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ORIGINAL RESEARCH

Sleep Deprivation Selectively Impairs Interpersonal Trust in Different Social Scenarios: Evidence from the Social Mindfulness Paradigm

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Background: Sleep deprivation (SD) is widely recognized for its negative impact on both cognitive abilities and social interactions. Nonetheless, the effect of sleep deprivation on interpersonal trust in social scenarios is poorly understood.

Purpose: This study investigated the impact of total sleep deprivation on interpersonal trust under two different social scenarios: kindness and unkindness.

Patients and Methods: All participants (N = 49) completed the Social Mindfulness paradigm (SoMi) after both normal sleep (NS) and SD. Alertness changes were assessed using the Psychomotor Vigilance test (PVT) and the Karolinska Sleepiness Scale (KSS).

Results: Our results demonstrated that SD significantly impaired interpersonal trust when perceiving unkind intentions but did not affect trust in kind intentions ($p < 0.05$). Additionally, this detrimental effect was not related to changes in alertness ($p > 0.05$).

Conclusion: These findings suggest that SD selectively impacts interpersonal trust, and this effect is not influenced by simple cognitive functions such as alertness. Further research could incorporate brain imaging techniques to explore the association of other cognitive and affective factors with interpersonal trust after sleep loss.

Keywords: sleep deprivation, interpersonal trust, intention

Introduction

A substantial body of research has demonstrated that sleep is essential for cognitive functions. When sufficient rest is deprived, cognitive functions, including attention, working memory, and long-term memory, undergo significant deterioration.[1,2] Besides, emerging research highlights that sleep also plays a key role in social functioning, and inadequate sleep is associated with diminished willingness to socialize and increased social withdrawal.[3,4] Subsequent research has examined the effects of sleep deprivation on helping behavior across individual, group, and societal levels. This study demonstrated that even brief periods of sleep loss can significantly diminish individuals' willingness to assist others.[5] These deteriorated social interactions after sleep deprivation may stem from a decreased ability to accurately perceive and interpret others' mental states, as this ability is essential for social interactions.[6–8]

A previous study has provided evidence to support the hypothesis. Ben Simon and Walker found that individuals after sleep deprivation exhibited increased social withdrawal, as measured by maintaining a greater physical distance from others in a simulated interaction.[3,4] This behavioral change was associated with decreased activity in the Theory of mind related regions. Theory of mind refers to the ability of individuals to understand their own and others' mental states (intentions, expectations, thoughts, and beliefs), and is crucial for understanding others' intentions in social interactions.[9,10] This finding indicates that the ability to perceive the intentions of others accurately decreases after sleep deprivation.[4]

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Interpersonal trust serves as a key factor in social interactions,[11] and is characterized by positive expectations toward others' behavior and intentions.[12] Studies have shown that people tend to share less money in the Trust game after inadequate sleep.[13,14] For instance, research has demonstrated that 36 hours of total sleep deprivation significantly reduces individual's propensity to trust others in the Trust game, suggesting that sleep deprivation impairs the ability to accurately perceive intentions of others from economic aspects.[14] In the Trust game, people face a social dilemma between trusting and potentially benefiting from reciprocity or distrusting to avoid betrayal, which requires assessing the partner's trustworthiness based on perceived intentions.[15–17] This phenomenon indicates that trust in economic decisions (the Trust game) is reduced after inadequate sleep, which might be associated with inaccurate speculation about the intentions of others based on the principles of reciprocity. The principle of reciprocity is a social norm of responding to an action executed by another person with a similar or equivalent action. This typically results in rewarding positive actions and punishing negative ones.[18] According to social exchange theory, social interactions operate on the principles of reciprocity,[19] where intentions are interpreted as either kindness or unkindness. People are more likely to trust and engage in social exchange when they perceive kind intentions.[20,21] Conversely, perceiving unkind intentions leads to defensive behavior and mistrust because it implies that others may be threatening or otherwise risky.[22] In both interpersonal and economic contexts, trust is established based on an optimistic assessment of others' intentions through the principles of reciprocity.[23,24] Thus, sleep loss may also impair interpersonal trust by decreasing the perceived accuracy of others' intentions.

