Neuroscience and Psychiatry, Oregon Health & Science University, Portland, OR, USA, [2]Oregon Institute of Occupational Health Sciences, Oregon Health & Science University, Portland, OR, USA,

*Corresponding author. Suzanne H. Mitchell, Department of Behavioral Neuroscience, L470, Oregon Health & Science University, 3181 SW Sam Jackson Park Road, Portland, OR 97239, USA. Email: mitchesu@ohsu.edu.

In a recent issue of SLEEP, Lim *et al.* [1] report how different forms of sleep loss moderate risky decision-making, and how this effect is dependent on gender. This was a comprehensive study that deployed two assessments of risky decision-making (minimizing losses or maximizing gains), explored two types of sleep loss (a night of sleep deprivation or consecutive nights of shorter sleep), and compared effects between men and women. The authors found interactions across all of these dimensions. Thus, there is a lot to unpack. The results are certainly intriguing, and potentially important given that sleep deficiency is rife across many societies [2]. Nonetheless, as discussed below, we feel that it is way too early to implement the authors' suggestion that "Efforts by organisations to reduce detrimental risky decisions made by employees should take into consideration the employees' sex, the type of sleep loss experienced, and the way decisions are framed."

Most people make hundreds of decisions daily; from the mundane (whether to pay extra for express package delivery) to the potentially high-stakes (whether to slow down or accelerate as traffic lights change). There has been much research into the factors influencing decision-making and their neurobiological bases. One approach examines the processing steps contributing to simple decisions [3–5]. For example, in making a choice between available commodities, one assesses the value of each commodity; compares values among all available commodities; and decides based on those relative values. Another approach focuses on how choice patterns in those simple decisions are affected by manipulations or conditions such as exposure to alcohol [6–8], substance use disorders [9], or psychiatric diagnoses [10]. Such research may identify causal mechanisms, providing potential targets for intervention. For example, limiting dopaminergic agonist therapy in Parkinsonism because prolonged use is associated with selecting riskier activities [11]. Public policy also considers factors that affect risky decisions, most noticeably by imposition of age requirements on driving because of the perceived riskier choices in some younger individuals [12].

Thus, there are numerous steps in the decision-making process where potential moderating factors, such as sleep or gender, can play a role. In their study, Lim *et al.* [1] used the Lottery Choice Task (LCT) that their group developed [13, 14]. Across numerous trials, participants were shown two options (A and B), each of which included three equally probable "payouts," and were required to choose either A or B. For option A possible "payouts" were $10, $10, or $20 (average = $13.33), whereas possible "payouts" for option B varied over trials and encompassed a larger range, for example, $2, $13, or $25 (average = $13.33). The same averages meant that both options had the same "expected" value, a factor known to affect choice [15]. The essence of the task was that the larger range in option B (with both lower and higher possible "payouts" than in option A), meaning that option B was always deemed to be the riskier choice. Analyses focused on the number of choices of option A versus B. In addition, options A and B were presented to participants in two batteries; either framed as amounts that a participant might earn (maximize gains) or as amounts that might be lost (minimize losses). The study had a realistic outcome. Following task completion, one of the trials was selected at random and the participant would win or lose the "payout" from that trial. This procedure presumably works well when participants earn money but begs the question of whether participants could actually lose money by volunteering in this study.

Lim *et al.* [1] compared LCT performances in a well-rested state (following six consecutive days with 9 h sleep opportunity per night) with LCT performance following two forms of sleep

loss: one night of total sleep deprivation (TSD), or following multiple consecutive days of sleep restriction (SR: 4 days of 4 h sleep opportunity per night). The sequences of well-rested and sleep loss were counterbalanced. An initial finding that validated the approach was that the risk averse, Option A, was selected more often when amounts were framed as maximizing gains (rather than minimizing losses); which is a well-established result in the decision-making literature [16]. Another useful validity check included the self-reported effects of sleep loss, which indicated that well-rested and sleep loss conditions differed in the expected directions. Then things got complicated: when compared to the well-rested state, and when trying to maximize gains, females were more risk averse following TSD and SR, whereas males were not systematically affected by sleep loss. On the other hand, when trying to minimize losses, females were not systematically affected by sleep loss, whereas males became more risk seeking during TSD alone. These are complex findings that can inform future studies.

