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The sleep maths: A strong correlation between more daytime light and better night-time sleep

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Lighting for workplaces and schools is typically specified to meet the needs of the visual system without sufficient regard to the lighting characteristics that are required by the human circadian system. In 2020, many workers and students were compelled by the COVID-19 pandemic to work and study from home, where light levels are typically even lower than those found in most schools and workplaces. Using online surveys, this study sought to quantify potential changes in daytime light exposures resulting from teleworking or self-isolating at home and how those changes might have affected self-reported sleep quality, psychological health and emotional health. The first survey was administered in early May 2020, and the second survey was administered in September 2020. In broad terms, our analysis indicates that the greater the amount of light one is exposed to during the day (either in the home or outdoors), the better the self-reported sleep outcomes. Stress and mood were also correlated with greater self-reported daytime light exposures. The results suggest that spending one to two hours outdoors or staying in a bright to very bright room indoors may improve night-time sleep. These results have important implications for daytime lighting in homes, offices and schools.

1. Introduction

Retinal light exposures affect human physiology and behaviour by directly stimulating the brain's biological clock, setting its timing and compelling us to sleep at night and stay awake during the day in synchrony with Earth's 24-hour axial rotation. Exposure to too little light during the day or too much light in the evening can desynchronize the biological clock and lead to circadian disruption, which has been linked to sleepiness during the day and poor night-time sleep, increased risk for psychological ailments such as anxiety, stress and depression, and negative health outcomes such as diabetes, obesity, cardiovascular disease and certain types of cancer.[1–4] The human circadian clock free-runs in the dark with a period slightly greater than 24 hours, so sustained morning light is needed to advance, and therefore synchronize, the biological clock to local time on Earth. Although the physiological, metabolic and behavioural effects of circadian disruption are broad ranging, the present study is primarily concerned with light's effects on the circadian system as they may affect sleep and behavioural health in both home and workplace environments.

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With respect to light, the human visual and circadian systems are interrelated but essentially different neurological processes. There are five important characteristics of light that are common to both systems: quantity, spectrum, timing, duration and distribution. The precise characteristics that are essential for vision, however, are quite different from those that are most effective for the circadian system.[5,6] Of particular interest in this study, it is known that the quantity of polychromatic white light necessary to activate the circadian system is significantly greater than the amount required to activate the visual system, as measured via the nocturnal suppression of the hormone melatonin (a key biomarker of the circadian system) or shifts in circadian phase. The spectral sensitivity of the circadian system peaks in the short wavelengths of the visible spectrum,[7,8] while the visual system is most sensitive to the middle-wavelength portion.

A considerable body of research exists for the effects of light's spectral characteristics, particularly with respect to high correlated colour temperature electrical sources and daylighting, as well as for the effects of light levels and the timing of light exposures, on human sleep and behaviour.[9–13] Field studies have demonstrated that light sources emitting a greater amount of short-wavelength light (e.g. 17,000 K compared to a 4000 K light sources) reduced subjective sleepiness and fatigue, improved subjective alertness and vitality and improved certain types of performance associated with mental effort.[9,10,14–16]

Consistent with the idea that reduced daytime light exposure might affect sleep quality and mood in office workers,[17–19] Boubekri *et al.*[20] showed that office workers sitting close to windows, and therefore receiving higher amounts of light during the day than their colleagues in windowless offices, exhibited greater activity overall, increased sleep duration, and improved sleep quality and vitality.

More recently, in 2017, Figueiro *et al.*[19] performed light measurements using calibrated devices that measure circadian light in five U.S. federal government office buildings and showed that occupants receiving higher circadian stimulation during the daytime (especially in the morning) had improved sleep at night and reduced self-reported depression. Personal circadian-effective light exposures and activity patterns were collected for seven consecutive days and the participants responded to questionnaires relating to mood and sleep quality. Those receiving high circadian stimulation in the morning fell asleep more quickly at bedtime, experienced less depression (Center for Epidemiological Studies-Depression) and had better quality sleep (Pittsburgh Sleep Quality Index [PSQI], Patient-Reported Outcomes Measurement Information System) compared to those receiving low circadian stimulation in the morning.