Several studies have been concerned with the impact of sleep deprivation on social interactions, such as cooperation,[25,26] and social withdrawal.[4] Nonetheless, to our knowledge, no study has focused on whether sleep deprivation influences interpersonal trust in real social scenarios. Individuals after sleep loss exhibit differential responses to different types of stimuli, with heightened sensitivity to negative stimuli,[27–30] suggesting that sleep loss may differentially influence the evaluation of positive and negative stimuli. Consequently, it is necessary to determine whether sleep deprivation exerts differential degrees of effects on interpersonal trust when kind and unkind intentions are perceived.

Given interpersonal trust is important in social interaction, research involving social contexts and interactions is more valuable than experiments conducted without social contexts. The social mindfulness paradigm is an approach that uses social contexts and interactions. It is widely used to induce social kindness and unkindness scenarios by manipulating different choices.[31] The current study utilized the social mindfulness paradigm to construct two types of social scenarios (social kindness scenarios and social unkindness scenarios) to investigate the impact of sleep deprivation on interpersonal trust across these two scenarios. A 2 (sleep state: normal sleep, sleep deprivation) × 2 (social scenarios: social kindness scenarios, social unkindness scenarios) experiment design was employed to investigate this question. We hypothesized that interpersonal trust scores in unkind scenarios would significantly decrease after sleep deprivation. Moreover, sleep deprivation robustly decreases alertness, which may also influence interpersonal trust due to insufficient resources to regulate cognitive and affective control after sleep loss.[32] We further hypothesized that changes in alertness are a potential factor affecting the relationship between interpersonal trust and sleep deprivation.

Materials and Methods

Participants

A prior power analysis was performed using G*Power,[33] indicating that a minimum sample size of 28 participants was required to achieve an 80% power (1-β = 0.95) to detect a medium effect size (Cohen's d = 0.5) at an alpha level of 0.05, with the statistical test: ANOVA (Repeated measures, within factors) used in G*Power to calculate the sample size. Therefore, 49 (53.1% females, age M ± SD = 21.3 ± 2.2) college students participated in this study. No participant reported any history of psychiatric, neurological, or sleep disorders. Participants met the following inclusion criteria: (1) normal or corrected-to-normal vision; (2) right-handedness; (3) no habitual drinking, smoking, or other substance addiction; (4) no shift work, trans-meridian travel or irregular sleep-wake routines in the 60 days before the in-lab experiment; (5) good sleep habits (sleep onset before 1:00 AM and wake time during 7:00 to 9:00 AM with 7–9 hours of total sleep time); (6) no caffeine or medicine intake 48 hours before the experiment. Informed written

consent was obtained from the participants before the experiment. The study was conducted in accordance with the principles of the "Helsinki Declaration" and was approved by the Ethics Committee of South China Normal University.

Experimental Procedure

In this study, we designed a 2 (sleep state: normal sleep, sleep deprivation) × 2 (social scenarios: social kindness scenarios, social unkindness scenarios) within-participants experiment. Participants were required to attend two visits to the laboratory with either a one-week (the normal sleep first) or three-week (the sleep deprivation first) interval between visits. To avoid potential sequence effects, all participants were randomly divided into two groups, with one group completing the normal sleep (NS) condition first and the other completing the sleep deprivation (SD) condition first (Figure 1).

Participants were continuously monitored in a semi-isolated living area and had contact only with research staff during their stay in the lab. During their free time, participants were permitted to read books and magazines and converse with the research staff. They were prohibited from engaging in physically demanding tasks or using light-emitting electronic equipment such as smartphones or tablets. Additionally, all participants were required to have approximately eight hours of sleep in the laboratory the night before the experiment. This familiarization with the experimental environment aimed to eliminate potential factors influencing their sleep. In the normal sleep condition, participants arrived at the laboratory in the evening around 19:00 and were required to sleep from 23:30 to 7:00. In contrast, during the sleep deprivation condition, participants were kept awake the entire night under the monitoring of the research staff. In the morning following each condition, participants filled in the Karolinska Sleepiness Scale,[34] and then performed a psychomotor vigilance test.[35] The social mindfulness paradigm was tested after the Karolinska Sleepiness Scale and the psychomotor vigilance test to assess the effects of sleep deprivation on interpersonal trust.