A full appreciation of the experimental nuances is needed though before further studies are performed to drill down on the effects found by Lim *et al.* [1]. First, we were intrigued that the authors aimed "…to examine the impacts of TSD and SR, independent of any effects of sleepiness." This is an interesting concept, as the neurophysiological underpinnings of sleep loss and sleepiness are unknown, the two almost inevitably go together, and the two probably cannot be separated—mechanistically or even statistically. Thus, it would have been interesting to assess whether *not* using the Karolinska Sleepiness Score as a covariate in the statistical models reduced or even improved the ability of detecting any overall effects of sleep loss on decision-making. Second, the sleepiness ratings were not broken down by participant gender, which was a lost opportunity to shed light on the well-reported gender differences in risk-taking. Third, the authors are to be commended by use of two sleep loss conditions which could increase the generalizability of the results. The condition of TSD is effectively a loss of 8 h of sleep across one night, and SR is effectively a loss of 16 h of sleep across four consecutive nights (presumably allowing some recovery across each night). While these somewhat arbitrary experimental choices may not emulate true life experience for everyone, these ranges do encompass the ranges of sleep loss that many people have encountered. However, given that differences emerged, one is left wondering if the different results are due to different mechanisms at play between those conditions, or the more likely situation that the differences were merely due to differences in the biological equivalence of the two selected sleep loss manipulations. Fourth, there were differences in clock times (as the authors noted) and prior light exposure between the well-rested and sleep loss conditions, which raises the concern that internal circadian phases are different and could have affected results. Fifth, the proximity to prior sleep, and therefore degrees of sleep inertia [17, 18], were also different between conditions and could have affected results. Thus, it would be useful to determine in future studies if risk-taking is affected by circadian phase or sleep inertia. Sixth, given their interest in gender differences, it is unfortunate that Lim *et al.* [1] did not collect information about menstrual cycle, which they themselves note as a limitation. Indeed, some studies have reported effects of menstrual cycle phase on decision-making tasks [19, 20], and recent research in rodents demonstrated interactions between gonadal regulatory mechanisms and brain regions associated with decision-making [21]. However, no studies have yet explored whether these interactions are moderated by SR.

Determining whether the gender differences reported by Lim *et al.* [1] can generalize beyond the LCT to other decision-making scenarios, and whether risky decisions are differentially affected by different degrees of sleep loss, are important next steps. While understanding the mechanisms is an intriguing future direction, the types of sleep loss and the types of risky decision-making tests used in the laboratory may be very far from what occurs in real life. For instance, an additional prominent moderating factor of decision-making is motivation [22, 23], which will likely be different in every situation, and is also affected by sleep [24, 25]. Nonetheless, it is certainly worth considering the applied importance of this research. Lim *et al.* [1] suggest that their findings may have implications for worker reliability and competence in professional settings that involve risky decision-making and work hours that curtail sleep (physicians and financial traders are mentioned). We contend that empowering employees by educating them about the possible risks they are taking, routine steps that can be used to reduce risks, and how risk-taking behaviors may be modulated by a number of factors, including sleep loss and gender, is a sensible approach. Of course, these findings could have just as much importance for choices involving risky options outside the workplace, such as driving, gambling, and all manner of social interactions. Finally, this research begs the question of whether these same effects pertain in people with disturbed sleep (e.g. sleep apnea or insomnia). Overall, this study by Lim *et al.* [1] is an important contribution to this area of research and reveals many important unanswered questions.

## Funding

This study is funded in part by National Institutes of Health awards R21 MH121073 and R35 HL155681.

## Disclosure Statement

Financial Disclosures: None declared.

Non-financial Disclosures: None declared.

