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The effect of five nights of sleep restriction on empathic propensity

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The authors declare that they have no conflict of interest.

Author contributions

Giulia Amicucci: Methodology, Investigation, Writing – original draft, Writing – review & editing. **Daniela Tempesta:** Conceptualization, Methodology, Supervision, Data curation, Writing – review & editing. **Federico Salfi**: Data curation, Formal analysis, Writing – review & editing. **Aurora D'Atri:** Writing – review & editing. **Lorenzo Viselli:** Investigation. **Luigi De Gennaro:** Writing – review & editing. **Michele Ferrara**: Conceptualization, Methodology, Supervision, Writing – review & editing.

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Abstract

Literature supports the existence of a significant relationship between sleep quality/quantity and empathy. However, empathic ability and empathic propensity are distinct constructs. Expression of empathic propensity depends on the subjective cognitive costs attributed to the empathic experience. Studies on the effects of the experimental reduction in sleep duration on empathic behavior are still lacking. Therefore, we investigated the consequences of five consecutive nights of sleep restriction on empathic propensity.

Forty-two university students (mean age ± SEM, 24.09 ± 0.65 years; 22 females) underwent a crossover design consisting of five consecutive nights of regular sleep and five consecutive nights of sleep restriction with a maximum of five hours of sleep per night. After each condition, all participants were evaluated using the Empathy Selection Task, a new test assessing the motivated avoidance of empathy for its associated cognitive costs.

The results showed different effects of sleep restriction depending on the habitual way of responding in the empathic context. Participants with baseline high levels of empathic propensity, reduced their empathic propensity after prolonged sleep restriction. Differently, subjects who tended to avoid empathizing already in the habitual sleep condition maintained their empathic behavior unchanged after sleep curtailment.

In conclusion, inter-individual variability should be taken into account when evaluating the effects of sleep restriction on empathic propensity. People with habitual higher tendency to empathize could choose to avoid empathic experience following several consecutive nights of inadequate sleep.

Keywords: sleep loss, empathy, individual differences, cognitive cost

Introduction

An ever-growing body of literature suggests that lack of sleep undermines the ability to process emotional information (for a review, Tempesta, Socci, De Gennaro, & Ferrara, 2018). Besides negatively impacting the encoding and consolidation of emotional information (Kaida, Niki, & Born, 2015; Tempesta, De Gennaro, Presaghi, & Ferrara, 2014, Tempesta, De Gennaro, Natale, & Ferrara, 2015; Tempesta et al., 2016), sleep loss affects mood (Rosen, Gimotty, Shea, & Bellini, 2006) and affective evaluation, modulating emotional reactivity. Indeed, an inadequate amount of sleep seems to cause a negative bias in the categorization of emotionally neutral stimuli, inducing a greater emotional reaction to them (Tempesta et al., 2010, Tempesta et al., 2015; Tempesta, Salfi, De Gennaro, & Ferrara, 2020), as well as increased attention to stimuli with negative valence (Tempesta et al., 2018).

Moreover, sleep deprivation impacts the ability to recognize and classify the emotions of others (Tempesta et al., 2010), selectively impairing the accuracy in judging human facial emotions (van der Helm, Gujar, & Walker, 2010).

The correct processing of emotional stimuli is a fundamental component of human empathy. Human beings are highly social creatures, and empathy represents an essential prerequisite for effective interpersonal interactions. Empathy can be defined as the individual's ability to understand another person's mental state in terms of emotions, feelings, and thoughts (Shamay-Tsoory, 2011). A recent two-dimensional conceptualization of empathy distinguishes an emotional and a cognitive component (Shamay-Tsoory, 2011). Emotional empathy refers to the capacity to experience affective reactions to others' experiences or share someone else's emotions to understand them. Cognitive empathy refers to the ability of adopting another's psychological point of view, a cognitive role-taking ability. Nowadays, a few studies have investigated the relationship between sleep and empathy (e.g., Gordon,

& Chen, 2013, Guadagni, Burles, Ferrara, & Iaria, 2014; Guadagni et al., 2017; Killgore et al., 2008), suggesting that sleep loss impacts complex emotional processes, such as those involved in empathy. In particular, fifty-five hours of sleep deprivation were associated with a decline in emotional intelligence, with significant reductions in intrapersonal functioning (reduced self-regard, assertiveness, sense of independence and self-realization), interpersonal functioning (reduced empathy towards others and reduced quality of interpersonal relationships), and stress management skills (Killgore et al., 2008). Furthermore, poor sleep quality was linked with reduced empathic capacity in young couples engaged in a conflictual conversation, through a reduction in the ability to infer their partner's emotions (Gordon, & Chen, 2013). Finally, other studies have shown that lack of sleep impairs the ability to share the emotional state of others (Guadagni et al., 2014), supporting the assumption that sleep quality is an important predictor of empathic abilities (Guadagni et al., 2017). Although limited in number, these studies showed that sleep loss has detrimental effects on the ability to understand the feelings of others and, therefore, it impairs the ability to be empathetic towards others.

However, a growing body of literature reported a dissociation between the constructs of empathic ability and empathic propensity (e.g. Keysers, & Gazzola, 2014). Empathic ability represents the maximum level of empathy that individuals exhibit in optimal conditions, while empathic propensity is the spontaneous individual tendency to empathize with others according to the context (Keysers, & Gazzola, 2014). The latter is strongly situation-dependent: according to the subjective value given to the context, people can exhibit high or low levels of empathic propensity.

Therefore, the choice to share others' emotional experience will depend on the cognitive costs attributed to the action and on the cost of other available courses of action (Cameron et al., 2019). The cost associated with experience sharing depends on the individual's goal, the object's features (race, sex, and identifiability) and the individual's relationship with the object (Keysers, & Gazzola, 2014). For example, people will tend to avoid empathy, due to its high self-perceived cognitive cost, when it is necessary to negotiate with an antagonist or to punish people who engage in exploitation, but also when the situation simply requires empathizing with strangers (Cameron et al., 2019). Therefore, two individuals with the same empathic abilities in normal conditions may show a different degree of empathic propensity in situations that discourage sharing the experience of others (Keysers, & Gazzola, 2014).

Since the current literature on the relationship between sleep deprivation and empathy has been limited to the assessment of empathic ability, it seems necessary to extend the investigation to the empathic propensity construct.

Sleep restriction is a condition that occurs in people's daily lives more often than total sleep deprivation. Guadagni and coworkers (2017) showed that the ability to be empathic towards others is influenced by total sleep time. However, there is still no empirical evidence on the consequences of the experimental reduction of the nocturnal sleep duration on empathic behavior.

Based on these separate lines of evidence, in the present study we investigated the effects of five consecutive nights of sleep restriction (five hours of sleep per night) on empathic propensity assessed by the Empathy Selection Task (EST; Cameron et al., 2019). The EST is a free-choice task that evaluates motivated avoidance of empathy taking into account the selection of the situation (Gross, & Thompson, 2007), an emotion regulation strategy commonly applied in contexts of motivated empathy (Cameron et al., 2019). This task measures empathic propensity based on the theoretical assumption that people tend to avoid an empathic experience because it often requires excessive cognitive effort (Cameron et al., 2019). Previous studies have already demonstrated that lack of sleep is accompanied by an increase in self-perceived cognitive effort, making the maintenance of performance increasingly challenging (e.g., Massar, Lim, & Huettel, 2019). Here we hypothesized that five nights of sleep restriction would affect empathic propensity, leading to an increase of empathy avoidance.

Participants and Methods

Forty-five subjects were selected from a population of university students (mean age ± SEM, 24.17 ± 0.60 yr; 24 females). Each participant filled out the Italian version of Pittsburgh Sleep Quality Index (PSQI; Curcio et al., 2013), the Insomnia Severity Index (ISI; Castronovo et al., 2016), the State-Trait Anxiety Inventory (STAI-T; Moroni et al., 2006) and the Beck Depression Inventory (BDI-II; Ghisi, Flebus, Montano, Sanavio, & Sica, 2006), to evaluate the presence of sleep disorders, insomnia, and anxiety or mood disorders. Inclusion criteria were: a score < 6 for the PSQI (group mean ± SEM, 3.69 ± 0.23), a score < 7 for the ISI (3.38 ± 0.41), a score < 41 for the STAI-T (33.86 ± 1.00) and a score < 14 for the BDI-II (5.67 ± 0.67). Additionally, we asked participants to complete a questionnaire about their habits on daily consumption of coffee, chocolate, cigarettes, stimulating drinks, alcohol, and drugs. All subjects declared to have habitual sleep duration of seven-eight hours per night and did not usually have daytime naps. Three subjects did not adhere to sleep restriction protocol and were, therefore, excluded from all analyses. The final group of participants included forty-two subjects (mean age ± SEM, 24.09 ± 0.65 yr; 22 females). The experiment has been approved by the Institutional Review Board of the University of L'Aquila (prot. 54464) and carried out according to the principles established by the Declaration of Helsinki. Written informed consent was obtained from all participants. The study belongs to a larger research project, part of which has already been published elsewhere (Tempesta et al., 2020).

