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# Gratitude, flourishing and prosocial behaviors following experimental sleep restriction and sleep extension

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**ABSTRACT**

People who are grateful, resilient and flourishing in life show better health, including better sleep. This correlational finding is typically attributed to personality factors or to positive outlooks causing better sleep. We investigated the reverse causal interpretation: do sleep losses and sleep gains experimentally affect feelings and expressions of gratitude, resilience and flourishing? Young adults ($N = 90$) were randomly assigned to sleep restriction, sleep extension or to sleep normally while wearing wristband actigraphy between Monday and Friday study sessions. State-level measures of flourishing, resilience and gratitude improved across the week with sleep extension and worsened with sleep restriction ($\eta_p^2 = .13$ to $.17$). Trait-level measures showed modest or no changes. Sleep-extended participants wrote twice as many details on their gratitude list as the other two conditions ($\eta_p^2 = .11$). Most effects persisted when accounting for mood. Therefore, subtle changes in nighttime sleep causally influence the components that underlie mental well-being.

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Sleep health; positive psychology; life satisfaction; donations; empathy; resentment

## Introduction

Adequate sleep is necessary for minimizing illnesses and functional limitations (Cable et al., 2021). There is likely more to sleep, though, than avoiding diseases and errors. According to Buysse's (2014) *sleep health framework*, the field's typical negative focus on sleep disorders and emphasis on the consequences of sleeping fewer than 7 hours/night should shift to focusing on the positive benefits of sleeping well to health and vitality. A similar idea arises from the field of positive psychology (Seligman et al., 2005), which has shifted the focus of psychological research from failures in human functioning to understanding the components that contribute to overall well-being (e.g. resilience, gratitude and flourishing; VanderWeele, 2017).

Shifting from negative frameworks to positive frameworks is not just a matter of semantics; this shift in conceptual framework is mirrored by shifts in types of manipulations and outcome measures. For example, the traditional approach in sleep and psychological research is to design an experiment to worsen some aspects of functioning (e.g. remove X to show a reduction in Y). By contrast, the positive psychology approach is to design experiments to improve an outcome (i.e. add Z to show an improvement in Y; Cohn & Fredrickson, 2010). The outcome measures also differ from traditional studies that target overall mood; targeted outcome measures typically focus on factors that are theorized to underly mental well-being such as resilience (ability to bounce back after negative events; Vella & Pai, 2019), gratitude (feelings of appreciation for positive events; Wood et al., 2008) and flourishing (a combination of positive life satisfaction with positive life functioning; Huppert & So, 2013).

Just as sleep health is linked to overall health and functioning, so are positive psychology outcome measures. Both *trait gratitude* (individual's average tendency toward thankfulness) and *state gratitude* (current appreciation in the moment) explain unique variance in mental health, physiological health and prosocial behaviors (Boggiss et al., 2020; Portocarrero et al., 2020). Though the early thinking in this literature was that a positive outlook and healthy behaviors could both be manifestations of a stable personality trait, the relationship appears to be causal: experimental inductions of gratitude improve markers of cardiovascular health, inflammation and mental health (e.g. Ginty et al., 2020; Jackowska et al., 2016; Southwell & Gould, 2017).

Positive psychology outcomes are not commonly targeted in sleep studies, but there are theoretical reasons

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why positive psychologists should engage with sleep research (and vice versa). For example, there is a large literature on sleep and emotional expression that has produced conflicting accounts. Historically, the field has focused on sleep loss producing mood disturbances (e.g. Baglioni et al., 2010; Demichelis et al., 2022), with correlational studies often finding that short sleep predicts later development of depressive symptoms and increases in suicidal ideations (Baglioni et al., 2011; Pigeon et al., 2012). A common explanation is that short sleep undermines emotional regulation leading to worsened emotional reactivity (e.g. Altena et al., 2016); consistent with this view, experimental studies have found that sleep restriction worsens feelings and expressions of anger, hostility, anxiety and irritability, especially in the context of stressors (Baum et al., 2014; Gao et al., 2024; Krizan & Hisler, 2019; Nguyen et al., 2019). However, sleep restriction studies that measured both positive and negative emotional states have typically reported that sleep loss changes overall mood primarily by reducing positive emotions (e.g. Alfano et al., 2020; Saksvik-Lehouillier et al., 2020; Shen et al., 2018). Some emerging perspectives are that sleep loss reduces positive emotions by reducing one's energy (Groeger et al., 2022), by attenuating emotional processing (e.g. Baran et al., 2012), by decreasing use of adaptive emotion regulation strategies (Parsons et al., 2022), by altering theory of mind network processing that supports understanding of others' emotions and intentions (Ben Simon et al., 2020) or by some combination of these factors (for review, see Palmer, Bower, et al., 2023).

Studies that have investigated sleep and positive psychology outcomes have typically had a unidirectional focus on positive attributes leading to better sleep (for review, see Ong et al., 2017). In correlational studies, gratitude, flourishing and resilience were found to be associated with better subjective sleep quality, even when controlling for demographics and personality traits (Kim et al., 2015; Seelig et al., 2016; Wood et al., 2009), which is usually interpreted to mean that having high levels of these positive attributes allow for better stress regulation and more positive pre-sleep cognitions (Ng & Wong, 2013; Steptoe et al., 2008). And, indeed, there is evidence that having research participants focus on gratitude at night can improve sleep outcomes. For example, experimental inductions of gratitude have led to better subjective sleep quality, increased sleep duration and improved feelings of being refreshed upon waking (Jackowska et al., 2016; Southwell & Gould, 2017).