Two additional field studies by the same research team employing parallel protocols in U.S. federal government office buildings and overseas embassies demonstrated broadly similar results to their 2017 study. The first study exposed office workers to two lighting interventions over the course of two days: (1) polychromatic overhead lighting and (2) custom-built desktop luminaires delivering cool-white or blue light. The interventions, which were designed to provide high levels of circadian stimulation at the occupants' eye level, significantly improved self-reported sleepiness scores (Karolinska Sleepiness Scale (KSS)) and the subjects reported feeling significantly more vital, energetic and alert at work.[16] The second, more-recent (2019) field study was performed in two different U.S. federal government office buildings and delivered the lighting intervention over the course of two weeks.[15] Although the results were mixed, the subjects' self-reported sleepiness (KSS) scores were significantly reduced during the afternoon at the time of the post-lunch dip (i.e. around 15:00).[21]

In mid-to-late March 2020, many federal and state-level governments around the world issued stay-at-home orders and recommendations in an effort to limit the spread and severity of the COVID-19 pandemic. In the U.S., this resulted in the closure of many non-essential business, the loss of roughly 16 million civilian jobs between March and May 2020[22] and 35% of the civilian workforce shifting to teleworking specifically due to the pandemic by May 2020.[23] As a consequence, tens of millions of people who had previously worked outside their homes on a daily basis were confined to their residences and underwent potentially significant changes in their daily light exposures. Recommended indoor residential light levels, for example, are generally lower (e.g. 30 lx (horizontal) for a living room, 200 lx (horizontal) for a home office) than light levels recommended for commercial office spaces (300–500 lx (horizontal) for most applications).[24] In the absence of regular commuting schedules and midday lunch breaks, moreover, it is reasonable to expect that newly homebound workers might have experienced significantly reduced daylight exposures, especially early in the day when light exposures play a crucial role in stimulating the circadian system and promoting entrainment.

The aim of the present study was to quantify potential changes in daytime light exposures resulting from teleworking or self-isolating at home and how those changes might have affected self-reported sleep quality, psychological health and emotional health. The study employed electronic surveys to collect subjective response data for measures of both daily indoor and outdoor light exposures, as well as measures of sleep quality and well-being. The first survey (project Phase 1) was administered in early May 2020, after COVID-19 stay-at-home orders and recommendations were enacted. The second survey (project Phase 2) was administered in September 2020, after those orders were relaxed and many businesses had resumed total or partial operation. The survey results were compared for respondents staying or working at home full-time, during the lockdown to responses from individuals still staying or working at home full-time or working part or full-time at their places of work, after the stay-at-home orders had been lifted.

2. Method

2.1 Data collection and participants

The surveys were conducted in two four-week phases. Phase 1 began in early May 2020, shortly after the enactment of COVID-19 stay-at-home orders. A total of 708 individuals responded to the Phase 1 survey, but only the results from 593 individuals (51% female, 45% male, 4% unspecified) who were working from or quarantining at home during the preceding two weeks were included in the Phase 1 analysis. The Phase 1 survey respondents' average age range lay within the survey's 45–54-year age bracket.

Phase 2 of the survey began in early September 2020, roughly three months after the lifting or relaxation of the last of the U.S. stay-at-home orders. A total of 210 individuals responded to the Phase 2 survey and out of that total, 104 were either employed or unemployed and working/staying at home full-time, 40 were working part-time at home and part-time at their place of work and 34 were working full-time at their place of work (with 31 out of the 34 working in either a private or open office environment). Of the 210 Phase 2 respondents, 177 (34% female, 61% male, 5% unspecified) had complete or partial data and were included in the analysis. The Phase 2 survey respondents' average age lay within the survey's 45–54-year age bracket.

The surveys were announced via e-mail and news releases on lighting industry publication websites and in the general media. Participants accessed the survey by way of a link embedded in e-mails and media releases and were directed to an electronic survey facilitated by SurveyMonkey (San Mateo, CA, USA). Survey participants were informed that their answers would be anonymous, that no identifying information would be collected and that by continuing with the survey, they thereby gave consent for their response data to be included in the analysis.

2.2 Outcome measures

The survey included a series of Patient-Reported Outcomes Measurement Information System (PROMIS) questionnaires for evaluating physical and mental health in children and adults that were developed and validated by the National Institutes of Health.[25] Each short-format survey included 4, 8 or 15 Likert-scale questions in which participants self-evaluated their sleep disturbance, sleep-related impairment, anxiety, stress, depression and positive affect over the previous seven-day period.