Experimental Protocol

The experimental protocol consisted of a cross-over design involving two conditions during two consecutive weeks in counterbalanced order. In the habitual sleep (HS) condition, the subjects were allowed to sleep at home for five consecutive nights (from Sunday to Thursday) according to their sleep habits. In the restricted sleep (RS) condition, participants were required to sleep at home for a maximum of five hours per night, for five consecutive nights (from Sunday to Thursday). In the RS condition, participants went to bed approximately at 2:00 a.m. and woke up at about 7:00 a.m. Daytime naps were prohibited throughout the entire experimental protocol. Compliance was assessed through actigraphy (see below).

In both the conditions, participants were monitored by one experimenter through telephone calls and text messages, sent at unpredictable times of the day. In addition each subject had to text the experimenter about the moment she/he went to bed, woke up and got out of bed. For the entire duration of both experimental weeks, all participants completed a sleep diary. To check the participants' adherence to the experimental protocol, an expert monitored all the actigraphic recordings (see "Sleep assessment" paragraph) to verify the reliability of falling asleep and awakening times declared by the participants in the sleep diaries and text messages.

The testing phase was carried out at the Laboratory of Sleep Psychophysiology and Cognitive Neurosciences, Department of Biotechnological and Applied Clinical Sciences of the University of L'Aquila, on the Friday morning of both weeks (9:00 – 10.00 a.m.). Subjects were requested not to smoke or eat during at least the thirty minutes prior each testing phase and not to increase their habitual consumption of caffeine, activating beverages, alcohol, medications, and cigarette throughout the experimental protocol.

Sleep Assessment

The participants filled out a sleep diary to report their subjective sleep duration and sleep quality each morning of the two consecutive experimental weeks.

Moreover, to obtain an objective assessment of sleep and to control participants' compliance with the experimental protocol, all subjects wore a Geneactiv accelerometer (ActivInsights Ltd., Kimbolton, UK) on the wrist of the non-dominant hand for the entire duration of both the experimental conditions.

The Geneactiv accelerometer is a reliable tool for evaluating sleep in adults (te Lindert, & Van Someren, 2013). Devices were initialized by the Geneactiv PC software (version 3.2, ActivIn-sights Ltd., Kimbolton, UK) with measurement frequency set to 50 Hz. Geneactiv data were uploaded to the computer using the same software. Calculation of the sleep parameters was performed offline using a custom-written MATLAB program with a graphical user interface (version 2018a, The MathWorks, Inc., Natick, Massachusetts, USA), obtained directly from the authors (te Lindert, & Van Someren, 2013). This program represents a validated method to transform accelerometry data into the traditional actigraphic movement counts.

For the five nights of each experimental condition, three variables were obtained by the Geneactiv data, with the support of sleep diaries: total sleep time (TST), sleep efficiency (SE%) and wake after sleep onset (WASO).

Testing phase

Subjective sleepiness, mood and alertness measures

To assess subjective sleepiness, alertness and mood, participants underwent a computerized version of the Karolinska Sleepiness Scale (KSS; Akerstedt, & Gillberg, 1990) and of the Visual Analogue Scale (VAS; Stern, Arruda, Hooper, Wolfner, & Morey, 1997) at the beginning of each testing phase.

The KSS requires to indicate the perceived sleepiness on a scale ranging from 1 (very alert) to 9 (very sleepy).

The VAS requires to self-evaluate one's current status for eight dimensions: happiness, sadness, tension, calmness, irritability, tiredness, energy and concentration. Each participant had to indicate how he/she felt in that moment by left-clicking the mouse on a 200 mm long line that appears on the computer screen, between the extremes of "not at all" and "very much". The values obtained from the typed pixels were transformed into a scale of values from 0 to 10. We calculated two indices: the Negative Mood Index (NMI) and the Alertness Index (AI). NMI (range 0-50) was obtained by summing the scores for the items sad, tense, irritable, and happy and calm (reverse scored). Similarly, AI (range: 0-30) was obtained by summing the scores for the items tired (reverse scored), energetic and concentrated.

Empathy Selection Task

For the evaluation of empathic propensity, the participants underwent the EST (Cameron et al., 2019), a free-choice task that was developed to examine how the cognitive costs associated with sharing experiences can lead to motivated avoidance of empathy. It was shown that the EST effectively measures the avoidance of empathy for the cognitive costs associated with it: people often consider empathy cognitively tiring, classifying it as more demanding, aversive and ineffective compared with other actions (Cameron et al., 2019). The rationale behind the task lies in the fact that people choose situations to enter into by analyzing the expected costs and benefits through a strategy of emotional regulation (Gross & Thompson, 2007).

In the present study, we adopted the first of eleven similar tasks presented by Cameron and coworkers (2019), to investigate how the willingness to empathize of participants changes according to the contextual characteristics imposed by the experimental protocol (HS, RS).

The test used here has some slight variations from the original one. First, in Cameron and collaborators' study (Cameron et al., 2019), the images used depict faces of refugee children; on the contrary, in this study the images, half collected online and half by the International Affective Pictures System (IAPS; Bradley, & Lang, 2007), portray ordinary faces of children. Secondly, the images shown in the study of Cameron et al. (2019) were forty, while in the present study we used thirty images. Therefore, a total of sixty images were divided into two samples of equal size and composition and were counterbalanced by experimental condition (HS, RS) and by session order.

Furthermore, these images were presented randomly and without repetitions and selected so that, for each test session, fifteen pictures were emotionally positive and fifteen negative. Emotionally positive images depicted faces of laughing children, while negative ones depicted faces of crying children. The task (Figure 1) was programmed using the Superlab 5.0.5 software (Cedrus, San Pedro, California, USA).

Participants were required to complete a series of thirty trials. In each trial, the participants were shown, on the computer screen, two decks of cards with their respective instruction sets: the left red deck, labeled "DESCRIBE" and the right blue deck, labeled "FEEL". The participant had to choose one of the two decks of cards. After each choice, a picture of a person appeared, and the participants were asked to perform one of two different sets of instructions, depending on the previously chosen deck of cards.

If they had chosen the "DESCRIBE" deck, the participants would have to describe, with one sentence, the age and sex of the subject represented in the photo. It was asked to them to be objective and to focus only on the external characteristics and appearance of the person in the image.

If they had chosen the "FEEL" deck, the participants would have to describe, with one sentence, the feelings and inner experiences of the person in the image. Therefore, in this case the participants were asked to empathize with the subject represented describing what that person feels.

Finally, as in the study by Cameron et al. (2019), also in the present study the participants were instructed, for each trial, to freely choose between the two decks of cards, even if this involved preferring one deck over the other. There was no time limit for performing the task, either by making the "DESCRIBE" choice or the "FEEL" choice. The main variable of the task is the number of FEEL choices, reflecting the empathic propensity.

Please insert Figure 1 about here

Data Analysis

To assess the effects of sleep restriction on subjective measures, KSS, NMI and AI scores were submitted to linear mixed model analyses, with conditions (HS vs RS) as within factor.

Likewise, to assess the differences in the amount/quality of sleep between the two experimental conditions, the same analysis was applied to the actigraphic variables (TST, SE%, WASO), comparing the values of the five nights of the two experimental conditions.

To evaluate the effects of five nights of sleep restriction on empathic propensity, the number of FEEL choices was submitted to a linear mixed-model analysis with *condition* as factor

(HS, RS). We also included NMI score as a covariate, to control for the influence of the mood changes following sleep loss.