Less work has examined whether experimental reductions in sleep compromise positive psychology outcomes (Ben Simon et al., 2020; Tomaso et al., 2021). Some evidence indicates that sleep loss decreases empathy (Guadagni et al., 2014; Rosen et al., 2006), sociability (Ben Simon & Walker, 2018) and social connectedness when reflecting on what others have done for oneself (Palmer, John-Henderson, et al., 2023), which may contribute to why sleep/circadian measures have been linked to willingness to sign a petition for recycling (Holbein et al., 2019) and rates of charitable donations (Ben Simon et al., 2022; Nickel et al., 2023). Positive attributes like gratitude, resilience and flourishing may also fluctuate following sleep loss/extension because of changes in cognitive functioning (Scullin & Bliwise, 2015). When people are well-rested, they feel greater alertness (Kamdar et al., 2004), perform better in their classes and jobs (Barnes & Watson, 2019; Scullin, 2019) and more effectively resolve relationship conflicts (Gordon & Chen, 2014). Therefore, there are multiple pathways by which changes in sleep could lead to changes in feelings of gratitude, resilience and flourishing.

In the current study, we tested whether sleep duration causally affected positive psychology outcomes across a workweek (Monday to Friday). We used state- and trait-level outcome measures for flourishing, resilience and gratitude and tested whether sleep-related alterations were explained by changes in overall mood. Because typical laboratory manipulations of sleep duration are abnormal to participants' lives (0 hours to 4 hours of sleep), we implemented a milder manipulation to assess whether the subtle changes in sleep that occur during workweeks bear causal significance to one's well-being. Furthermore, most studies on this topic have manipulated sleep duration only by depriving participants of sleep, which may be stress-inducing by nature. Far fewer studies have examined the experimental effects of increasing sleep duration as a form of positive intervention. Therefore, to determine whether sleep duration per se was a causal influencer of outcomes, the current work compared sleep restriction, naturalistic sleep and sleep extension conditions.

## Methods

### *Participants*

Ninety adult participants were recruited through local advertising ($M_{Age} = 19.14$, $SD = 1.10$, range: 18–24 years; 74.4% female, 53.3% nonwhite). The sample size was selected based on power analyses that showed that $N = 90$ provided sufficient power ($1\text{-}\beta = .90$) to detect medium-sized effects ($f = .15$) in a repeated measures design for the primary outcome measures (gratitude and similar measures typically show $\geq .70$ correlations with repeated testing; Jans-Beken et al., 2015). Exclusion criteria were being younger than 18 years old, testing positive or having symptoms of COVID-19 in the past 2 weeks and having a habitual bedtime later than 1:30am. Descriptive data for participant characteristics are provided in Table 1. The study was approved by the Baylor University Institutional Review Board. All participants read and signed an informed consent and were provided monetary compensation for their participation.

### Design overview and experimental manipulation

All participants completed Session 1 on a Monday and Session 2 on a Friday of a single week. Between sessions, participants were randomly assigned to one of the three sleeping conditions at home, following previous work (e.g. Scullin et al., 2020). In the naturalistic sleep condition, participants were not given any guidelines on bedtimes or wake times. In the sleep restriction condition, participants were instructed to maintain a bedtime of 2:00 AM and a wake time of 7:30 AM. In the sleep extension condition, participants were instructed to keep a bedtime of 10:30 PM and wake time of 7:30 AM. The experimenter who interacted with participants was kept blinded at both sessions by providing participants with sealed envelopes that included the condition assignments (which were prepared by other research team members). Between sessions, participants were asked to keep a sleep diary and sleep/wake state was objectively estimated using wristband actigraphy (Philips Respironics Actiwatch Spectrum Pro devices), with 30-second epochs and medium threshold for arousals.

### Outcome measures

To characterize the sample, at Session 1, participants completed the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989), demographic measures (age, gender identity, race/ethnicity identity), socioeconomic status (Adler et al., 2000) and religious identity (a known correlate of gratitude; J. Tsang et al., 2022).

At both Session 1 and Session 2, we administered the Karolinska Sleepiness Scale (KSS; Åkerstedt & Gillberg, 1990) and the Profile of Mood States (POMS; Grove & Prapavessis, 1992) to determine if there were changes in current sleepiness and current mood disturbances, respectively. We used the shortened version of the POMS (40 items) that was initially validated in a study of competitive athletes but has since been used in studies of sleep restriction (e.g. Nguyen et al., 2019). Higher scores on the KSS and POMS indicated worse sleepiness and worse mood, respectively.