2.2.1 Sleep disturbance

The PROMIS Short Form v1.0 – Sleep Disturbance 4a[26] is a four-question self-assessment form evaluating subjective perceptions of sleep quality, sleep depth and restoration associated with sleep, and includes impressions of difficulties falling asleep or staying asleep. The Sleep Disturbance form does not address specific symptoms of clinical sleep disorders nor does it provide any estimations of quantitative measures of sleep quantity (e.g. sleep duration, sleep efficiency, sleep onset or offset latency, etc.).

2.2.2 Sleep-related impairment

The PROMIS Short Form v1.0 – Sleep-Related Impairment 8a[27] is an eight-question self-assessment form evaluating perceptions of alertness, sleepiness, tiredness during waking hours and the perceived impairments attributable to poor sleep quality. This form does not directly address cognitive performance impairment, but measures subjective waking alertness, sleepiness and function within the overall sleep–wake function context.

2.2.3 Anxiety

The PROMIS Short Form v1.0 – Anxiety 4a[28] in a four-question assessment of self-reported fear, anxiousness, hyperarousal (e.g. nervousness, restlessness, tension, etc.) and somatic symptoms of arousal (e.g. racing heart, etc.). Anxiety is differentiated by symptoms of autonomic arousal and the experience of external threat. Behavioural avoidance is not fully evaluated by this item and the anxiety measures are universal rather than disease-specific.

2.2.4 Stress

The PROMIS Pediatric Short Form v1.0 Psychological Stress Experiences 4a[29] is a four-question self-assessment evaluating thoughts or feelings about one's self in the world with respect to environmental or internal challenges. The questionnaire examines three facets of psychological stress: feeling overwhelmed, perceived lack of control or capacity to manage one's life and cognitive–perceptual disruption. The Paediatric self-report instrument is intended for ages 8–17 years, though the questions are appropriate and applicable to adults. (See the *Scoring* section of the respective methodologies for notes on the t-scoring adjustment procedure used for the stress instrument to apply the standardized t-scores used for the PROMIS surveys to the general adult population.)

2.2.5 Depression

The PROMIS Short Form v1.0 – Depression 4a[30] is a four-question self-assessment evaluating negative mood (i.e. sadness, guilt), views of self-worth, as well as decrease of positive affect and engagement (i.e. loss of interest, meaning, purpose). This assessment does not evaluate somatic symptoms such as change in appetite or sleeping patterns and is universal rather than disease-specific.

2.2.6 Positive affect

The PROMIS Short Form v1.0 – Positive Affect 15a[31] is a 15-question self-assessment evaluating momentary positive or rewarding affective experiences such as feelings or moods associated with pleasure, joy, elation, contentment, pride, affection, happiness, engagement and excitement.

2.3 Data analysis

2.3.1 Independent variables

The study investigated the effects of phase (i.e. during lockdown vs. post-lockdown) and individual work status (i.e. working/staying at home full-time, working part-time at home and part-time at the office, or working full-time at the office) on participants' light exposures to assess how any changes in these variables may have affected participants' questionnaire scores. To understand individual indoor light exposures, the participants were asked to provide a subjective rating of the overall light level in the room where they spent the most time during the day (whether at home or at work) from 'very dim' to 'very bright.' To assess individual outdoor light exposures, participants were asked to indicate the amount of time they spent outside on a typical weekday (from <10 minutes to >2 hours) in addition to the time of day they typically spent the most time outside (from early morning to evening) during the previous week.

2.3.2 PROMIS instrument scoring

The PROMIS surveys were scored following the guidelines provided in manuals for each outcome measure (see section 2.2). Each scoring manual provided the methodology for calculating a t-score for each instrument. The t-score is a re-scaled standardized score with a mean of 50 and a standard deviation of 10. For an individual PROMIS instrument, a score of 50 is the average for the U.S. general population generated through wide-scale testing of a large U.S. population sample. The t-score is provided with a standard error of the mean, which is the statistical margin of error for the t-score.