All the models included a random intercept per participant, taking into account the hypothesized variability of between participant responses and the repeated-measures nature of the data. To better understand and isolate the effects observed in the main analysis, additional analyses were carried out, described in detail in the “Results” section.

For all the analyses, Fisher LSD *post hoc* tests were carried in case of significant effects; the level of significance was always set at $p < 0.05$. The linear mixed model analyses were performed using the lme4 R package (R Core Team, 2018), providing functions for fitting and analyzing mixed models. Models were fitted using REML, and p-values were derived using the Satterthwaite approximation (Luke, 2017). *Post hoc* comparisons were performed using the “emmeans” R package (Length, Singmann, Love, Buerkner, Herve, 2020).

Results

Actigraphic sleep variables

Actigraphic recordings confirmed participants’ compliance with the experimental protocol (TST < 5 h). TST for the sleep restriction condition (mean ± SEM, 265.60 ± 3.44) was significantly lower than the regular sleep condition (419.54 ± 3.44; $F_{1,377} = 1806.40$, $p < 0.001$). Furthermore, actigraphic recordings showed that, following prolonged sleep restriction, SE% increased (HS: 89.39 ± 0.53; RS: 90.61 ± 0.53; $F_{1,377} = 7.23$, $p = 0.01$), while WASO decreased (HS: 29.54 ± 1.39; RS: 14.88 ± 1.39; $F_{1,377} = 291.00$, $p < 0.001$), suggesting an increased homeostatic sleep pressure.

Subjective sleepiness, mood and alertness measures

The analysis of KSS, NMI and AI scores showed significant differences between conditions (KSS: $F_{1,41} = 32.15$, $p < 0.001$; NMI: $F_{1,41} = 19.18$, $p < 0.001$; AI: $F_{1,41.} = 48.72$, $p < 0.001$). After five nights of sleep restriction, participants self-evaluated sleepier (KSS; HS: mean ± SEM, 3.43 ± 0.33; RS: 5.55 ± 0.33), with a higher negative mood (NMI; HS: 12.79 ± 1.28; RS: 18.55 ± 1.28), and less alert (AI; HS: 20.40 ± 0.83; RS: 12.89 ± 0.83).

Empathy Selection Task

The analysis of the number of FEEL choices did not show significant effects of the *condition* (HS, RS) factor ($F_{1,47.86} = 0.73$, $p = 0.40$). The subjects did not differ between the two experimental conditions on the number of describe/feel choices. The mood covariate did not yield a significant effect (NMI: $F_{1,\ 78.62} = 0.29$, $p = 0.59$).

The random intercept was significant (LRT = 7.04, $p = 0.008$), suggesting high variability in the responses across participants regardless of the experimental condition. In the HS condition, some participants showed a greater empathic propensity (higher FEEL choices) and others showed a higher empathic avoidance (higher DESCRIBE choices). To evaluate if the between-subjects variability of responses in normal conditions influenced the effect of sleep restriction, an additional analysis was conducted. We adopted the EST scores of the HS condition as index of participants' habitual empathic propensity and we divided the sample into two sub-groups based on the median score of the FEEL choices variable. We obtained a group that chose to empathize more often and another group that chose to describe more frequently when well-rested. We labeled them as “HighEmp” and “LowEmp”, respectively.

Subsequently, we performed a new linear mixed-model analysis, also including *level of empathic propensity* as a between-subject factor (HighEmp, LowEmp). As expected, this analysis showed a significant main effect for the *level of empathic propensity* factor ($F_{1,39.86} = 31.65$, $p < 0.001$). In particular, *post hoc* comparisons pointed to differences between the two subgroups (HighEmp vs LowEmp) in the choice to feel/describe in both the HS condition (HS; $p < 0.001$) and the RS condition (RS; $p < 0.001$; see Figure 2). The HighEmp subgroup tended to empathize more in both conditions than the LowEmp, which show a greater tendency to describe. The *condition* factor was not significant ($F_{1,47.54} = 0.88$, $p = 0.35$), confirming the analysis on the whole sample. However, the interaction between *condition* (HS, RS) and *level of empathic propensity* factor (HighEmp, LowEmp) was significant ($F_{1,40.25} = 5.03$, $p = 0.03$). Therefore, the prolonged sleep restriction affected the two groups differently. Remarkably, this effect was obtained controlling for the covariate of the NMI score, which was not significant ($F_{1,\ 78.66} = 0.47$, $p = 0.49$). *Post hoc* comparisons (Figure 2) showed that LowEmp subjects did not differ significantly in their choices following sleep restriction ($p = 0.42$). On the other hand, HighEmp participants significantly reduced their empathic propensity following five nights of sleep restriction ($p = 0.03$),

Please insert Figure 2 about here

Finally, a linear mixed model control analysis was carried out, including *condition* and *sex* as two-level factors, their interaction, and NMI as covariate, to evaluate possible sex differences. Again, the *condition* factor and NMI covariate were not significant ($F_{1,\ 46.44} = 0.90$, $p = 0.35$; $F_{1,\ 75.08} = 0.45$, $p = 0.50$; respectively). Moreover, the analysis yielded no significant effect both for *sex* factor ($F_{1,\ 42.13} = 0.43$, $p = 0.52$), and for the interaction between *condition* and *sex* ($F_{1,\ 39.62} = 0.28$, $p = 0.60$).

Discussion

The present study represents the first investigation aimed at evaluating the effects of an experimental reduction of nocturnal sleep duration on empathic propensity, using the first valid tool (EST) that allows to specifically evaluate empathic propensity (Cameron et al., 2019). Results showed that sleep restriction did not affect empathic propensity on the entire sample. However, we highlighted a wide inter-individual variability in the responses exhibited by the participants in the HS condition. This evidence led us to hypothesize that individual differences in empathic propensity might influence the response to sleep restriction. To support this interpretation, we performed an exploratory analysis, assuming that the effect of sleep restriction would differ as a function of the participants' habitual (baseline) empathic propensity. The analyses showed that the protracted sleep reduction led to decreased empathic propensity only in the subgroup who tended to empathize more when well-rested (HighEmp). On the other hand, the participants who empathized less in the HS condition (LowEmp), maintained unchanged their empathic behavior across the two experimental conditions.

Empathic sharing of experience is evolutionarily adaptive because it allows the individual to predict the behavior of others but empathizing with others requires a cost and therefore each individual adapts his own empathic propensity to the situation (Keysers, & Gazzola, 2014). Consequently, empathy represents the result of a motivated behavioral decision (Cameron et al., 2019): when different courses of action are available, people choose to empathize according to the subjective value attributed to the situation (Keysers, & Gazzola, 2014). People could choose to avoid empathic engagement because it requires a temporal, economic or emotional cost (Andreoni, Rao, & Trachtman, 2017, Cameron, & Payne, 2011, Cameron, Harris, & Payne, 2016), but primarily a cognitive cost (Cameron et al., 2019).

Empathic avoidance could then be the consequence of a calculation of the general cognitive effort applied to empathic experience (Kool, McGuire, Rosen, & Botvinick, 2010; Westbrook, Kester, & Braver, 2013). The task used in the present study, EST, was modeled on previous effort avoidance tasks (Kool et al., 2010) and its outcome was correlated with an assessment of cognitive costs through an adapted version of NASA's Task Load Index (Cameron et al., 2019).

In this view, we can hypothesize that the "LowEmp" subgroup showed a low empathic propensity because of its perceived cognitive cost, preferring an alternative course of action. On the other hand, the greater tendency to empathize showed by the "HighEmp" subgroup in the normal sleep condition can occur when there are sufficient social rewards that can offset the perceived costs involved (Cameron et al., 2019). Some people, in fact, see the empathic experience as a strong reward (Inzlicht, Legault, & Teper, 2014), reducing their perception of effort. Even the effort itself can be rewarding (Inzlicht, Shenhav, & Olivola, 2018): people may be willing to share an empathic experience because understanding the others' emotional state can enrich a person to the point of compensating for the costs involved (Cameron et al., 2019). Therefore, the different responses presented by the subgroups in the HS condition of our study could reflect different cost-benefit evaluations.