Two cognitive measures were included at each session: the psychomotor vigilance task (PVT; Dinges &

**Table 1.** Participant characteristics across conditions at session 1 (baseline).

| Variables | Naturalistic Sleep ($n = 30$) | Sleep Restriction ($n = 30$) | Sleep Extension ($n = 30$) | Main Effect |
|---|---|---|---|---|
| Age (years) | 19.40 (1.40) | 19.00 (.91) | 19.03 (.89) | $F(2,87) = 1.23$, $p = .296$, $\eta_p^2 = .028$ |
| Gender Identity: (%)[a] | 70% female<br>30% male | 70% female<br>30% male | 83.3% female<br>16.7% male | $X^2 = 1.87$, $p = 0.393$, $\varphi = .144$ |
| Race/Ethnicity Identity (%) | 13.3% Asian/PI<br>3.3% Black/AA<br>20.0% Hispanic<br>60.0% White<br>3.3% Multiple | 26.7% Asian/PI<br>6.7% Black/AA<br>16.7% Hispanic<br>36.7% White<br>13.3% Multiple | 13.3% Asian/PI<br>16.7% Black/AA<br>13.3% Hispanic<br>43.3% White<br>13.3% Multiple | $X^2 = 3.48$, $p = 0.175$, $\varphi = .197$ (for proportion nonwhite) |
| Religious Identity (%) | 16.7% No religion<br>73.3% Christianity<br>3.3% Hinduism<br>0.0% Islam<br>3.3% Buddhism<br>3.3% Judaism | 13.3% No religion<br>73.3% Christianity<br>13.3% Hinduism<br>0.0% Islam<br>0.0% Buddhism<br>0.0% Judaism | 10.0% No religion<br>80.0% Christianity<br>6.7% Hinduism<br>3.3% Islam<br>0.0% Buddhism<br>0.0% Judaism | $X^2 = 0.58$, $p = 0.75$, $\varphi = .08$ (for proportion religious-affiliated) |
| SES Ladder (1 – 10 range) | 5.93 (1.44) | 6.17 (1.68) | 6.20 (1.24) | $F(2,87) = 0.295$, $p = .745$, $\eta_p^2 = .007$ |
| PSQI Global Score (0 – 21 range) | 6.03 (2.40) | 5.63 (2.90) | 5.23 (2.21) | $F(2,87) = 0.757$, $p = .472$, $\eta_p^2 = .017$ |
| Typical Bedtime | 12:04 AM (1.35) | 12:01 AM (1.07) | 11.59 PM (0.98) | $F(2,87) = 0.040$, $p = .961$, $\eta_p^2 = .001$ |
| Typical Waketime | 7:52am (1.12) | 7:47am (1.15) | 7:44am (0.74) | $F(2,87) = 0.112$, $p = .894$, $\eta_p^2 = .003$ |

Abbreviations. PSQI: Pittsburgh Sleep Quality Index; SES: Socioeconomic Status (MacArthur Ladder); [a]No study participants selected other or non-binary options for gender identity.

Powell, 1985) and the Raven's Advanced Progressive Matrices (RAPM; Raven, 1938). We implemented the cognitive measures in ePrime 3.0 using publicly available programs for the PVT (https://support.pstnet.com/hc/en-us/articles/360008697713-Psychomotor-Vigilance-Task-PVT-30113) and for the RAPM (https://support.pstnet.com/hc/en-us/articles/360046082014-Ravens-Progressive-Matrices-34568). Briefly, the PVT is a 10-minute computerized task that measures participants' reaction times to a red dot appearing on the screen. The PVT is sensitive to total sleep deprivation, but its sensitivity to subtle changes in sleep (<1 hour) has been less documented. The RAPM is a measure of fluid intelligence in which participants are shown a 3 × 3 matrix with an image in all but one square and they must select the correct image from eight options. Participants were given 10 minutes to answer as many of the 18 problems as possible and different stimuli were used across sessions. Fluid intelligence was not expected to be influenced by sleep loss (for meta-analysis, see Lowe et al., 2017), and therefore the RAPM task served as a negative control to ensure the sleep manipulation was not simply leading to response bias or differential effort.

Because there has been minimal sleep research on positive psychology outcomes, we included a range of common measures of resilience, flourishing and gratitude, which were repeated at Session 1 and Session 2. To estimate resilience, we included the Brief Resilience Scale (B. W. Smith et al., 2008) in which participants rated six statements on a 5-point Likert scale (strongly disagree to strongly agree). Negatively worded items were reverse scored such that higher average values represented greater resilience. To assess feelings of flourishing in life, we drew six items from the Global Flourishing Study that focused on life purpose, life satisfaction, life goals, hope, spiritual comfort and forgiveness over the past week (Crabtree et al., 2021). Inspection of the scree plot of these six items at Session 1 suggested a single factor (Figure S1); therefore, we transformed each item to z-scores and averaged them to form a composite (separately for Session 1 and Session 2) with higher scores indicating greater feelings of flourishing. The six-item flourishing composite showed a Cronbach's alpha of .62, and therefore, we created a second composite that dropped the spiritual comfort and forgiveness items that correlated modestly with the overall composite score (Cronbach's alpha of .82 for the four-item flourishing composite). Because the main outcomes were similar for the six-item and four-item flourishing composites, we retained the six-item composite score in the main text and report the four-item composite score findings in the supplemental section (Figure S1).

To measure state feelings of gratitude, participants rated on a 5-point Likert scale to what extent they currently felt appreciative, grateful and thankful. Ratings were averaged such that higher scores represented greater state/current gratitude. Cronbach's alpha was .93.

We also included trait-level measures of gratitude. In the GQ-6 questionnaire (McCullough et al., 2002), participants rated agreement to six statements, such as 'I am grateful to a wide variety of people'. Ratings used a 7-point Likert scale and were averaged such that higher scores indicated greater trait gratitude. Whereas the GQ-6 is a positively oriented trait measure of gratitude, the Lack of a Sense of Deprivation subscale of the GRAT is a negatively oriented measure (e.g. resentment; Watkins et al., 2003). This subscale includes six statements regarding the individual's belief that they have been deprived of good things in life, that bad things happen to them, and that the world owes them something. To be consistent with the other gratitude measures, the negatively worded items were reverse scored and ratings were averaged so that higher scores indicated lower resentment.