A participant's t-score for each PROMIS instrument was determined by first calculating the raw sum-total of the measure, and then using a conversion table provided by the respective PROMIS instrument scoring manual. Each response for a given survey question was assigned a numerical value. For example, the anxiety survey response values were as follows: 'never' = 1; 'rarely' = 2; 'sometimes' = 3; 'often' = 4; 'always' = 5. For the four-question anxiety survey, the minimum raw sum for an individual participant was 4 (the participant selected 'never' for each of the four questions, representing the lowest amount of anxiety); and the maximum possible raw sum was 20 (the participant selected 'always' for each of the four questions, representing the maximum amount of anxiety).

Calculating t-scores using the scoring tables provided in the respective PROMIS instrument scoring manuals was only possible if a participant answered every question of a given survey. Therefore, participants who skipped even a single question in any PROMIS survey were excluded from the analysis of that survey.

The t-scores for the PROMIS Pediatric Psychological Stress Experiences instrument needed to be adjusted so that a score of 50 would represent the mean score of the general adult population (18 years of age or older.) To do this, the t-score scoring table from the NIH Toolbox adult version[32,33] of the stress survey was utilized to perform a conversion calculation. The NIH Toolbox is a set of neuro-behavioural measurements, similar to the PROMIS instruments, that are used to assess cognitive, emotional, sensory and motor functions based on a nationally representative sample set.

2.3.3 Statistical analyses

The effects of (1) study phase, (2) at-home light exposure, (3) time spent outdoors and (4) time of day spent outdoors, which were considered main factors in the analyses, were investigated with respect to (a) sleep disturbance, (b) sleep-related impairment, (c) anxiety, (d) stress, (e) depression and (f) positive affect. Three sets of univariate analyses used phase, and either at-home light exposure, time spent outdoors or time of day spent outdoors as fixed factors. Multiple comparisons with Sidak correction were performed when ANOVA revealed statistically significant effects due to main factors and/or their interactions. Fisher's exact test was used to analyse the dependency between variables because the sample sizes in Phase II were too small to achieve reliable Pearson's chi-square test results. Two-sided tests were performed when the Fisher's exact tests revealed statistically significant associations. The reported *p*-values were adjusted for multiple comparisons using the Bonferroni correction.

3. Results

3.1 Effects of phase on at-home light exposure and time spent outdoors

The analyses revealed that the proportion of participants who stayed at home in Phase I and spent <10 minutes outdoors (7.9%) was significantly ($p = 0.046$) greater than the proportion of participants who stayed at home in Phase II and spent <10 minutes outdoors (2.2%). It was also shown that the proportion of the participants who worked part-time in Phase II (42.1%) and spent >2 hours outdoors was significantly ($p = 0.004$) greater than the proportion of participants who stayed at home in Phase I and spent >2 hours outdoors (19.1%). There was no discernible difference in the proportions of participants staying at home in Phase I, staying at home in Phase II, working part-time in Phase II and working full-time in Phase II who spent 10–30 minutes, 30–60 minutes or 1–2 hours outdoors. The analyses, however, did not show significant study-phase associations with work status and at-home light exposure. Fisher's exact tests showed a statistically significant relationship between the pairs of work status and time spent outdoors ($p < 0.001$).

3.2 Effects of phase on questionnaire scores

There was a statistically significant main effect of phase for anxiety ($F(1, 732) = 4.471$, $p = 0.035$, $\eta_p^2 = 0.006$). Participants reported higher anxiety scores in Phase I compared to Phase II (Figure 1). There was neither a

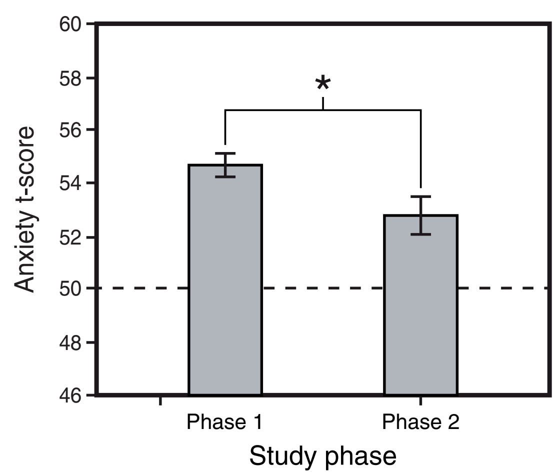

Figure 1 Estimated mean anxiety scores for each study phase. The dashed line represents the mean t-score (50) for the general U.S. adult population. Lower scores represent improvement in the outcome. The error bars represent standard error of the mean. The asterisk represents statistical significance (*$p < 0.05$)

significant main effect of time of day spent outdoors nor significant interactions between phase and time of day spent outdoors for any of the other outcome measures.