To date, it is well-known that performance based on self-reported cognitive effort perception can be further affected by suboptimal conditions such as sleep deprivation conditions (Massar et al., 2019). Lack of sleep reduces the availability of energy resources necessary to perform (Engle-Friedman, 2014): an individual perceives the maintenance of performance as more demanding because it is associated with an increase in self-perceived cognitive effort, producing slower and more error-prone activities (Massar et al., 2019). Accordingly, sleep-deprived individuals who are allowed to choose one of several available courses of action freely, will choose to pursue less difficult and demanding activities than individuals who have achieved a regular amount of sleep (Engle-Friedman, 2014). Behaviorally, sleep deprivation would therefore produce an increase in motivated avoidance of empathic experience, favouring less demanding courses of action.

However, those who choose to avoid empathizing under the HS condition (LowEmp) did not significantly change the degree of empathic propensity under sleep restriction. We hypothesize that "LowEmp" exhibited higher self-perceived cognitive effort already in the HS condition, and this possibly prevented sleep restriction to affect their level of empathic propensity further. Consequently, the different levels of empathic propensity normally exhibited by participants in emotional sharing contexts influenced the responses of the two subgroups to the sleep restriction protocol in different ways.

As far as individual differences are concerned, in our study no sex differences emerged in the levels of empathic propensity exhibited among participants within and between experimental conditions. This was unexpected since scientific literature generally identify females as more empathic than males. Notably, the presence of sex differences in empathy is partly attributable to the type of construct investigated. For example, when it comes to emotional empathy, females show higher emotional responsivity, more altruistic behavior, and better emotion recognition abilities than males (Christov-Moore et al., 2014). On the other hand, when it comes to cognitive empathy, females do not seem to show the same obvious advantage over males (Christov-Moore et al., 2014). It is possible that empathic propensity represents one of the dimensions of empathic behavior in which no evident gender differences emerge. Future studies need to investigate in more detail the role of sex in empathic propensity and its interaction with sleep.

Despite the large number of studies aimed at evaluating the relationship between sleep and emotional regulation, few studies have focused on evaluating the relationship between sleep and empathic behavior (Guadagni et al., 2014; Guadagni et al., 2017). These studies have supported the existence of a significant relationship between sleep and empathy. They demonstrated that sleep deprivation significantly reduces the expression of emotional empathy (Guadagni et al., 2014), finding a predictive effect of sleep quality on this construct (Guadagni et al., 2017). The present study adds to this literature by showing that an inadequate amount of sleep affects empathic propensity depending on the habitual individual's way of responding in empathic contexts. Therefore, our data support the hypothesis of a relationship between sleep restriction and inter-individual differences in empathic propensity.

Notably, in the study by Guadagni et al. (2014), one night of sleep deprivation impaired the ability to share the emotional state of others regardless the baseline empathic abilities. Instead in our study, inter-individual differences in empathic propensity and sleep restriction interacted, causing an increased avoidance of the empathic experience only in participants with higher levels of empathic propensity at baseline. It is worth noting that the two studies evaluated different empathic dimensions (emotional ability vs. propensity). Moreover, the different results could be attributed to the type of experimental sleep manipulation performed. Unlike total sleep loss, sleep restriction occurs regularly in everyday life, especially among young people. Therefore, it is conceivable that the impact of a modest and constant loss of sleep on the empathic behavior of young university students will be different from the effect of one night of total sleep deprivation. Recently, Tamm et al. (2017) found a non-uniform effect of sleep restriction on empathic responses for pain across different age groups, with elderly participants exhibiting increased perceived unpleasantness to observed pain compared to younger subjects. These findings suggest that age may interact with sleep restriction in their effect on empathy (Tamm et al., 2017). Future studies should investigate this issue.

Since individual differences may hide the effects of sleep loss, producing misleading conclusions and interpretations, future studies should use preliminary assessments to identify individual differences in empathic propensity (Guadagni et al., 2014). Context characteristics and perceived cognitive demand strongly influence empathic behaviour, they are indeed the elements most directly responsible for the motivated avoidance patterns observed (Kool et al., 2010; Cameron et al., 2019). For this reason future studies could also investigate situational and cognitive aspects imposed by the experimental protocols more specifically. Furthermore, future studies could examine how cognitive effort manifests itself in different contexts (Cameron et al., 2019), testing the association between choices in the EST and choices in other effort tasks. Next, the effect of sleep restriction on these different measures of cognitive control could be investigated.

One of the limitations of this study concerns the reduced experimental control over possible confounding environmental factors due to the absence of a laboratory setting, typical of sleep restriction protocols. However, sleep restriction is a more prevalent condition in today's societies, better reflecting the chronic partial sleep deprivation to which most of the population is subjected in daily life. Furthermore, despite the presence of a control condition confirming the participants' usual amount of sleep (seven hours of sleep per night), it would have been preferable to pre-evaluate participants' habitual sleep at baseline. Another limitation concerns the sample population, composed of young university students. This does not allow a complete generalizability of the results. Finally, another possible limitation concerns the stimuli used in the EST. Under ecological conditions, emotions are elicited by dynamic stimuli (Wicker et al., 2003). However, static images were used in the present study, mostly taken from the IAPS (Bradley, & Lang, 2007). Future studies should use more dynamic stimuli (e.g., Tempesta et al., 2016) to improve the validity of the task.

In conclusion, empathic propensity represents an important dimension of empathic behavior, capable of explaining most of the inter- and intra-individual differences of the construct itself (Keysers, & Gazzola, 2014). Our study suggests that the effects of an inadequate amount of sleep on empathic propensity are a function of the specific response exhibited by an individual in empathic situations at baseline (i.e., when not sleep deprived). In order to distinguish the impact of lack of sleep on empathic propensity and empathic ability, future studies should evaluate both the constructs simultaneously.

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Figure Legends

Figure 1. Typical screen of the Empathy Selection Task (EST).

Participants were asked to choose between the deck labeled "DESCRIBE" or "FEEL" with their respective instructions. Once the choice was made, an image (emotionally positive or negative) appeared, and the participants had to type the answer in the appropriate box presented, respecting the set of instructions associated with each card deck.

Figure 2. Interaction between level of empathic propensity (HighEmp, LowEmp) and experimental condition (Habitual sleep, Restricted Sleep) factors on the mean score of the number of FEEL choices variable. Mean (and standard error) of the number of feel choices in the habitual sleep and sleep restriction condition for the HighEmp and LowEmp groups. Results of *post hoc* comparisons are reported with asterisks: * $p < 0.05$; ** $p < 0.001$.

Abbreviations: HS, Habitual Sleep condition; RS, Restricted Sleep condition

The effect of five nights of sleep restriction on empathic propensity

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The authors declare that they have no conflict of interest.

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Abstract

Literature supports the existence of a significant relationship between sleep quality/quantity and empathy. However, empathic ability and empathic propensity are distinct constructs. Expression of empathic propensity depends on the subjective cognitive costs attributed to the empathic experience. Studies on the effects of the experimental reduction in sleep duration on empathic behavior are still lacking. Therefore, we investigated the consequences of five consecutive nights of sleep restriction on empathic propensity.

Forty-two university students (mean age ± SEM, 24.09 ± 0.65 years; 22 females) underwent a crossover design consisting of five consecutive nights of regular sleep and five consecutive nights of sleep restriction with a maximum of five hours of sleep per night. After each condition, all participants were evaluated using the Empathy Selection Task, a new test assessing the motivated avoidance of empathy for its associated cognitive costs.

The results showed different effects of sleep restriction depending on the habitual way of responding in the empathic context. Participants with baseline high levels of empathic propensity, reduced their empathic propensity after prolonged sleep restriction. Differently, subjects who tended to avoid empathizing already in the habitual sleep condition maintained their empathic behavior unchanged after sleep curtailment.

In conclusion, inter-individual variability should be taken into account when evaluating the effects of sleep restriction on empathic propensity. People with habitual higher tendency to empathize could choose to avoid empathic experience following several consecutive nights of inadequate sleep.

Keywords: sleep loss, empathy, individual differences, cognitive cost

Introduction

An ever-growing body of literature suggests that lack of sleep undermines the ability to process emotional information (for a review, Tempesta, Socci, De Gennaro, & Ferrara, 2018). Besides negatively impacting the encoding and consolidation of emotional information (Kaida, Niki, & Born, 2015; Tempesta, De Gennaro, Presaghi, & Ferrara, 2014, Tempesta, De Gennaro, Natale, & Ferrara, 2015; Tempesta et al., 2016), sleep loss affects mood (Rosen, Gimotty, Shea, & Bellini, 2006) and affective evaluation, modulating emotional reactivity. Indeed, an inadequate amount of sleep seems to cause a negative bias in the categorization of emotionally neutral stimuli, inducing a greater emotional reaction to them (Tempesta et al., 2010, Tempesta et al., 2015; Tempesta, Salfi, De Gennaro, & Ferrara, 2020), as well as increased attention to stimuli with negative valence (Tempesta et al., 2018).