Session 2 additionally included measures of behavioral expressions of positive psychology attributes and prosocial behaviors. Behaviorally expressed gratitude was assessed with a gratitude list writing task (Tsang et al., 2023). Participants were told to write anything for which they were grateful or thankful in open response boxes. They were instructed that they could write as much or as little as they liked. To objectively examine the quantity and quality of writings, we used Linguistics Inquiry and Word Count (LIWC) software to extract total word count (quantity) and content themes (quality) (Pennebaker et al., 2015). In addition, we developed a novel vignette rating task that was conceptually based on prior work (Nguyen et al., 2019). Participants read 12 vignettes, each describing a person who was undergoing an undesirable circumstance. One example vignette is displayed below (see Appendix S1 for all vignettes).

> Sophia is young, eats the right foods, and exercises regularly. However, during a routine check-up, doctors discover that Sophia has cancer. The news is shocking, and the doctor informs Sophia that it will require aggressive treatment with chemotherapy, which will cause complete hair loss and other side effects. With aggressive treatment, there will be a 31% chance of surviving.

After reading each vignette, participants rated on a 1 to 9 scale a) how rare they believed this circumstance to be, b) how much empathy they felt for the person in the vignette, c) how depressed they think the person in the vignette feels, d) how much gratitude or resentment the person in each vignette should feel and e) how much gratitude the person in the vignette should feel towards a higher power (data analyzed for participants who identified as religious). In each vignette, the person was given either a male name or female name, and we created two, counterbalanced sets of vignettes (see Appendix S1).

At the end of all study procedures, we included an exploratory donation task. Participants were given the opportunity to anonymously donate all, half or none of their study compensation (two $25 payment cards) to a local charity when submitting a receipt form in a sealed envelope (Barraza et al., 2011). We examined the proportion of participants who donated at least one payment card. This task was considered to be exploratory because we did not power the study to detect significant effects for categorical variables.

### *Statistical analysis*

We used correlational analyses to examine associations amongst the variables at baseline and analyses of variance (ANOVAs) to determine whether the sleep manipulation produced differential changes in outcome measures across sessions. All analyses followed conservative intention-to-treat principles (analyzing data from every participant according to randomized condition assignment; Gupta, 2011). When statistically significant effects were observed, we conducted independent sample and paired *t* tests across groups and sessions, respectively, to determine the source of the interaction. In addition, we determined whether significant effects were explained by mood alterations by controlling for Session 2 POMS mood disturbances. All tests were two-tailed with alpha set to .05 and *p* values were accompanied by estimates of effect size (Cohen's d, phi and partial eta squared). Variability in degrees of freedom indicates some data were missing for that measure (e.g. n = 1 missing actigraphy data). Statistical analyses were conducted using SPSS version 28 and figures were generated using GraphPad Prism version 9.

## Results

### *Baseline characteristics and experimental manipulation checks*

All 90 participants completed both sessions. Participant characteristics are displayed in Table 1 and there were no significant differences across the conditions for demographic factors, baseline sleep quality or baseline bedtimes/waketimes. Actigraphy data (Table S1) showed that average bedtimes during the experimental phase significantly differed across the sleep extension (11:10 PM), naturalistic sleep (12:21 AM) and sleep restriction conditions (1:00 AM), $F(2,86) = 19.59$, $p < .001$, $\eta_p^2 = .313$. Average wake times were similar across the three groups (8:15 AM, 8:22 AM, 8:08 AM, respectively; $F(2,86) = 0.346$, $p = .709$, $\eta_p^2 = .008$). While the actigraphy-measured bedtimes and waketimes differed from the instructions given to the participants, the experimental manipulation was still effective at significantly changing total sleep time, $F(2,86) = 13.04$, $p < .001$, $\eta_p^2 = .233$. Relative to the naturalistic sleep condition, the sleep extension manipulation increased sleep duration by 46 minutes per night, $t(58) = 2.83$, $p=.006$, $d = 0.73$, and the sleep restriction manipulation decreased sleep duration by 37 minutes per night, $t(57) = 2.27$, $p = .027$, $d = 0.59$ (Figure S2); therefore, the sleep extension and sleep restriction conditions differed by 83 minutes per night, $t(57) = 5.12$, $p < .001$, $d = 1.33$. These changes in sleep duration occurred without significantly changing actigraphy-measured sleep onset latency, wake after sleep onset or sleep efficiency (Table S1). Therefore, the manipulation created subtle nightly differences in sleep duration (*M*s = 7.36, 6.60 and 5.98 hours in the extended, naturalistic and restricted conditions, respectively).