Measures

Social Mindfulness Paradigm

The social mindfulness paradigm (SoMi task) is a social design-making task that has been well-validated to measure social kindness.[31] This paradigm was used to evoke kindness and unkindness scenarios in this study. The experimental materials are six commonly used items, including daily necessities (cup, umbrella, hat) and office supplies (pen,

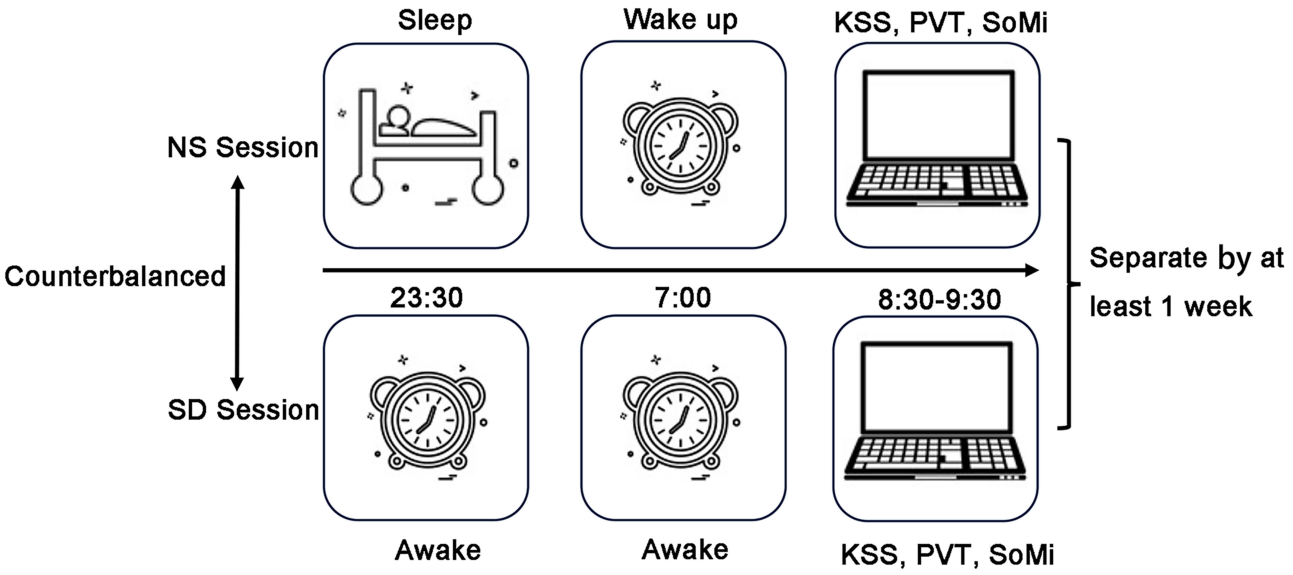

Figure 1 Experimental protocol of normal sleep and sleep deprivation conditions.
Abbreviations: NS, normal sleep; SD, sleep deprivation; KSS, Karolinska Sleepiness Scale; PVT, Psychomotor vigilance test; SoMi, Social Mindfulness Paradigm.

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notebook, U disk). In each trial, two people in sequence select one item from four identical items that differ only in color. For example, there may be three blue cups, one purple cup, three purple cups, and one blue cup (see Figure 2A). In this study, the first person was virtual, and the participants were always the second to choose, allowing them to perceive different intentions. All images of virtual individuals were selected from the Chicago face database, which ensures that all individuals have provided informed consent for research purposes.[36] To illustrate, the scenario where the virtual person chose a non-unique cup and offered the second person a choice to select a color was labeled a kindness scenario. Conversely, taking away the unique cup and leaving the second person without the chance to choose was labeled an unkind scenario. The control trials, which served as a baseline, displayed the color of the item in a 2:2 ratio (eg, two blue cups and two purple cups, see Figure 2A). In these trials, there were no social consequences of participants' choices. After each trial, participants were asked to score the level of trust in the first person after completing the choice.