Moreover, sleep deprivation impacts the ability to recognize and classify the emotions of others (Tempesta et al., 2010), selectively impairing the accuracy in judging human facial emotions (van der Helm, Gujar, & Walker, 2010).

The correct processing of emotional stimuli is a fundamental component of human empathy. Human beings are highly social creatures, and empathy represents an essential prerequisite for effective interpersonal interactions. Empathy can be defined as the individual's ability to understand another person's mental state in terms of emotions, feelings, and thoughts (Shamay-Tsoory, 2011). A recent two-dimensional conceptualization of empathy distinguishes an emotional and a cognitive component (Shamay-Tsoory, 2011). Emotional empathy refers to the capacity to experience affective reactions to others' experiences or share someone else's emotions to understand them. Cognitive empathy refers to the ability of adopting another's psychological point of view, a cognitive role-taking ability. Nowadays, a few studies have investigated the relationship between sleep and empathy (e.g., Gordon,

& Chen, 2013, Guadagni, Burles, Ferrara, & Iaria, 2014; Guadagni et al., 2017; Killgore et al., 2008), suggesting that sleep loss impacts complex emotional processes, such as those involved in empathy. In particular, fifty-five hours of sleep deprivation were associated with a decline in emotional intelligence, with significant reductions in intrapersonal functioning (reduced self-regard, assertiveness, sense of independence and self-realization), interpersonal functioning (reduced empathy towards others and reduced quality of interpersonal relationships), and stress management skills (Killgore et al., 2008). Furthermore, poor sleep quality was linked with reduced empathic capacity in young couples engaged in a conflictual conversation, through a reduction in the ability to infer their partner's emotions (Gordon, & Chen, 2013). Finally, other studies have shown that lack of sleep impairs the ability to share the emotional state of others (Guadagni et al., 2014), supporting the assumption that sleep quality is an important predictor of empathic abilities (Guadagni et al., 2017). Although limited in number, these studies showed that sleep loss has detrimental effects on the ability to understand the feelings of others and, therefore, it impairs the ability to be empathetic towards others.

However, a growing body of literature reported a dissociation between the constructs of empathic ability and empathic propensity (e.g. Keysers, & Gazzola, 2014). Empathic ability represents the maximum level of empathy that individuals exhibit in optimal conditions, while empathic propensity is the spontaneous individual tendency to empathize with others according to the context (Keysers, & Gazzola, 2014). The latter is strongly situation-dependent: according to the subjective value given to the context, people can exhibit high or low levels of empathic propensity.

Therefore, the choice to share others' emotional experience will depend on the cognitive costs attributed to the action and on the cost of other available courses of action (Cameron et al., 2019). The cost associated with experience sharing depends on the individual's goal, the object's features (race, sex, and identifiability) and the individual's relationship with the object (Keysers, & Gazzola, 2014). For example, people will tend to avoid empathy, due to its high self-perceived cognitive cost, when it is necessary to negotiate with an antagonist or to punish people who engage in exploitation, but also when the situation simply requires empathizing with strangers (Cameron et al., 2019). Therefore, two individuals with the same empathic abilities in normal conditions may show a different degree of empathic propensity in situations that discourage sharing the experience of others (Keysers, & Gazzola, 2014).

Since the current literature on the relationship between sleep deprivation and empathy has been limited to the assessment of empathic ability, it seems necessary to extend the investigation to the empathic propensity construct.

Sleep restriction is a condition that occurs in people's daily lives more often than total sleep deprivation. Guadagni and coworkers (2017) showed that the ability to be empathic towards others is influenced by total sleep time. However, there is still no empirical evidence on the consequences of the experimental reduction of the nocturnal sleep duration on empathic behavior.

Based on these separate lines of evidence, in the present study we investigated the effects of five consecutive nights of sleep restriction (five hours of sleep per night) on empathic propensity assessed by the Empathy Selection Task (EST; Cameron et al., 2019). The EST is a free-choice task that evaluates motivated avoidance of empathy taking into account the selection of the situation (Gross, & Thompson, 2007), an emotion regulation strategy commonly applied in contexts of motivated empathy (Cameron et al., 2019). This task measures empathic propensity based on the theoretical assumption that people tend to avoid an empathic experience because it often requires excessive cognitive effort (Cameron et al., 2019). Previous studies have already demonstrated that lack of sleep is accompanied by an increase in self-perceived cognitive effort, making the maintenance of performance increasingly challenging (e.g., Massar, Lim, & Huettel, 2019). Here we hypothesized that five nights of sleep restriction would affect empathic propensity, leading to an increase of empathy avoidance.

Participants and Methods

Forty-five subjects were selected from a population of university students (mean age ± SEM, 24.17 ± 0.60 yr; 24 females). Each participant filled out the Italian version of Pittsburgh Sleep Quality Index (PSQI; Curcio et al., 2013), the Insomnia Severity Index (ISI; Castronovo et al., 2016), the State-Trait Anxiety Inventory (STAI-T; Moroni et al., 2006) and the Beck Depression Inventory (BDI-II; Ghisi, Flebus, Montano, Sanavio, & Sica, 2006), to evaluate the presence of sleep disorders, insomnia, and anxiety or mood disorders. Inclusion criteria were: a score < 6 for the PSQI (group mean ± SEM, 3.69 ± 0.23), a score < 7 for the ISI (3.38 ± 0.41), a score < 41 for the STAI-T (33.86 ± 1.00) and a score < 14 for the BDI-II (5.67 ± 0.67). Additionally, we asked participants to complete a questionnaire about their habits on daily consumption of coffee, chocolate, cigarettes, stimulating drinks, alcohol, and drugs. All subjects declared to have habitual sleep duration of seven-eight hours per night and did not usually have daytime naps. Three subjects did not adhere to sleep restriction protocol and were, therefore, excluded from all analyses. The final group of participants included forty-two subjects (mean age ± SEM, 24.09 ± 0.65 yr; 22 females). The experiment has been approved by the Institutional Review Board of the University of L'Aquila (prot. 54464) and carried out according to the principles established by the Declaration of Helsinki. Written informed consent was obtained from all participants. The study belongs to a larger research project, part of which has already been published elsewhere (Tempesta et al., 2020).

Experimental Protocol

The experimental protocol consisted of a cross-over design involving two conditions during two consecutive weeks in counterbalanced order. In the habitual sleep (HS) condition, the subjects were allowed to sleep at home for five consecutive nights (from Sunday to Thursday) according to their sleep habits. In the restricted sleep (RS) condition, participants were required to sleep at home for a maximum of five hours per night, for five consecutive nights (from Sunday to Thursday). In the RS condition, participants went to bed approximately at 2:00 a.m. and woke up at about 7:00 a.m. Daytime naps were prohibited throughout the entire experimental protocol. Compliance was assessed through actigraphy (see below).

In both the conditions, participants were monitored by one experimenter through telephone calls and text messages, sent at unpredictable times of the day. In addition each subject had to text the experimenter about the moment she/he went to bed, woke up and got out of bed. For the entire duration of both experimental weeks, all participants completed a sleep diary. To check the participants' adherence to the experimental protocol, an expert monitored all the actigraphic recordings (see "Sleep assessment" paragraph) to verify the reliability of falling asleep and awakening times declared by the participants in the sleep diaries and text messages.

The testing phase was carried out at the Laboratory of Sleep Psychophysiology and Cognitive Neurosciences, Department of Biotechnological and Applied Clinical Sciences of the University of L'Aquila, on the Friday morning of both weeks (9:00 – 10.00 a.m.). Subjects were requested not to smoke or eat during at least the thirty minutes prior each testing phase and not to increase their habitual consumption of caffeine, activating beverages, alcohol, medications, and cigarette throughout the experimental protocol.

Sleep Assessment

The participants filled out a sleep diary to report their subjective sleep duration and sleep quality each morning of the two consecutive experimental weeks.