Given the experimental manipulation of sleep duration, we expected the conditions to differ on subjective sleepiness and total mood disturbances (Figure 1 and Table S2). We conducted a series of 3 (condition) × 2 (session) ANOVAs, which showed significant interactions for both KSS sleepiness, $F(2,87) = 11.39$, $p < .001$, $\eta_p^2=.207$, and POMS mood disturbances, $F(2,87) = 10.08$, $p < .001$, $\eta_p^2=.188$. There were no condition differences at Session 1 (*p*s > .05), but moderate- to large-sized differences at Session 2. Figure 1(a) shows that alertness/sleepiness significantly worsened after four nights of mild sleep restriction ($t(29) = 3.80$, $p < .001$, $d = 0.69$) and significantly improved after four nights of mild sleep extension ($t(29) = 3.33$, $p=.002$, $d = 0.61$), while remaining unchanged in the naturalistic sleep condition ($t(29) = 0.28$, $p = 0.79$, $d = 0.05$). Overall mood worsened from Monday to Friday in the naturalistic sleep condition ($t(29) = 2.78$, $p=.01$, $d = 0.51$), a pattern that was exaggerated following sleep restriction ($t(29) = 8.04$, $p < .001$, $d = 1.47$), but blunted to nonsignificant levels following sleep extension ($t(29) = 1.13$, $p=.27$, $d = 0.21$; Figure 1(b)). The conditions did not significantly differ on PVT or RAPM tests (Table S2, Figure S3-S4), suggesting similar levels of cognitive ability and effort across conditions.

### *Associations across outcome measures*

We next evaluated the primary outcomes of resilience, flourishing and gratitude. A heat map correlation matrix

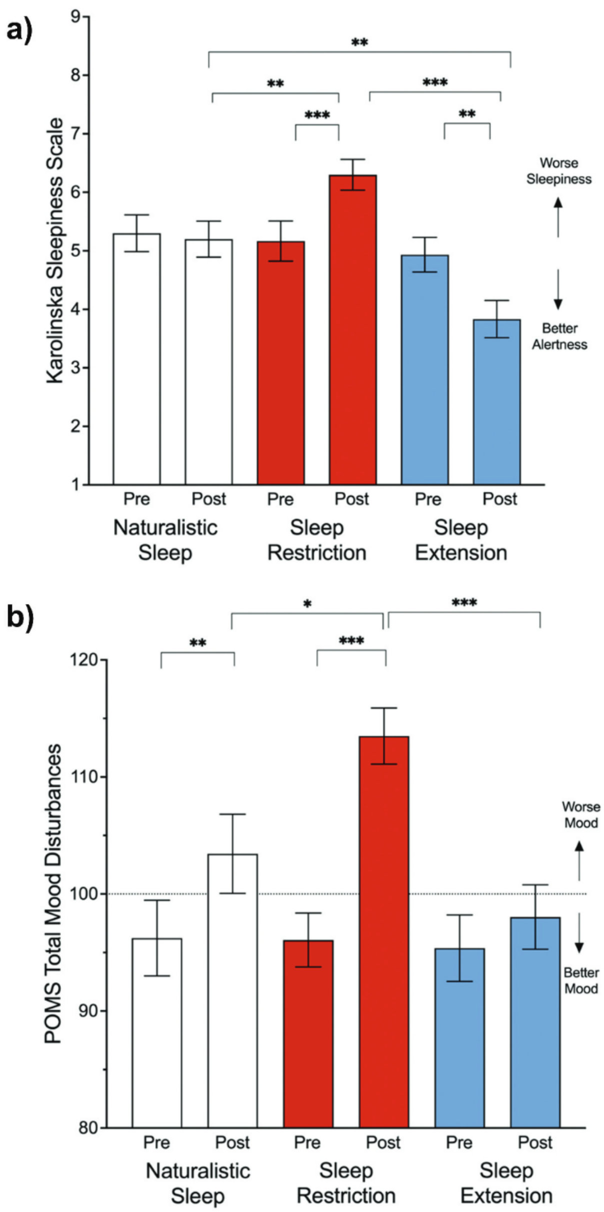


**Figure 1.** Subjective sleepiness (a) and total mood disturbances (b) across conditions from Monday (pre) to Friday (post). Error bars are standard errors, ns indicates $p \geq .06$, *indicates $p < .05$, **indicates $p < .01$ and ***indicates $p < .001$.

of these measures is included in Figure S5. As expected, most of the primary outcome measures were associated in the moderate to strong range (*rs* of .30 to .50; e.g. Portocarrero et al., 2020), except for the exploratory donation measure (most *rs* < .10). Demographic variables were weakly and non-significantly associated (*rs*<.20) with measures of resilience, flourishing and gratitude, except that individuals who identified as religious showed higher levels of trait gratitude (GQ-6; J. Tsang et al., 2022). Replicating prior work, we found that lower resilience, flourishing and gratitude outcomes were associated with worse mood disturbances (Nezlek et al., 2017) and worse PSQI global sleep quality at baseline (Seelig et al., 2016; Wood et al., 2009).

## Resilience, flourishing and feelings of gratitude

We next tested whether the amount of sleep could be causally driving changes in resilience, flourishing and gratitude and if these changes were independent of alterations to overall mood. Figure 2(a) shows that feelings of resilience changed across the study in relation to sleep condition, $F(2,87) = 7.75$, $p < .001$, $\eta_p^2 = .15$ (main effects: ps > .10). Participants in the sleep extension condition showed an increase in resilience ($t(29) = 3.10$, $p = .004$, $d = 0.57$), whereas participants in the sleep restriction condition showed a decrease in resilience ($t(29) = 2.02$, $p = .05$, $d = 0.37$). These patterns were not explained by overall mood; the session by condition interaction remained significant when controlling for Session 2 POMS mood disturbances, $F(2,86) = 4.76$, $p = .01$, $\eta_p^2 = .10$.