Using a within-participants design, the SoMi task was tested after normal sleep and sleep deprivation, respectively. Each round consisted of 72 trials, including 24 kindness scenarios trials, 24 unkindness scenarios trials, and 24 control trials, three types of conditions randomly appeared during the SoMi task. In each trial, a face of the same gender as the participant was presented with the note "this person chooses first" lasting 1500 ms. The stimulus of cups was presented for 1000 ms, followed by a randomly jittered blank screen lasting between 400–800 ms. After this, the stimulus of cups reappeared with the first person's choice frame highlighted in red, lasting 1500 ms. The participants then needed to select one of the remaining three cups and rate their level of trust for the first person (How much do you trust A, from 1 to 9 means extremely distrust to extremely trust) until they chose a cup. The location of the unique item and the first person's choice is randomized (see Figure 2B).

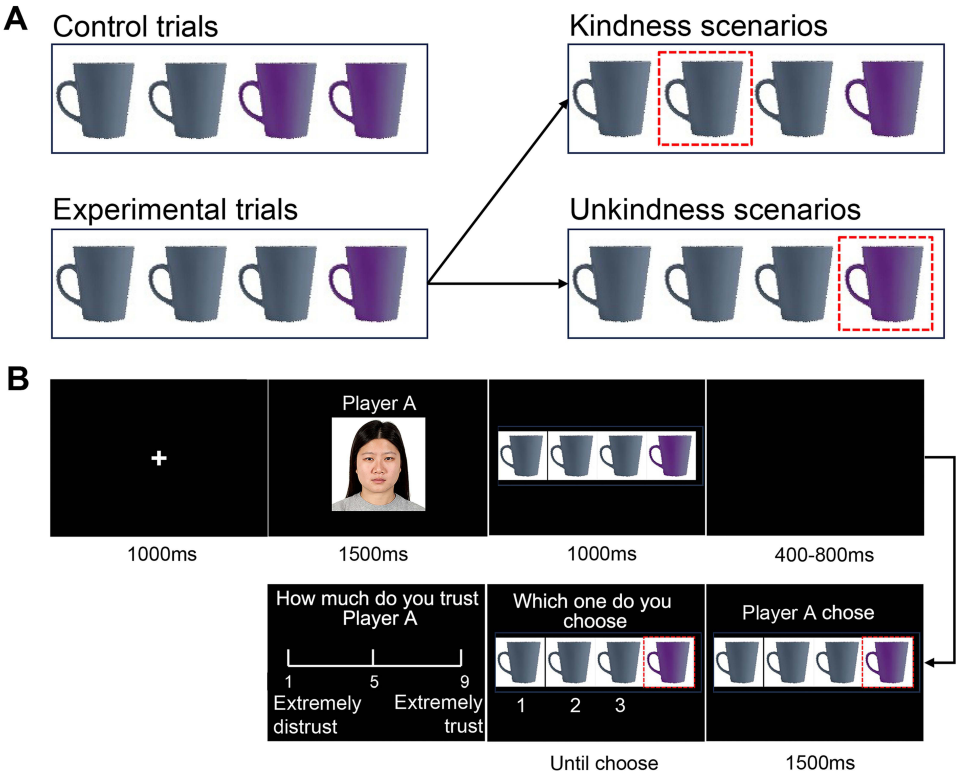

Figure 2 Experimental design. (**A**) Control trials (2:2 ratios) and experimental trials (3:1 ratios). In the experimental trials, if player A chose the unique item, it was classified as "unkindness"; otherwise, if player A chose one of the other items, it was classified as "kindness". (**B**) Trial structure. In each trial, after a 1000ms fixation, the actor's (A's) photo was presented for 1500ms, followed by the objects for 1000ms. After a 400–800ms blank period, A's choice was marked with a red square and lasted for 1500ms. Then, the participant chose one item in the remaining three in 3000ms. After this, the participant was asked about the trust level of player A "How much do you trust Player A" (Rating on a 1–9 scale: 1 = extremely distrust, 9 = extremely trust).