Moreover, to obtain an objective assessment of sleep and to control participants' compliance with the experimental protocol, all subjects wore a Geneactiv accelerometer (ActivInsights Ltd., Kimbolton, UK) on the wrist of the non-dominant hand for the entire duration of both the experimental conditions.

The Geneactiv accelerometer is a reliable tool for evaluating sleep in adults (te Lindert, & Van Someren, 2013). Devices were initialized by the Geneactiv PC software (version 3.2, ActivIn-sights Ltd., Kimbolton, UK) with measurement frequency set to 50 Hz. Geneactiv data were uploaded to the computer using the same software. Calculation of the sleep parameters was performed offline using a custom-written MATLAB program with a graphical user interface (version 2018a, The MathWorks, Inc., Natick, Massachusetts, USA), obtained directly from the authors (te Lindert, & Van Someren, 2013). This program represents a validated method to transform accelerometry data into the traditional actigraphic movement counts.

For the five nights of each experimental condition, three variables were obtained by the Geneactiv data, with the support of sleep diaries: total sleep time (TST), sleep efficiency (SE%) and wake after sleep onset (WASO).

Testing phase

Subjective sleepiness, mood and alertness measures

To assess subjective sleepiness, alertness and mood, participants underwent a computerized version of the Karolinska Sleepiness Scale (KSS; Akerstedt, & Gillberg, 1990) and of the Visual Analogue Scale (VAS; Stern, Arruda, Hooper, Wolfner, & Morey, 1997) at the beginning of each testing phase.

The KSS requires to indicate the perceived sleepiness on a scale ranging from 1 (very alert) to 9 (very sleepy).

The VAS requires to self-evaluate one's current status for eight dimensions: happiness, sadness, tension, calmness, irritability, tiredness, energy and concentration. Each participant had to indicate how he/she felt in that moment by left-clicking the mouse on a 200 mm long line that appears on the computer screen, between the extremes of "not at all" and "very much". The values obtained from the typed pixels were transformed into a scale of values from 0 to 10. We calculated two indices: the Negative Mood Index (NMI) and the Alertness Index (AI). NMI (range 0-50) was obtained by summing the scores for the items sad, tense, irritable, and happy and calm (reverse scored). Similarly, AI (range: 0-30) was obtained by summing the scores for the items tired (reverse scored), energetic and concentrated.

Empathy Selection Task

For the evaluation of empathic propensity, the participants underwent the EST (Cameron et al., 2019), a free-choice task that was developed to examine how the cognitive costs associated with sharing experiences can lead to motivated avoidance of empathy. It was shown that the EST effectively measures the avoidance of empathy for the cognitive costs associated with it: people often consider empathy cognitively tiring, classifying it as more demanding, aversive and ineffective compared with other actions (Cameron et al., 2019). The rationale behind the task lies in the fact that people choose situations to enter into by analyzing the expected costs and benefits through a strategy of emotional regulation (Gross & Thompson, 2007).

In the present study, we adopted the first of eleven similar tasks presented by Cameron and coworkers (2019), to investigate how the willingness to empathize of participants changes according to the contextual characteristics imposed by the experimental protocol (HS, RS).

The test used here has some slight variations from the original one. First, in Cameron and collaborators' study (Cameron et al., 2019), the images used depict faces of refugee children; on the contrary, in this study the images, half collected online and half by the International Affective Pictures System (IAPS; Bradley, & Lang, 2007), portray ordinary faces of children. Secondly, the images shown in the study of Cameron et al. (2019) were forty, while in the present study we used thirty images. Therefore, a total of sixty images were divided into two samples of equal size and composition and were counterbalanced by experimental condition (HS, RS) and by session order.

Furthermore, these images were presented randomly and without repetitions and selected so that, for each test session, fifteen pictures were emotionally positive and fifteen negative. Emotionally positive images depicted faces of laughing children, while negative ones depicted faces of crying children. The task (Figure 1) was programmed using the Superlab 5.0.5 software (Cedrus, San Pedro, California, USA).

Participants were required to complete a series of thirty trials. In each trial, the participants were shown, on the computer screen, two decks of cards with their respective instruction sets: the left red deck, labeled "DESCRIBE" and the right blue deck, labeled "FEEL". The participant had to choose one of the two decks of cards. After each choice, a picture of a person appeared, and the participants were asked to perform one of two different sets of instructions, depending on the previously chosen deck of cards.

If they had chosen the "DESCRIBE" deck, the participants would have to describe, with one sentence, the age and sex of the subject represented in the photo. It was asked to them to be objective and to focus only on the external characteristics and appearance of the person in the image.

If they had chosen the "FEEL" deck, the participants would have to describe, with one sentence, the feelings and inner experiences of the person in the image. Therefore, in this case the participants were asked to empathize with the subject represented describing what that person feels.

Finally, as in the study by Cameron et al. (2019), also in the present study the participants were instructed, for each trial, to freely choose between the two decks of cards, even if this involved preferring one deck over the other. There was no time limit for performing the task, either by making the "DESCRIBE" choice or the "FEEL" choice. The main variable of the task is the number of FEEL choices, reflecting the empathic propensity.

Please insert Figure 1 about here

Data Analysis

To assess the effects of sleep restriction on subjective measures, KSS, NMI and AI scores were submitted to linear mixed model analyses, with conditions (HS vs RS) as within factor.

Likewise, to assess the differences in the amount/quality of sleep between the two experimental conditions, the same analysis was applied to the actigraphic variables (TST, SE%, WASO), comparing the values of the five nights of the two experimental conditions.

To evaluate the effects of five nights of sleep restriction on empathic propensity, the number of FEEL choices was submitted to a linear mixed-model analysis with *condition* as factor

(HS, RS). We also included NMI score as a covariate, to control for the influence of the mood changes following sleep loss.

All the models included a random intercept per participant, taking into account the hypothesized variability of between participant responses and the repeated-measures nature of the data. To better understand and isolate the effects observed in the main analysis, additional analyses were carried out, described in detail in the "Results" section.

For all the analyses, Fisher LSD *post hoc* tests were carried in case of significant effects; the level of significance was always set at $p < 0.05$. The linear mixed model analyses were performed using the lme4 R package (R Core Team, 2018), providing functions for fitting and analyzing mixed models. Models were fitted using REML, and p-values were derived using the Satterthwaite approximation (Luke, 2017). *Post hoc* comparisons were performed using the "emmeans" R package (Length, Singmann, Love, Buerkner, Herve, 2020).

Results

Actigraphic sleep variables

Actigraphic recordings confirmed participants' compliance with the experimental protocol (TST < 5 h). TST for the sleep restriction condition (mean ± SEM, 265.60 ± 3.44) was significantly lower than the regular sleep condition (419.54 ± 3.44; $F_{1,377} = 1806.40$, $p < 0.001$). Furthermore, actigraphic recordings showed that, following prolonged sleep restriction, SE% increased (HS: 89.39 ± 0.53; RS: 90.61 ± 0.53; $F_{1,377} = 7.23$, $p = 0.01$), while WASO decreased (HS: 29.54 ± 1.39; RS: 14.88 ± 1.39; $F_{1,377} = 291.00$, $p < 0.001$), suggesting an increased homeostatic sleep pressure.

Subjective sleepiness, mood and alertness measures

The analysis of KSS, NMI and AI scores showed significant differences between conditions (KSS: $F_{1,41} = 32.15$, $p < 0.001$; NMI: $F_{1,41} = 19.18$, $p < 0.001$; AI: $F_{1,41.} = 48.72$, $p < 0.001$). After five nights of sleep restriction, participants self-evaluated sleepier (KSS; HS: mean ± SEM, 3.43 ± 0.33; RS: 5.55 ± 0.33), with a higher negative mood (NMI; HS: 12.79 ± 1.28; RS: 18.55 ± 1.28), and less alert (AI; HS: 20.40 ± 0.83; RS: 12.89 ± 0.83).

Empathy Selection Task

The analysis of the number of FEEL choices did not show significant effects of the *condition* (HS, RS) factor ($F_{1,47.86} = 0.73$, $p = 0.40$). The subjects did not differ between the two experimental conditions on the number of describe/feel choices. The mood covariate did not yield a significant effect (NMI: $F_{1, 78.62} = 0.29$, $p = 0.59$).