Figure 2(b) illustrates a similar interaction for flourishing, $F(2,87) = 8.88$, $p < .001$, $\eta_p^2 = .17$ (main effects: *ps*>.10). Feelings of flourishing increased across sessions in the sleep extension condition ($t(29) = 2.03$, $p = .05$, $d = 0.37$) and decreased in the sleep restriction condition ($t(29) = 3.55$, $p = .001$, $d = 0.65$). This interaction was robust to controlling for overall mood, $F(2,86) = 5.87$, $p = .004$, $\eta_p^2 = .12$ (see also Figure S1).

Gratitude was more strongly impacted by sleep when using state-based measures than trait-level measures. Figure 2(c) illustrates a significant session by condition interaction for state gratitude, $F(2,87) = 6.76$, $p = .002$, $\eta_p^2 = .13$, that remained significant even when controlling for Session 2 POMS mood disturbances, $F(2,86) = 4.66$, $p = .01$, $\eta_p^2 = .10$. The conditions showed similar ratings at baseline ($F(2,87) = 1.83$, $p = .17$, $\eta_p^2 = .04$), but sleep-extended participants showed significantly higher ratings of state gratitude than sleep-restricted participants at Session 2 ($t(58) = 2.58$, $p = .01$, $d = 0.67$).

In contrast to the state-level measures, the GQ-6 trait-based measure of gratitude did not interact with sleep condition, $F(2,87) = 1.36$, $p = .26$, $\eta_p^2 = .03$ (Figures S6-S7). In addition, the negatively oriented measure of gratitude (GRAT subscale) only showed moderately sized interactive effects (Figure S8), $F(2,87) = 3.17$, $p = .047$, $\eta_p^2 = .068$, that were no longer significant when controlling for POMS mood disturbances ($F(2,86) = 2.04$, $p = .14$, $\eta_p^2 = .045$).

## Expressions of gratitude

We assessed expressions of gratitude using a validated gratitude list writing task, a novel vignette rating task

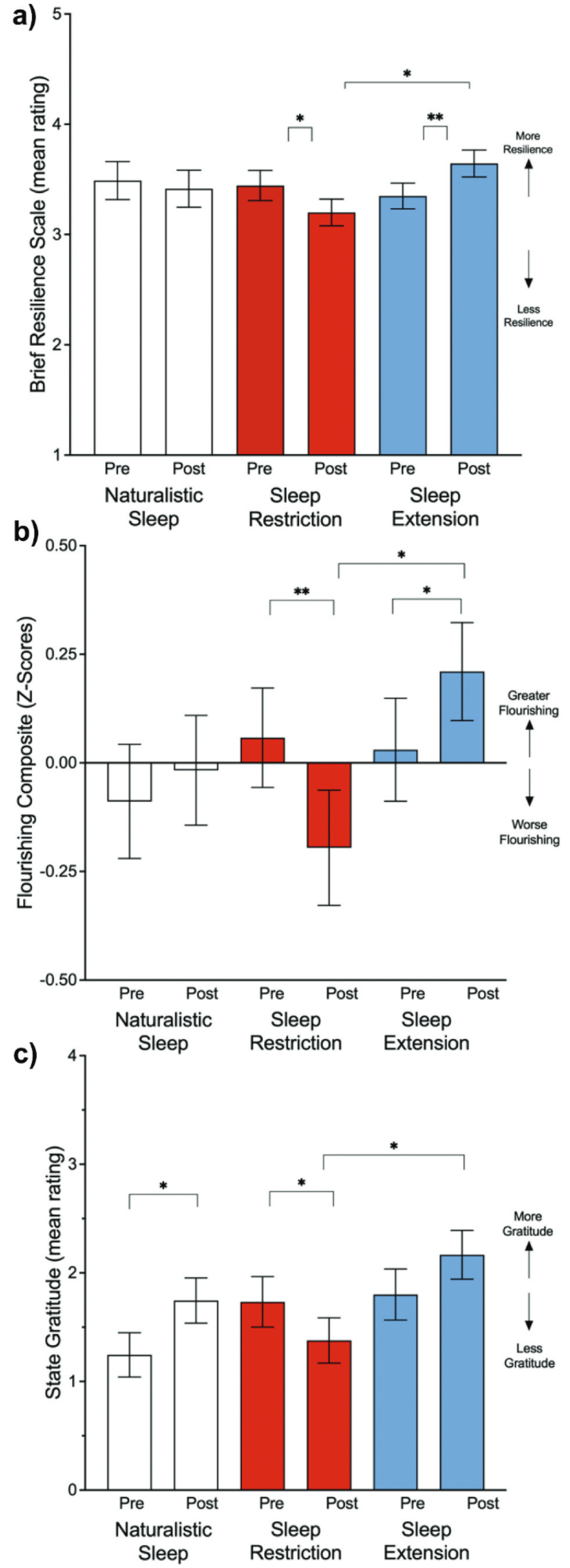


**Figure 2.** Primary outcome measures across conditions including resilience (a), flourishing (b) and state gratitude (c). Error bars are standard errors, *indicates $p \leq .05$, **indicates $p < .01$.

and the exploratory donation task. The sleep manipulation led to significant differences in the total quantity of gratitude list writing, $F(2,87) = 3.60$, $p$=.03, $\eta_p^2$=.076. Inspection of Figure 3 reveals one extreme outlier value (>4 SDs above the mean) that was having a suppressing effect. After removal, the main effect on sleep was significant even when controlling for Session 2 POMS scores, $F(2,86) = 5.16$, $p$=.008, $\eta_p^2$=.108. Participants in the sleep extension group wrote twice as much on their gratitude list as the naturalistic sleep group, $t(57) = 2.64$, $p$ = .011, $d$=.68, and sleep restriction group, $t(57) = 2.60$, $p$ = .012, $d$ = .68. The content of the writings – controlling for differences in quantity – was similar across conditions (Table S3). In other words, the types of themes that participants wrote about (e.g. friends, family) were similar across conditions, but the sleep-extended participants wrote more overall.