Psychomotor Vigilance Test

The Psychomotor Vigilance Test (PVT) is a sensitive measure of sustained attention and alertness under sleep loss.[35] We used a ten-minute standard PVT based on Matlab in this study. During the test, participants were asked to focus on a red rectangular box in the middle of the computer screen and press a button as fast as possible once the box turned yellow. The inter-stimulus interval was random, ranging from 2 to 10 seconds. The yellow box lasted at most 10 seconds, and the reaction time appeared on the screen as feedback for each trial. Reaction times longer than 500 ms were recorded as a lapse in performance. The reaction times, response speed, and lapse number were used to test objective alertness.

Karolinska Sleepiness Scale

Karolinska Sleepiness Scale (KSS) is often used to report instantaneous sleepiness.[34] Permission to employ the KSS in this study was obtained in advance. The KSS is a 1-item visual analogue scale. The 9-point KSS was used in this study: 1 = very alert, 3 = alert, 5 = neither alert nor sleepy, 7 = sleepy (but not fighting sleep), 9 = very sleepy (fighting sleep). The KSS was utilized to assess subjective alertness.

Data Analysis

Behavior and demographic data were analyzed using the Statistical Package for the Social Sciences (SPSS, version 25.0). The Shapiro–Wilk test was used to test the normal distribution of all data. A two-way repeated measures ANOVA was conducted to analyze the difference in trust scores between sleep state and social scenarios. To further explain the influence of sleep state and social scenarios, we employed a simple effect analysis. The difference in reaction times (RT), response speed, lapse number, and KSS scores between normal sleep and sleep deprivation were assessed using the paired *t*-test or Wilcoxon matched-pairs signed rank test (if the normal distribution is rejected). Additionally, we examined the association between RT, response speed, lapse number, KSS, and trust scores. Spearman correlation was used for data that did not fit the normal distribution, and Pearson correlation was used for the rest. To account for multiple comparisons, we applied the Bonferroni correction. Specifically, we calculated the differences in trust scores, RT, response speed, lapse number, and KSS between SD and NS in both kindness and unkindness scenarios. Trust scores in kindness and unkindness scenarios were adjusted by subtracting the baseline (control trials in social mindfulness paradigm, displayed the color of the item in a 2:2 ratio, see Figure 2A) scores, respectively, to obtain the final trust scores in these scenarios.

Results

Sleep Deprivation Decreases Interpersonal Trust in Unkind Scenarios

The results showed a main effect of the social scenarios, F (2, 96) = 28.263, $p < 0.001$, $\eta_p^2 = 0.386$, and no main effect of sleep state, F (2,98) = 0.039, $p < 0.845$, $\eta_p^2 = 0.001$. Interpersonal trust scores in the kindness scenarios were significantly higher than in the unkindness scenarios, indicating that kind and unkind intentions could be distinguished under both sleep states. Importantly, we found a significant interaction between the sleep state and social scenarios, F (2, 96) = 6.078, $p = 0.018$, $\eta_p^2 = 0.119$. Post hoc analysis revealed that under the unkindness scenarios, participants showed significantly lower trust scores in the SD condition (M ± SD = −0.883 ± 1.005), compared to the NS condition (M ± SD = −0.59 ± 0.901; $p = 0.042$, Bonferroni corrected). In contrast, there was no significant difference in trust scores between SD (M ± SD = 0.333 ± 0.702) and NS (M ± SD = 0.269 ± 0.748) under the kindness scenarios (see Figure 3). There was no significant difference in interpersonal trust scores between NS and SD (NS: M ± SD = 5.010 ± 0.837; SD: M ± SD = 5.107 ± 1.009; $p = 0.441$) in the control condition.