The random intercept was significant (LRT = 7.04, p = 0.008), suggesting high variability in the responses across participants regardless of the experimental condition. In the HS condition, some participants showed a greater empathic propensity (higher FEEL choices) and others showed a higher empathic avoidance (higher DESCRIBE choices). To evaluate if the between-subjects variability of responses in normal conditions influenced the effect of sleep restriction, an additional analysis was conducted. We adopted the EST scores of the HS condition as index of participants' habitual empathic propensity and we divided the sample into two sub-groups based on the median score of the FEEL choices variable. We obtained a group that chose to empathize more often and another group that chose to describe more frequently when well-rested. We labeled them as “HighEmp” and “LowEmp”, respectively.

Subsequently, we performed a new linear mixed-model analysis, also including *level of empathic propensity* as a between-subject factor (HighEmp, LowEmp). As expected, this analysis showed a significant main effect for the *level of empathic propensity* factor ($F_{1,39.86} = 31.65$, $p < 0.001$). In particular, *post hoc* comparisons pointed to differences between the two subgroups (HighEmp vs LowEmp) in the choice to feel/describe in both the HS condition (HS; $p < 0.001$) and the RS condition (RS; $p < 0.001$; see Figure 2). The HighEmp sub-group tended to empathize more in both conditions than the LowEmp, which show a greater tendency to describe. The *condition* factor was not significant ($F_{1,47.54} = 0.88$, $p = 0.35$), confirming the analysis on the whole sample. However, the interaction between *condition* (HS, RS) and *level of empathic propensity* factor (HighEmp, LowEmp) was significant ($F_{1,40.25} = 5.03$, $p = 0.03$). Therefore, the prolonged sleep restriction affected the two groups differently. Remarkably, this effect was obtained controlling for the covariate of the NMI score, which was not significant ($F_{1, 78.66} = 0.47$, $p = 0.49$). *Post hoc* comparisons (Figure 2) showed that LowEmp subjects did not differ significantly in their choices following sleep restriction ($p = 0.42$). On the other hand, HighEmp participants significantly reduced their empathic propensity following five nights of sleep restriction ($p = 0.03$),

Please insert Figure 2 about here

Finally, a linear mixed model control analysis was carried out, including *condition* and *sex* as two-level factors, their interaction, and NMI as covariate, to evaluate possible sex differences. Again, the *condition* factor and NMI covariate were not significant ($F_{1, 46.44} = 0.90$, $p = 0.35$; $F_{1, 75.08} = 0.45$, $p = 0.50$; respectively). Moreover, the analysis yielded no significant effect both for *sex* factor ($F_{1, 42.13} = 0.43$, $p = 0.52$), and for the interaction between *condition* and *sex* ($F_{1, 39.62} = 0.28$, $p = 0.60$).

Discussion

The present study represents the first investigation aimed at evaluating the effects of an experimental reduction of nocturnal sleep duration on empathic propensity, using the first valid tool (EST) that allows to specifically evaluate empathic propensity (Cameron et al., 2019). Results showed that sleep restriction did not affect empathic propensity on the entire sample. However, we highlighted a wide inter-individual variability in the responses exhibited by the participants in the HS condition. This evidence led us to hypothesize that individual differences in empathic propensity might influence the response to sleep restriction. To support this interpretation, we performed an exploratory analysis, assuming that the effect of sleep restriction would differ as a function of the participants' habitual (baseline) empathic propensity. The analyses showed that the protracted sleep reduction led to decreased empathic propensity only in the subgroup who tended to empathize more when well-rested (HighEmp). On the other hand, the participants who empathized less in the HS condition (LowEmp), maintained unchanged their empathic behavior across the two experimental conditions.

Empathic sharing of experience is evolutionarily adaptive because it allows the individual to predict the behavior of others but empathizing with others requires a cost and therefore each individual adapts his own empathic propensity to the situation (Keysers, & Gazzola, 2014). Consequently, empathy represents the result of a motivated behavioral decision (Cameron et al., 2019): when different courses of action are available, people choose to empathize according to the subjective value attributed to the situation (Keysers, & Gazzola, 2014). People could choose to avoid empathic engagement because it requires a temporal, economic or emotional cost (Andreoni, Rao, & Trachtman, 2017, Cameron, & Payne, 2011, Cameron, Harris, & Payne, 2016), but primarily a cognitive cost (Cameron et al., 2019).

Empathic avoidance could then be the consequence of a calculation of the general cognitive effort applied to empathic experience (Kool, McGuire, Rosen, & Botvinick, 2010; Westbrook, Kester, & Braver, 2013). The task used in the present study, EST, was modeled on previous effort avoidance tasks (Kool et al., 2010) and its outcome was correlated with an assessment of cognitive costs through an adapted version of NASA's Task Load Index (Cameron et al., 2019).

In this view, we can hypothesize that the "LowEmp" subgroup showed a low empathic propensity because of its perceived cognitive cost, preferring an alternative course of action. On the other hand, the greater tendency to empathize showed by the "HighEmp" subgroup in the normal sleep condition can occur when there are sufficient social rewards that can offset the perceived costs involved (Cameron et al., 2019). Some people, in fact, see the empathic experience as a strong reward (Inzlicht, Legault, & Teper, 2014), reducing their perception of effort. Even the effort itself can be rewarding (Inzlicht, Shenhav, & Olivola, 2018): people may be willing to share an empathic experience because understanding the others' emotional state can enrich a person to the point of compensating for the costs involved (Cameron et al., 2019). Therefore, the different responses presented by the subgroups in the HS condition of our study could reflect different cost-benefit evaluations.

To date, it is well-known that performance based on self-reported cognitive effort perception can be further affected by suboptimal conditions such as sleep deprivation conditions (Massar et al., 2019). Lack of sleep reduces the availability of energy resources necessary to perform (Engle-Friedman, 2014): an individual perceives the maintenance of performance as more demanding because it is associated with an increase in self-perceived cognitive effort, producing slower and more error-prone activities (Massar et al., 2019). Accordingly, sleep-deprived individuals who are allowed to choose one of several available courses of action freely, will choose to pursue less difficult and demanding activities than individuals who have achieved a regular amount of sleep (Engle-Friedman, 2014). Behaviorally, sleep deprivation would therefore produce an increase in motivated avoidance of empathic experience, favouring less demanding courses of action.

However, those who choose to avoid empathizing under the HS condition (LowEmp) did not significantly change the degree of empathic propensity under sleep restriction. We hypothesize that “LowEmp” exhibited higher self-perceived cognitive effort already in the HS condition, and this possibly prevented sleep restriction to affect their level of empathic propensity further. Consequently, the different levels of empathic propensity normally exhibited by participants in emotional sharing contexts influenced the responses of the two subgroups to the sleep restriction protocol in different ways.

As far as individual differences are concerned, in our study no sex differences emerged in the levels of empathic propensity exhibited among participants within and between experimental conditions. This was unexpected since scientific literature generally identify females as more empathic than males. Notably, the presence of sex differences in empathy is partly attributable to the type of construct investigated. For example, when it comes to emotional empathy, females show higher emotional responsivity, more altruistic behavior, and better emotion recognition abilities than males (Christov-Moore et al., 2014). On the other hand, when it comes to cognitive empathy, females do not seem to show the same obvious advantage over males (Christov-Moore et al., 2014). It is possible that empathic propensity represents one of the dimensions of empathic behavior in which no evident gender differences emerge. Future studies need to investigate in more detail the role of sex in empathic propensity and its interaction with sleep.

Despite the large number of studies aimed at evaluating the relationship between sleep and emotional regulation, few studies have focused on evaluating the relationship between sleep and empathic behavior (Guadagni et al., 2014; Guadagni et al., 2017). These studies have supported the existence of a significant relationship between sleep and empathy. They demonstrated that sleep deprivation significantly reduces the expression of emotional empathy (Guadagni et al., 2014), finding a predictive effect of sleep quality on this construct (Guadagni et al., 2017). The present study adds to this literature by showing that an inadequate amount of sleep affects empathic propensity depending on the habitual individual's way of responding in empathic contexts. Therefore, our data support the hypothesis of a relationship between sleep restriction and inter-individual differences in empathic propensity.