3.3 Effects of at-home light exposure on questionnaire scores

The two-way ANOVAs revealed statistically significant main effects of at-home light exposure on sleep disturbance ($F(4, 699) = 8.23$, $p < 0.001$, $\eta_p^2 = 0.045$); sleep-related impairment ($F(4, 682) = 6.17$, $p < 0.001$, $\eta_p^2 = 0.035$); anxiety ($F(4, 701) = 3.55$, $p = 0.007$, $\eta_p^2 = 0.020$); stress ($F(4, 697) = 10.09$, $p < 0.001$, $\eta_p^2 = 0.055$); depression ($F(4, 695) = 5.02$, $p = 0.001$, $\eta_p^2 = 0.028$); and positive affect ($F(4, 676) = 5.57$, $p < 0.001$, $\eta_p^2 = 0.032$). Neither the main effect of study phase nor the interaction between the effects of study phase and at-home light exposure were statistically significant.

Post hoc tests using the Sidak correction indicated that participants' sleep disturbance scores were significantly lower in the very bright group compared to the very dim ($p = 0.012$) and somewhat dim ($p < 0.001$) groups. The level of sleep disturbances in the somewhat dim group was also significantly higher compared to the neutral ($p = 0.007$) and somewhat bright ($p = 0.007$) groups (Figure 2(a)).

Participants in the very bright group had significantly lower sleep-related impairment scores compared to participants in the neutral ($p = 0.033$) and somewhat dim ($p < 0.001$) groups. The level of sleep-related impairment in the somewhat dim group was also significantly higher compared to the somewhat bright ($p = 0.012$) group (Figure 2(b)).

With respect to anxiety, participants in the somewhat bright group reported significantly lower scores than those in the somewhat dim ($p = 0.006$) group. None of the differences between other groups reached statistical significance after Sidak correction (Figure 2(c)).

Multiple comparisons for stress and depression, respectively, showed that participants in the somewhat dim group had significantly higher stress compared to participants in the neutral ($p < 0.001$, $p = 0.010$); somewhat bright ($p < 0.001$, $p < 0.001$); and very bright ($p < 0.001$, $p = 0.012$) groups (Figure 2(d,e)).

Positive affect in the very bright group was higher compared to the somewhat dim ($p < 0.001$) and neutral ($p = 0.034$) groups. Positive affect was also higher in the somewhat bright group compared to the somewhat dim ($p = 0.012$) group (Figure 2(f)).

3.4 Effects of time spent outdoors on questionnaire scores

The analyses revealed statistically significant main effects of time spent outdoors on sleep disturbance ($F(4, 718) = 5.381$, $p < 0.001$, $\eta_p^2 = 0.029$); sleep-related impairment ($F(4, 700) = 9.363$, $p < 0.001$, $\eta_p^2 = 0.051$); anxiety ($F(4, 720) = 4.814$, $p = 0.001$, $\eta_p^2 = 0.026$); stress ($F(4, 716) = 5.519$, $p < 0.001$, $\eta_p^2 = 0.030$); depression ($F(4, 714 = 3.377)$, $p = 0.009$, $\eta_p^2 = 0.019$); and positive affect ($F(4, 704) = 6.526$, $p < 0.001$, $\eta_p^2 = 0.036$). The main effect of phase and the interaction between the effects of phase and at-home light exposure, however, were not statistically significant.

Multiple comparisons showed that participants who spent 10–30 minutes outdoors had significantly higher sleep disturbance and sleep-related impairment scores, respectively, than participants who spent 1–2 hours ($p = 0.005$, $p < 0.001$) and >2 hours ($p < 0.001$, $p < 0.001$) outdoors (Figure 3(a,b)). Significantly higher sleep-related impairment scores were observed for those who spent 30–60 minutes outdoors compared to those who spent 1–2 hours ($p = 0.029$) and more than 2 hours ($p = 0.002$) outdoors (Figure 3(b)).