## References

1. Lim JYL, *et al.* Sex moderates the effects of total sleep deprivation and sleep restriction on risk preference. *Sleep.* 2022. doi:10.1093/sleep/zsac120.
2. Luyster FS, *et al.* Sleep: a health imperative. *Sleep.* 2012;**35**(6):727–734. doi:10.5665/sleep.1846.
3. Gigerenzer G, *et al.* Heuristic decision making. *Annu Rev Psychol.* 2011;**62**:451–482.
4. Kahneman D, *et al.* Prospect theory: an analysis of decision under risk. *Econometrica.* 1979;**47**(2):263–292.
5. Tversky A, *et al.* Judgment under uncertainty: heuristics and biases. *Science.* 1974;**185**(4157):1124–1131.
6. Euser AS, *et al.* Acute effects of alcohol on feedback processing and outcome evaluation during risky decision-making: an ERP study. *Psychopharmacology (Berl).* 2011;**217**(1):111–125.

7. George S, *et al*. The acute effect of alcohol on decision making in social drinkers. *Psychopharmacology (Berl)*. 2005;**182**(1):160–169.
8. Tobias-Webb J, *et al*. The effects of alcohol on sequential decision-making biases during gambling. *Psychopharmacology (Berl)*. 2020;**237**(2):395–407.
9. Amlung M, *et al*. Steep delay discounting and addictive behavior: a meta-analysis of continuous associations. *Addiction*. 2017;**112**(1):51–62.
10. Amlung M, *et al*. Delay discounting as a transdiagnostic process in psychiatric disorders: a meta-analysis. *JAMA Psychiatry*. 2019;**76**(11):1176–1186.
11. Voon V, *et al*. Dopamine agonists and risk: impulse control disorders in Parkinson's disease. *Brain*. 2011;**134**(Pt 5):1438–1446.
12. Best R, *et al*. Age differences in the effect of framing on risky choice: a meta-analysis. *Psychol Aging*. .2015;**30**(3):688–698.
13. Dickinson DL, *et al*. The impact of self-selected short sleep on monetary risk taking. *J Sleep Res*. 2022;**31**(3):e13529.
14. McKenna BS, *et al*. The effects of one night of sleep deprivation on known-risk and ambiguous-risk decisions. *J Sleep Res*. 2007;**16**(3):245–252.
15. Tversky A, *et al*. The framing of decisions and the psychology of choice. *Science*. 1981;**211**(4481):453–458.
16. Ramar K, *et al*. Sleep is essential to health: an American Academy of Sleep Medicine position statement. *J Clin Sleep Med*. 2021;**17**(10):2115–2119.
17. Blatter K, *et al*. Circadian rhythms in cognitive performance: methodological constraints, protocols, theoretical underpinnings. *Physiol Behav*. 2007;**90**(2–3):196–208.
18. Jewett ME, *et al*. Time course of sleep inertia dissipation in human performance and alertness. *J Sleep Res*. 1999;**8**(1):1–8.
19. Lazzaro SC, *et al*. The impact of menstrual cycle phase on economic choice and rationality. *PLoS One*. 2016;**11**(1):e0144080.
20. Zhuang JY, *et al*. Neural basis of increased cognitive control of impulsivity during the mid-luteal phase relative to the late follicular phase of the menstrual cycle. *Front Hum Neurosci*. 2020;**14**:568399.
21. Orsini CA, *et al*. Regulation of sex differences in risk-based decision making by gonadal hormones: insights from rodent models. *Behav Processes*. 2022;**200**:104663.
22. Berridge KC, *et al*. Decision utility, the brain, and pursuit of hedonic goals. *Soc Cogn*. 2008;**26**(5):621–646.
23. Berridge KC, *et al*. Liking, wanting, and the incentive-sensitization theory of addiction. *Am Psychol*. 2016; **71**(8):670–679.
24. Benedict C, *et al*. Acute sleep deprivation enhances the brain's response to hedonic food stimuli: an fMRI study. *J Clin Endocrinol Metab*. 2012;**97**(3):E443–E447.
25. Rihm JS, *et al*. Sleep deprivation selectively upregulates an amygdala-hypothalamic circuit involved in food reward. *J Neurosci*. 2019;**39**(5):888–899.