Notably, in the study by Guadagni et al. (2014), one night of sleep deprivation impaired the ability to share the emotional state of others regardless the baseline empathic abilities. Instead in our study, inter-individual differences in empathic propensity and sleep restriction interacted, causing an increased avoidance of the empathic experience only in participants with higher levels of empathic propensity at baseline. It is worth noting that the two studies evaluated different empathic dimensions (emotional ability vs. propensity). Moreover, the different results could be attributed to the type of experimental sleep manipulation performed. Unlike total sleep loss, sleep restriction occurs regularly in everyday life, especially among young people. Therefore, it is conceivable that the impact of a modest and constant loss of sleep on the empathic behavior of young university students will be different from the effect of one night of total sleep deprivation. Recently, Tamm et al. (2017) found a non-uniform effect of sleep restriction on empathic responses for pain across different age groups, with elderly participants exhibiting increased perceived unpleasantness to observed pain compared to younger subjects. These findings suggest that age may interact with sleep restriction in their effect on empathy (Tamm et al., 2017). Future studies should investigate this issue.

Since individual differences may hide the effects of sleep loss, producing misleading conclusions and interpretations, future studies should use preliminary assessments to identify individual differences in empathic propensity (Guadagni et al., 2014). Context characteristics and perceived cognitive demand strongly influence empathic behaviour, they are indeed the elements most directly responsible for the motivated avoidance patterns observed (Kool et al., 2010; Cameron et al., 2019). For this reason future studies could also investigate situational and cognitive aspects imposed by the experimental protocols more specifically. Furthermore, future studies could examine how cognitive effort manifests itself in different contexts (Cameron et al., 2019), testing the association between choices in the EST and choices in other effort tasks. Next, the effect of sleep restriction on these different measures of cognitive control could be investigated.

One of the limitations of this study concerns the reduced experimental control over possible confounding environmental factors due to the absence of a laboratory setting, typical of sleep restriction protocols. However, sleep restriction is a more prevalent condition in today's societies, better reflecting the chronic partial sleep deprivation to which most of the population is subjected in daily life. Furthermore, despite the presence of a control condition confirming the participants' usual amount of sleep (seven hours of sleep per night), it would have been preferable to pre-evaluate participants' habitual sleep at baseline. Another limitation concerns the sample population, composed of young university students. This does not allow a complete generalizability of the results. Finally, another possible limitation concerns the stimuli used in the EST. Under ecological conditions, emotions are elicited by dynamic stimuli (Wicker et al., 2003). However, static images were used in the present study, mostly taken from the IAPS (Bradley, & Lang, 2007). Future studies should use more dynamic stimuli (e.g., Tempesta et al., 2016) to improve the validity of the task.

In conclusion, empathic propensity represents an important dimension of empathic behavior, capable of explaining most of the inter- and intra-individual differences of the construct itself (Keysers, & Gazzola, 2014). Our study suggests that the effects of an inadequate amount of sleep on empathic propensity are a function of the specific response exhibited by an individual in empathic situations at baseline (i.e., when not sleep deprived). In order to distinguish the impact of lack of sleep on empathic propensity and empathic ability, future studies should evaluate both the constructs simultaneously.

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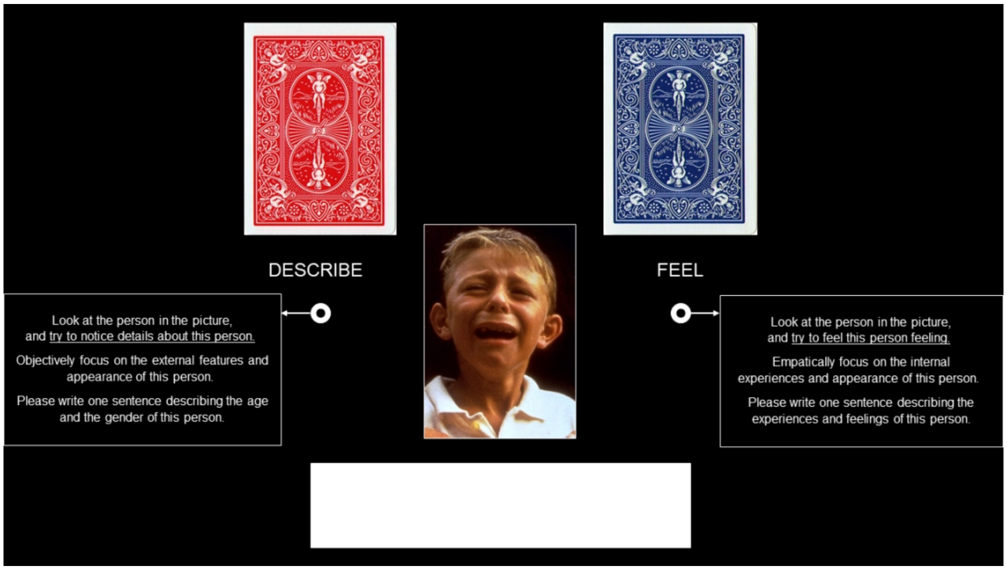
Figure Legends

Figure 1. Typical screen of the Empathy Selection Task (EST).

Participants were asked to choose between the deck labeled "DESCRIBE" or "FEEL" with their respective instructions. Once the choice was made, an image (emotionally positive or negative) appeared, and the participants had to type the answer in the appropriate box presented, respecting the set of instructions associated with each card deck.

Figure 2. Interaction between level of empathic propensity (HighEmp, LowEmp) and experimental condition (Habitual sleep, Restricted Sleep) factors on the mean score of the number of FEEL choices variable. Mean (and standard error) of the number of feel choices in the habitual sleep and sleep restriction condition for the HighEmp and LowEmp groups. Results of *post hoc* comparisons are reported with asterisks: * $p < 0.05$; ** $p < 0.001$.

Abbreviations: HS, Habitual Sleep condition; RS, Restricted Sleep condition



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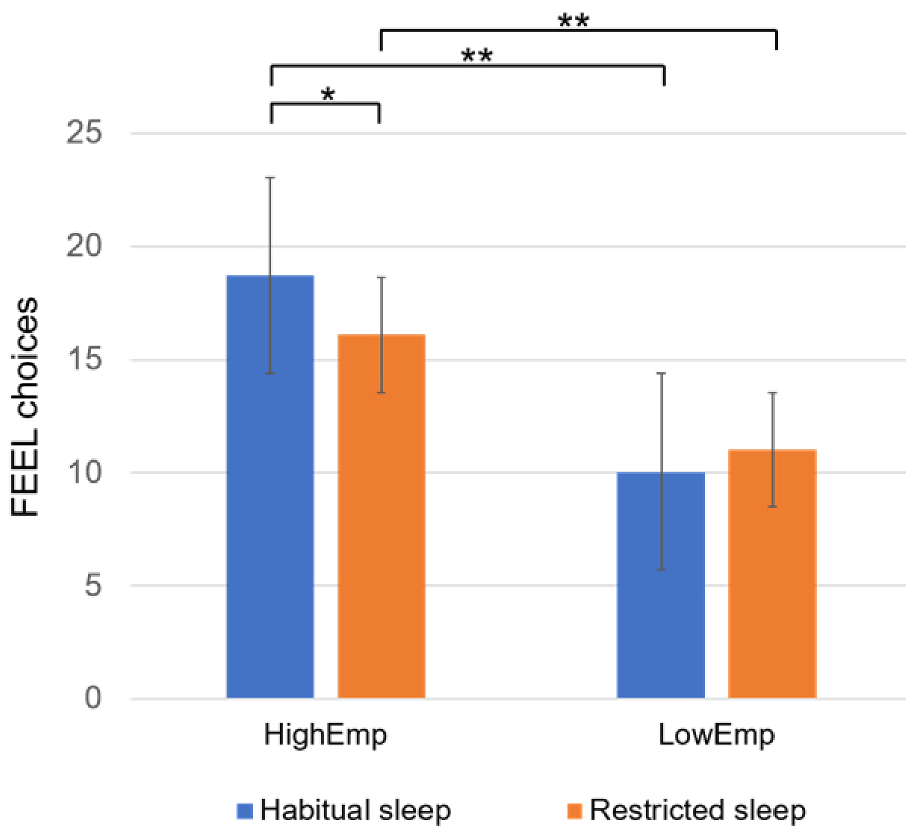
54x30mm (600 x 600 DPI)



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23x22mm (700 x 700 DPI)