Changes in Interpersonal Trust Were Not Associated with Alertness

The KSS, reaction time, response speed and lapse number of the PVT did not fit the normal distribution. Wilcoxon matched-pairs signed rank test on these factors revealed significant differences between NS and SD (see Table 1). Specifically, compared with normal sleep, participants displayed higher KSS scores ($Z = -6.132$, $p < 0.001$, Figure 4a),

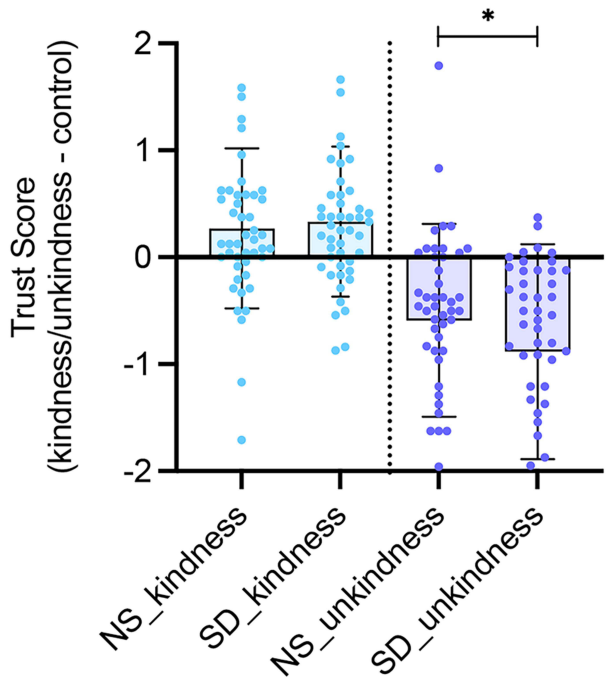

Figure 3 Trust score for kindness and unkindness scenarios under normal sleep and sleep deprivation conditions.
Note: *$p < 0.05$.
Abbreviations: NS represents normal sleep; SD represents sleep deprivation.

longer reaction time (Z = −6.063, $p < 0.001$, Figure 4b), response speed (Z = −6.063, $p < 0.001$, Figure 4c) and more lapses (Z = −6.044, $p < 0.001$, Figure 4d) after sleep deprivation.

To further explore the relationship between sleep deprivation and interpersonal trust, Spearman correlation analysis and Pearson correlation analysis were conducted. In the kindness scenarios, the analyses did not reveal any significant associations between differences in interpersonal trust scores and differences in reaction times ($r = 0.192$, $p = 0.207$, Spearman correlation), response speed ($r = -0.234$, $p = 0.121$, Pearson correlation), lapse number ($r = 0.238$, $p = 0.115$, Pearson correlation), and KSS ($r = 0.193$, $p = 0.205$, Spearman correlation). Similarly, in the unkindness scenarios, the difference in interpersonal trust scores was not significantly related to differences in reaction times ($r = 0.165$, $p = 0.280$, Spearman correlation), response speed ($r = -0.218$, $p = 0.151$, Spearman correlation), lapse number ($r = 0.079$, $p = 0.604$, Spearman correlation), and KSS ($r = 0.096$, $p = 0.532$, Spearman correlation).

Table 1 The Result of Wilcoxon Matched-Pairs Signed Rank Test Between NS and SD Conditions (n = 49)

Measures	NS	SD	*Z*
KSS	4.829 ± 1.340	8.148 ± 0.806	−6.132***
Reaction time (ms)	348.494 ± 41.865	760.306 ± 363.044	−6.063***
Response speed	0.029 ± 0.003	0.002 ±0.001	−6.063***
Lapses number	3.787 ± 4.413	24.489 ± 11.846	−6.044***

Note: ***$p < 0.001$.
Abbreviations: NS represents normal sleep; SD represents sleep deprivation; KSS represents the Karolinska Sleepiness Scale.