Anxiety scores were significantly lower for participants who spent 1–2 hours outdoors compared to those who spent 10–30 minutes

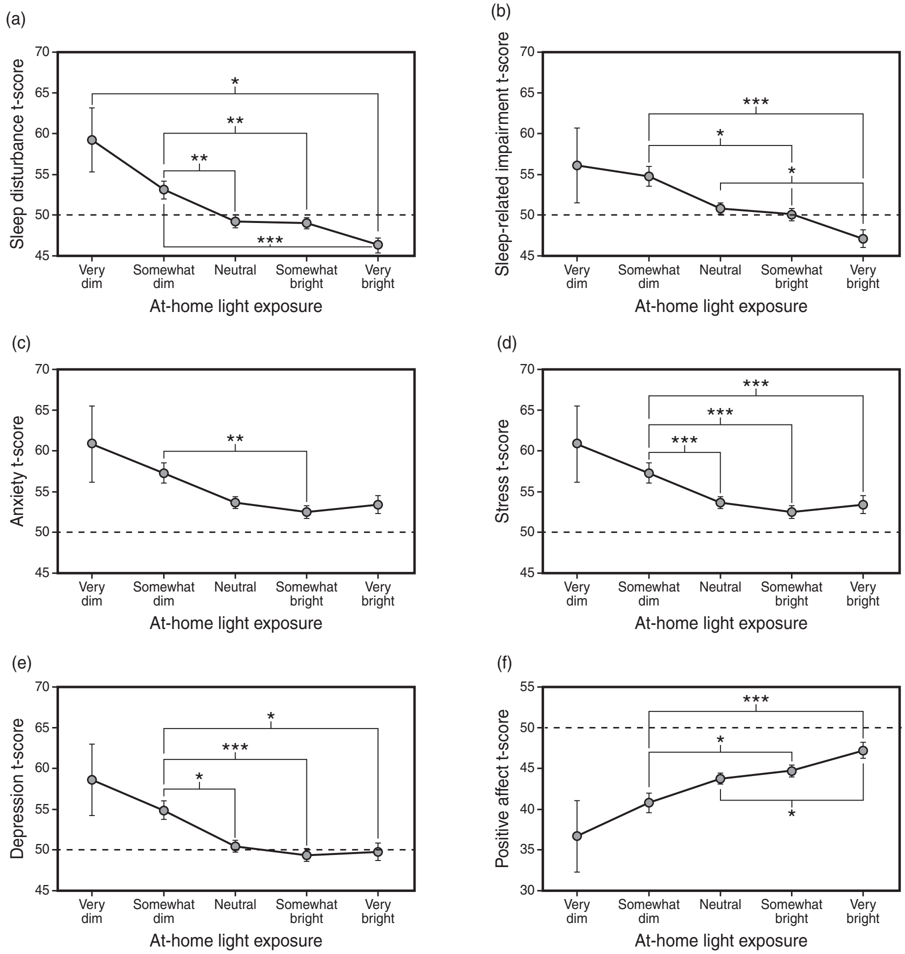

Figure 2 Estimated mean scores for at-home light exposures, study Phases 1 and 2 combined: (a) sleep disturbance, (b) sleep-related impairment, (c) anxiety, (d) stress, (e) depression and (f) positive affect. The dashed line in each panel represents the mean t-score score (50) for the general U.S. adult population. Lower scores represent improvement in the outcomes for panels (a)–(e), and higher scores represent improvement in the positive affect outcome (f). The error bars represent standard error of the mean. The asterisks represent statistical significance (*$p<0.05$, **$p<0.01$, ***$p<0.001$)

($p=0.014$) and 30–60 minutes ($p=0.039$) outdoors (Figure 3(c)). Participants' level of stress was also significantly lower for those who spent 1–2 hours outdoors than those who spent 10–30 minutes outdoors ($p=0.001$) (Figure 3(d)).

Multiple comparisons indicated higher positive affect scores for those who spent > 2 hours compared to those who spent 30–60 minutes ($p=0.004$) and 10–30 minutes ($p<0.001$) outdoors. Positive affect scores were also higher for participants who spent 1.2 hours outdoors compared to those who spent 10–30 minutes ($p=0.015$) outdoors (Figure 3(f)). Although participants' depression scores decreased by the amount of time they spent outdoors, none of the comparisons reached statistical significances after Sidak correction (Figure 3(e)).