The full results from the vignette rating task are detailed in Table S4. As an overview, there were no differences across vignettes with a female name or a male name ($p$s>.05), and the conditions showed similar ratings on situation rarity and empathy. However, as illustrated in Figure 4, the sleep conditions differed in how much individuals believed the people in the vignettes should be feeling gratitude versus resentment in the undesirable circumstance. The sleep restriction group expressed that significantly less gratitude (more resentment) should be felt, relative to the naturalistic sleep condition ($t(58)$ =

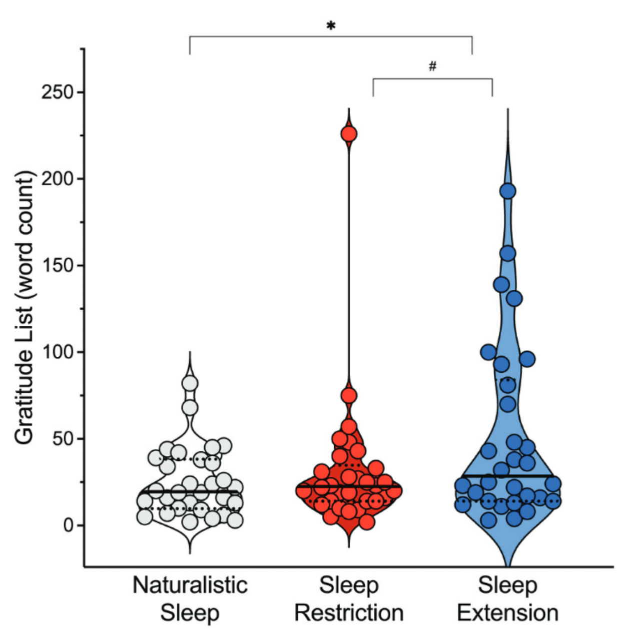


**Figure 3.** Length of gratitude list writing across conditions. The solid lines indicate median values, dotted lines indicate quartiles, *indicates $p < .05$ and # indicates $p < .01$ following removal of the outlier in the sleep restriction condition (>4 SDs above the mean).

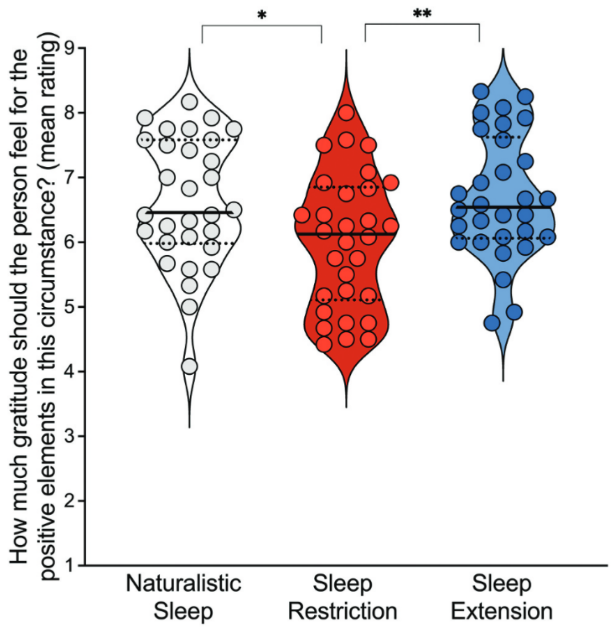


**Figure 4.** Vignette task ratings of whether another person should feel gratitude in an undesirable circumstance (1–9 scale). The solid lines indicate median values, dotted lines indicate quartiles, *indicates $p < .05$ and **indicates $p < .01$.

2.38, $p$ = .02, $d$ = .62) and the sleep extension condition ($t$(58) = 2.68, $p < .01$, $d$ = .69). Initially, these effects appeared to be negated when controlling for Session 2 POMS mood scores ($F$ = 1.36, $p$ = .23, $\eta_p^2$ = .034), which could indicate that the vignette measures are similar to trait measures of gratitude. In support of this possibility, vignette ratings were strongly associated with trait gratitude (Figure S5). Interestingly, when both Session 2 POMS scores and Session 2 GQ-6 scores were included as covariates, the sleep condition main effect was again significant for vignette ratings of gratitude, $F(2,85) = 3.11$, $p < .05$, $\eta_p^2$=.07.

For the exploratory donation task, only 10% of sleep-restricted participants donated some of their compensation. In comparison, 17% of participants in the naturalistic sleep condition and 17% of participants in the sleep extension condition donated (condition main effect: $X^2(2) = 0.72$, $p$ = 0.684, φ=.089).

## Discussion

Following a workweek of extended sleep, participants showed improvements in resilience, gratitude and flourishing. The opposite pattern occurred following mild sleep restriction. As expected, the sleep manipulations also affected mood, but overall mood did not explain most of the outcomes for flourishing, resilience and gratitude. Based on the existing literature and the current findings, sleep should be added to the list of factors important for positive psychology outcomes (Seligman et al., 2005), and resilience, gratitude and flourishing should be added to the list of potential targets for sleep health interventions (Buysse, 2014).