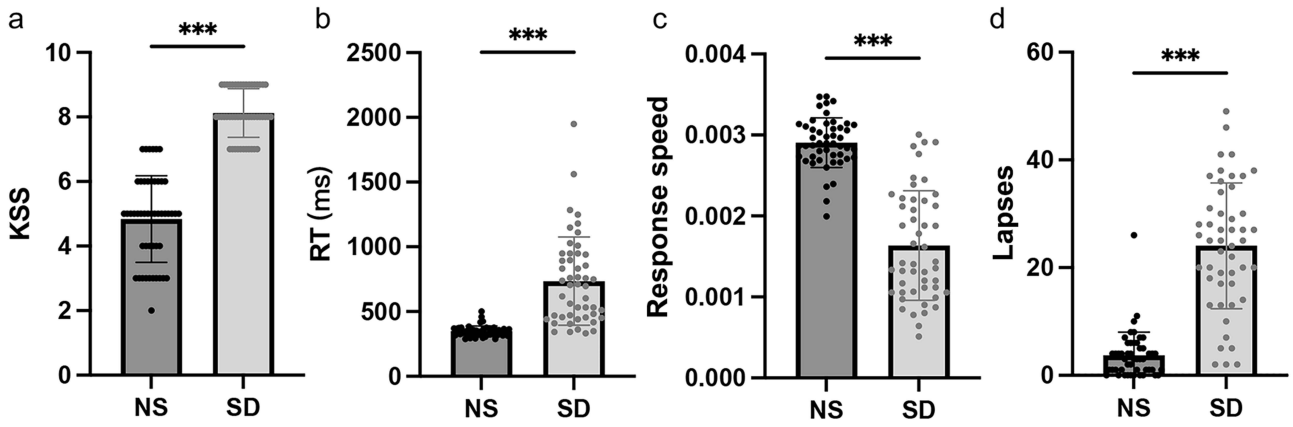

Figure 4 Wilcoxon matched-pairs signed rank test results of KSS (**a**), RT (**b**), Response speed (**c**), Lapses (**d**).
Note: ***$p < 0.001$.
Abbreviations: NS represents normal sleep; SD represents sleep deprivation.

Discussion

The present study investigated the impact of sleep deprivation on interpersonal trust across scenarios characterized by kindness and unkindness. In line with our hypothesis, the findings indicated that sleep deprivation significantly decreases interpersonal trust in unkindness scenarios but not in kindness scenarios. This differential impact highlights the complex relationship between sleep deprivation and interpersonal trust, particularly in how individuals interpret and respond to different behaviors after sleep deprivation.

Inconsistent with our hypothesis, the reduced alertness does not account for decreased interpersonal trust after sleep deprivation. Other factors might be related to the decreased trust. One key factor is reduced cognitive resources following sleep deprivation, which results in an increased tendency towards automated processing.[37,38] This shift can be attributed to the brain's prioritization of efficiency over accuracy when cognitive resources are limited.[39] Automatic processing is a rapid, low-resource form of cognitive processing that draws upon past experiences, stereotypes, and preexisting cognitive frameworks.[40] Furthermore, individuals with sufficient rest also processed negative information more automatically than positive information. This may be attributed to the fact that negative information has higher survival relevance, and the brain has evolved to rapidly process such information through automated processing to respond appropriately.[41] Combining the tendency to process negative information automatically and the heightened reliance on automatic processing after sleep deprivation, the reduction in cognitive resources further exacerbates this tendency towards the automatic processing of negative information. The theory of mind network requires cognitive resources to integrate social cues and accurately infer the intentions behind other's behavior.[42] Moreover, the ability of the theory of mind is associated with the comprehension of others' intentions,[43] and is reduced after sleep deprivation.[4] This reduction weakens empathy and impairs the ability to make deliberate judgments about others' intentions. Consequently, sleep deprivation impacts interpersonal trust in unkind scenarios, where individuals automatically process unkind intentions without sufficient cognitive resources to engage in more deliberate judgments.

Another possible contributing factor to the decline in interpersonal trust is the increased attentional bias and heightened sensitivity to negative stimuli following sleep deprivation. Individuals after sleep deprivation are more likely to focus on negative stimuli while decreasing attention to positive stimuli.[44,45] However, attentional bias alone does not fully account for the decline in interpersonal trust. Sleep deprivation also increases sensitivity to negative social stimuli like threatening facial expressions.[28,29] This sensitivity is characterized by stronger responses to negative stimuli and the amplified perception of negative stimuli. Research has shown that individuals after sleep deprivation not only focus more on negative stimuli but also exhibit reduced accuracy in stimuli discrimination, particularly when interpreting subtle stimuli variations.[46,47] This decline in discrimination further impairs threat detection, as sleep deprivation reduces the ability to distinguish between affiliative and threatening facial expressions, resulting in heightened threat perception.[28,29,48] This phenomenon is observed in individuals experiencing total sleep deprivation

and those with partial or chronic sleep restriction.[49,50] Furthermore, individuals after sleep deprivation exhibit lower thresholds for negative stimuli and respond more intensely.[30] These combined effects of attentional bias and increased sensitivity to negative stimuli following sleep deprivation might help to explain the decreases in interpersonal trust in unkindness scenarios after sleep deprivation.