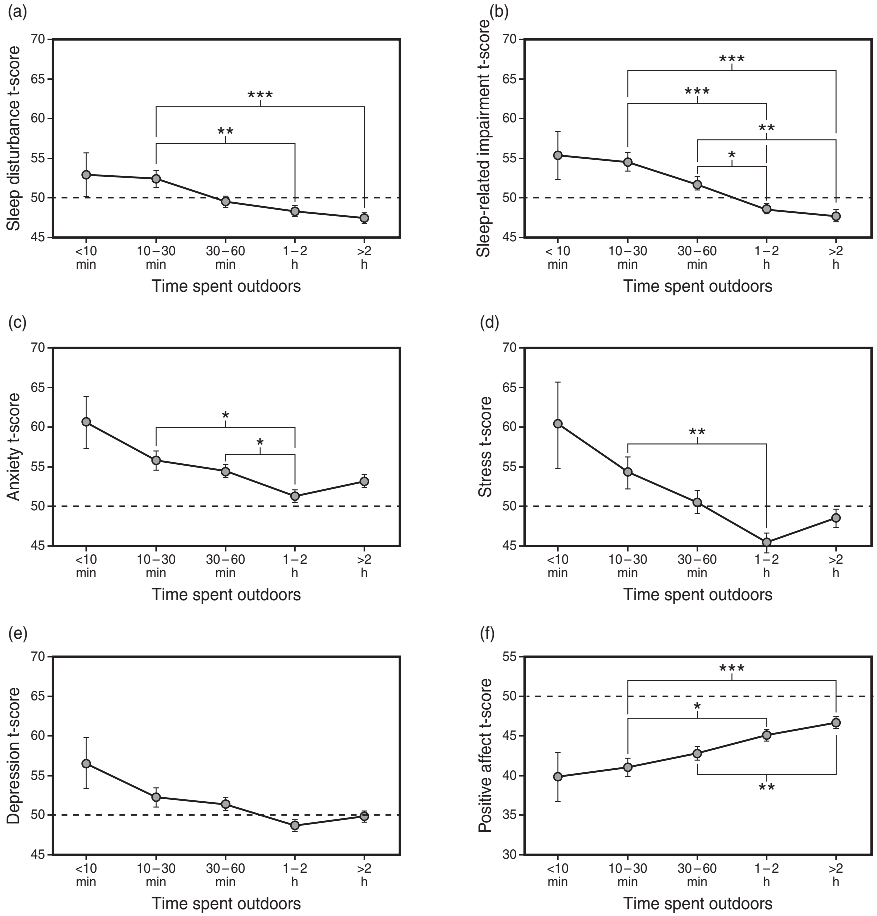

Figure 3 Estimated mean scores for time spent outdoors, study Phases 1 and 2 combined: (a) sleep disturbance, (b) sleep-related impairment, (c) anxiety, (d) stress, (e) depression and (f) positive affect. The dashed line in each panel represents the mean t-score (50) for the general U.S. adult population. Lower scores represent improvement in the outcomes for panels (a)–(e), and higher scores represent improvement in the positive affect outcome (f). The error bars represent standard error of the mean. The asterisks represent statistical significance (*$p<0.05$, **$p<0.01$, ***$p<0.001$)

4. Discussion

The survey data from over 700 participants over the two study phases confirm the results from various previous field studies showing that daytime light exposure is significantly correlated with night-time sleep and overall mood. In general, the greater the amount of light one is exposed to during the day (either in the home or outdoors), the better the self-reported sleep outcomes. Stress and mood were also correlated with higher self-reported daytime light exposures. The effect sizes showed that at-home light exposure or time spent outdoors were highly correlated with the stress and sleep measures. Everything else being equal, these results suggest that spending 1–2 hours outdoors or staying in a bright to very bright room indoors may improve night-time sleep. It should be noted, however, that the definition of a 'bright' to 'very bright' room indoors may vary among individuals, so a logical next step would be to measure indoor light exposures and correlate the resulting light measurements with self-reported results.