Most prior work on sleep and positive psychology outcomes found that the more a person was resilient, grateful and flourishing in life, the more likely they were to sleep well (Kim et al., 2015; Ng & Wong, 2013; Ong et al., 2017; Seelig et al., 2016; Steptoe et al., 2008; Wood et al., 2009). The current work replicated this finding: better PSQI sleep quality scores at baseline were associated with higher resilience, gratitude and flourishing at baseline. One interpretation of these correlations would be that good sleep and positive psychology attributes are two manifestations of a positively predisposed personality. Consistent with this idea, studies have connected prosocial preferences to relative slow wave activity (stable, trait like marker of sleep depth; Studler et al., 2024) and a person's global sleep quality is associated with personality traits such as neuroticism and extraversion (e.g. Duggan et al., 2014). Most views of personality traits conceptualize them as stable features that should fluctuate minimally across time (for an alternative model, see Roberts, 2018), but in the current study we found that state-measured gratitude, resilience and flourishing fluctuated substantially and independently of overall mood. Thus, the current results are unlikely to be explained solely by personality or other disposition-related factors.

Another possible interpretation is that positive psychology attributes promote better sleep (unidirectional hypothesis). For example, if high levels of gratitude and resilience eliminate negative pre-sleep cognitions, then sleep quality should improve (Wood et al., 2009). This causal direction (positivity ➔ sleep) has theoretical grounding (Harvey, 2002) and is supported by prior experimental designs that observed improvements to sleep quality after inducing feelings of gratitude (Jackowska et al., 2016; Southwell & Gould, 2017). The other causal direction is worth consideration though (sleep ➔ positivity) and was targeted by the present study's design. We found that resilience and flourishing increased following sleep extension and decreased following mild sleep restriction. In other words, improving sleep may enhance well-being whereas losing sleep may exacerbate ill-being.

The gratitude outcomes showed a slightly more complex pattern across experimental conditions. Losing a few hours of sleep (cumulatively) across a workweek reduced state gratitude and worsened outcomes that included negative wording (GRAT), though the latter tendencies toward resentment were generally explained by sleep-related alterations in overall mood. Gaining a few hours of sleep during the workweek improved state feelings of gratitude, perceptions of how much gratitude other people should feel (vignette ratings), as well as behavioral expressions of gratitude (list writing). The observed divergences across extended and restricted sleep conditions add to broader conversations in the literature regarding whether sleep loss worsens mental well-being by heightening negative emotions, by reducing positive emotions/attributes or by doing both (Palmer, Bower, et al., 2023). Additional work is needed in this area to understand mechanistic pathways, individual differences and contextual dependency.

Another area for further research is investigating bidirectional links between sleep and prosocial behaviors. Some work has found that sleep loss decreases voting behaviors (Holbein et al., 2019) and that charitable giving is lower following the spring daylight saving time shift (Ben Simon et al., 2022). If an association exists, it is likely a small effect size that would require large sample sizes to detect condition effects (Nickel et al., 2023). However, if the true effect size is small, that would not mean that society-wide improvements in sleep would be insignificant for prosocial behaviors. For example, in the United States alone, annual donations are approximately $500 billion. As such, increasing the probability of making charitable donations in the population (e.g. from 10% to 17%) by increasing society-wide sleep duration would have a sizeable impact on many communities and organizations.

Limitations of this study included a sample that is not generalizable to all segments of the population. In addition, while the PVT, RAPM and POMS are typical measures of cognitive performance and mood disturbances, these instruments may be imperfectly matched to the types of effort and overall mood that are involved in responding to positive psychology measures. Future work on sleep and positive attributes would benefit from including personality assessments, validated measures of flourishing (e.g. Diener et al., 2010) and post-study checks on whether the experimenter became unblinded to study condition. Moreover, though the current work used validated positive psychology outcome measures, self-report measures are susceptible to biases. Here, it is reassuring that the sleep manipulation primarily influenced outcomes on state-based measures, with less influence on trait-based measures, indicating that participants were not simply globally changing their response patterns.

Additional work is needed to understand if further extending sleep duration – for example to ≥8 hours/night – produces additional benefits to gratitude, resilience and flourishing (Scullin, 2019). A laboratory-controlled, cross-over study design would be preferable to ensure adherence to set bedtimes and rise times (Klerman et al., 2021) and to compare within-person changes across a week of sleep restriction, a week of sleep extension and a week of self-selected bedtimes and rise times (Skorucak et al., 2018). For future work that uses a parallel group design, it would be valuable to include longer-term follow-up sessions to assess rates of change in positive attributes (M. G. Smith et al., 2021).

## Conclusion

The current work provides evidence that the subtle changes in sleep duration that are routine for many people during workweeks can have an impact on mood, resilience, gratitude and flourishing. These findings may be timely, as happiness has hit record lows in some societies in recent years (e.g. Twenge, 2019). Even though population-wide trends in sleep duration and well-being will continue to be debated (Sheehan et al., 2019; Youngstedt et al., 2016), it is widely agreed that sleep health and well-being can and should be improved across the globe (Cable et al., 2021). As such, if a society's goal is to improve overall well-being, then a good next target should be prioritizing sleep health.

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