Interpersonal trust only decreased in unkind scenarios following sleep deprivation, which aligned with evolutionary models that enhanced negative stimuli perception rather than positive ones.[51] This phenomenon may be associated with different neural basis when processing positive and negative stimuli. The perception of positive stimuli recruits the reward system, including the prefrontal cortex, the ventral striatum, and the temporoparietal junction.[52,53] Activity in the reward system increases after sleep deprivation, which might help to perceive positive stimuli. Conversely, perceiving negative stimuli relies on subcortical threat-detection systems (amygdala, anterior insula).[54] Increased amygdala activation after sleep loss might result in heightened perception of negative stimuli.

Clinical and Real-World Implications

This study reveals that sleep deprivation selectively impairs trust in negative social scenarios. It highlights the close relationship between sleep and social function, which hints at considering adaptive changes in patients' social function when treating sleep disorders. The present study used an acute sleep deprivation model; however, the findings can be extrapolated to populations experiencing chronic sleep deprivation, such as shift workers and adolescents. The disruption of sleep rhythm over time may lead to adverse effects on processing social information, resulting in maladaptive behaviors. Our findings suggest that improving sleep quality may provide a new intervention to improve social adjustment.

Limitations and Future Directions

This study demonstrated that interpersonal trust in unkind scenarios significantly decreased after sleep deprivation, but the results should be considered in the context of several limitations. First, the age range of the sample was focused on healthy young people. Future studies might need to generalize the present findings with other people having more social experience. Second, the decrease in interpersonal trust might be caused by sleep deprivation amplifying the perception of unkind intentions, but the underlying mechanisms were still unclear. Moreover, the increased automated processing might be one reason the perception of unkind intentions was amplified after sleep deprivation. In addition, changes in emotion between normal sleep and sleep deprivation may account for decreased interpersonal trust, as studies suggest that sleep deprivation increases the activity of the amygdala,[54,55] which need further exploration. Thus, further research could incorporate brain imaging techniques to explore the association of other cognitive and affective factors (eg, emotion and cognitive control) with interpersonal trust after sleep loss.

Conclusion

Overall, the study demonstrated that sleep deprivation selectively affected interpersonal trust in kind and unkind scenarios. Specifically, there was a significant decrease in interpersonal trust when people perceived unkind intentions after sleep deprivation, but no significant change in interpersonal trust in kind scenarios. The current results also revealed that reduced alertness was not associated with the change in interpersonal trust. This finding suggests that factors other than alertness might mediate the relationship between sleep deprivation and interpersonal trust. Future research could investigate other cognitive and affective factors with the alterations of interpersonal trust after sleep loss using brain imaging techniques.

Data Sharing Statement

Data will be provided upon reasonable request from the corresponding author.

Ethics Statement

All participants provided written informed consent to take part in the study. This study was conducted in accordance with the Declaration of Helsinki and approved by the Medical Ethical Committee of the South China Normal University (of the principal investigator N.M., Approval No. SCNU-PSY-2021-215).

Author Contributions

Wenwei Zhu: investigation, formal analysis, writing – original draft, writing – review and editing. Tianxiang Jiang: investigation, formal analysis, writing – review and editing; Yixuan Cao: investigation, writing – review and editing. Ning Ma: conceptualization, funding acquisition, resources; writing-review and editing, supervision. All authors had full access to all data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis. All authors agreed on the journal to which the article will be submitted, reviewed and agreed on all versions of the article before submission, during revision, the final version accepted for publication, and any significant changes introduced at the proofing stage, agreed to take responsibility and be accountable for the contents of the article.

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Disclosure

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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