Although the sample size differed considerably between phases, we did not observe a statistically significant effect of phase on at-home light exposures, which makes sense as we did not expect those exposures to be different between phases. In terms of time spent outside, we only observed a significant effect of phase in participants who stayed at home and spent either <10 minutes or >2 hours outdoors. Fewer participants who stayed at home in Phase 2 spent <10 minutes outdoors. Furthermore, a greater number of participants who stayed at home in Phase 2 spent >2 hours outdoors than their Phase 1 counterparts. We also observed a significant effect of study phase on anxiety scores. Clearly, after six months of the pandemic, anxiety levels were reduced but the relationship between daytime light exposures and better sleep remained. This suggests that irrespective of where participants were working (i.e. home or office), the results support our previous findings that daytime light exposure is a significant factor in obtaining better night-time sleep.[18,19,34] It is also possible that there was a difference in light level exposures between homes and offices, but because this difference is small, a larger sample size in Phase 2 would be required to observe statistically significant effects.

It should be noted that up to now, the lighting industry's principal concern has been the optimal illumination of office and school buildings, but the COVID-19 pandemic has shifted the spotlight to the home lighting environment. The presence of lighting controls in the home environment becomes crucial because while daytime light exposures should be high, evening light exposures should remain below threshold for activating the human circadian system. It should also be noted that the circadian-effective light does not necessarily need to come from the ceiling. Users should consider the use of portable luminaires that can be placed near the work or study space. Employing light sources that change light levels and spectrum over the course of the day would ensure that users are exposed to circadian-effective light during the day and circadian-ineffective light in the evening.

These results underscore the importance of the newly proposed design guide by Underwriters Laboratory (UL 24480), which was developed by a committee of individuals representing a wide range of lighting stakeholders, from scientists, to manufacturers, to consultants to programme managers and underwent two rounds of published public comments.[35] That document provides guidelines for designing lighting for daytime people; that is, those who are awake during the day and asleep at night. Given that the characteristics of light for the circadian system are different from those of light for vision, that document provides a calculation method for achieving levels of illumination during the day that are bright enough to support circadian entrainment. Since there are a number of ways to calculate circadian-effective light, a procedure to compare calculation methods is also provided in the document. UL24880 was developed for public benefit. It was not developed to support conventional lighting industry interests, but it is sincerely hoped that this document provides the foundation for lighting innovations and practices that serve the public better than is common today.

Of course, and as noted above, a major limitation of the study is that we were unable to collect neither daytime nor evening light measurements. The study's light levels were subjectively assessed, and what might have been considered bright for some could have been rated as dim to somewhat dim for others. Finally, the present results are correlational and cannot be definitively interpreted as a prescription that greater exposures to daytime light will inevitably lead to better sleep at night. Nonetheless, despite these limitations, the fact that the results corroborate those from a previous field study, wherein light exposures were measured using a calibrated device (e.g. Figueiro *et al.*[19]), reinforces the strong correlation between daytime light exposures and better night-time sleep.

5. Conclusions

Good sleep is essential for good health, and may even have a protective effect against COVID-19 because a healthy, regular sleep pattern promotes a strong immune system.[36–38] For those who continue to work from home, or commute to and from work before sunrise and after sunset (e.g. during the winter months in northern latitudes), the following tips might be helpful for promoting better sleep at night and greater feelings of well-being during the day.

1) Spend 1–2 hours outdoors, especially in the morning after daybreak.
2) If one must stay indoors during the daytime, work facing a window. Open the window curtains or shades to let in daylight. Remember to keep ambient room lighting turned on during the day to reduce glare from the window.
3) If one does not have a window in the workspace, add more lighting fixtures. For example, if there is only a single table lamp near a desk, add three additional lamps to the space to deliver at least 350 lx of 3000 K or 300 lx of 5000 K light to the eye. Do not forget to turn off the extra lights later in the day and through the evening or place the table lamps on timers that will automatically turn off the extra lights in the evening.
4) In the evening, use warm, low-level, dim lighting and turn off your self-luminous displays 1–2 hours before bedtime. The intense glow from the screen can make it harder to fall asleep.

Another noteworthy potential benefit of working or quarantining at home is that one can have more control over the environment, such as setting up the workspace facing an open window. Everyone can also benefit from flexibility in the work schedule, and can choose to work or take breaks outdoors, which may not be an option when working at the office. These factors can increase daily light exposure, which is correlated with many benefits, as revealed by the present results.

For years, the lighting industry has been concerned with exposure to ‘too much light at night’ because of its negative consequences for health and well-being. It should not be forgotten, however, that light during the day is just as important as light at night. We need both, bright days and dark nights. This concept is true for both schools and office environments.

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