Handelshøyskolen BI

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Deltaker

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ved Handelshøyskolen BI

- Randomized controlled light intervention in an occupational setting and the effects on stress and work performance -

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Table of Contents

Contents

Abstract

Background: Coping with stress is crucial for the individual to retain a healthy work-life balance, work satisfaction and work performance. Light has powerful effects on mood, sleep, and the circadian biorhythms, and disruption of circadian biorhythms is associated with several diseases. Here we examine the relationship between positive stress and work performance, and if outdoor light exposure positively affects both stress and work performance.

Methods: We performed randomized controlled trial with light intervention with 18 subjects in a call center, and we assessed various parameters of work performance and stress.

Results: We identified positive correlation between some of the stress parameters and work performance parameters, including a positive correlation between work performance parameters and the affect part of the stress experience. We did not find such correlation with the perceived stress part or the circadian vulnerability part of the stress experience, nor with the stress arousal response. The light intervention did not positively affect the different stress parameters or work performance parameters.

Conclusions: Our studies constitute an important first pilot with regards to finding relationships between occupational stress and employee-level performance. We tested an intervention with outdoor lunchtime light exposure as a simple measure that can be easily adapted in work environments if supported by data. Hence, although our light intervention data did not confirm the partially beneficial effects of light exposure from our initial exploratory studies (Hypothesis #1), further studies of this exiting relationship is warranted, building on the suggested framework. A bigger size of the study population and a longer duration of the studies would be recommended for future studies.

1. Introduction and state-of-the-art

1.1 Motivation for our studies

Stress is a major factor contributing to sick leave in Norway, where 60 percent is due to mental illness and muscle ailments, which is often related to stress (Berg & Karlsen, 2016). Coping with stress is crucial for the individual to retain a healthy work-life balance, work satisfaction and work performance. The cost of individual stress can be high for organizations, both social and economic, because of employee turnover, absence due to illness, decreased job satisfaction and well-being and burn-out (Berg & Karlsen, 2013). We wanted to assess outdoor light exposure during lunchtime as one possible measure for organizations to implement that could potentially reduce stress and increase work performance. The reason for choosing outdoor light is that stress is related to biorhythms and light, and we wanted to see if a light intervention could positively affect both stress and work performance.

1.2 Light, circadian biorhythms, sleep and health

The predictable daily solar cycle of 24 hours profoundly affects environmental light, temperature and food availability (Foster & Kreitzman, 2017). Living organisms have evolved to anticipate this 24 hour cycle by developing internal biological oscillations known as circadian rhythms which constitute the human internal clock (Foster & Kreitzman, 2017). Examples of measurable oscillatory circadian changes between minimum values (nadir) and maximum values (zenit) in human beings include mood, alertness/sleep cycle, body core temperature, blood pressure and the secreted levels of the stress hormone cortisol (Foster & Kreitzman, 2017). In the absence of external signals that calibrate the internal 24 hour cycle - the so called entraining Zeitgebers (time-givers), the internal circadian rhythm will deviate from the 24 hour solar cycle entering periods between 22 and 25 hours – so called free run (Foster & Kreitzman, 2017). Among several Zeitgebers (light, temperature, food intake, physical activity, etc.), light has been shown to be the strongest regulator of circadian rhythms (Roenneberg & Foster, 1997). Studies have identified a direct pathway from the eye (retinal ganglion cells) to the master clock of the brain (suprachiasmatic nucleus) which regulates several of the circadian systems including sleep and hormones (i.e., melatonin and cortisol), and, in

particular, the blue-enriched light signals constitute the "daylight signal" (Foster & Kreitzman, 2017). Hence, during darkness and sleep, and in particular during the first three hours after sleep onset with deep sleep (deep non-rapid eye movement, REM, sleep), the release of the stress hormone cortisol is suppressed (Born & Fehm, 1998). By exposure to light and by wakening up, the cortisol levels increase significantly during a period of 20 minutes (Weibel, Follenius, Spiegel, Ehrhart, & Brandenberger, 1995), highlighting the link between light, circadian biorhythms, sleep and health. During the last hundred years, however, electrical light has become available, and the last 30 years we have witnessed the coming of computers, iPads and smartphones with screens emitting blue-enriched light close to the frequency of daylight, providing an alternative Zeitgeber to daylight that may potentially disrupt the circadian rhythm and lead to psychiatric illness (Foster & Kreitzman, 2017) and other adverse health effects (Gronli et al., 2016).

1.3 Light, circadian biorythms, sleep, stress and disease

Research conducted over the last 40 years has found a strong link between disruption of the human circadian system and adverse health effects, including chronic diseases such as depression, obesity, diabetes, cardiovascular risk, cancer and several other diseases (Smolensky, Hermida, Reinberg, Sackett-Lundeen, & Portaluppi, 2016; Zimmet et al., 2019). Sleep and circadian rhythm disruption (SCRD) is associated with poor health and psychiatric illness, and recent studies indicate that the presence of SCRD may lead to psychiatric illness or vice versa, with the subsequent activation of the hypothalamus-pituitary-adrenal (HPA) stress axis leading to increased cortisol secretion which drives several of the health problems mentioned above (Foster & Kreitzman, 2017).

"Psychological" stress and emotional events are also activating the HPA axis (Biondi & Picardi, 1999; Nejtek, 2002), and may or may not overlap with SCRD and psychiatric disease (Foster & Kreitzman, 2017). As the term "stress" is often ambiguous, it can be useful to operationalize stress as one of four aspects of stress:

1) The stress stimuli ("stressors")
2) The stress experience (how the stress stimuli are perceived/appraised; the same stressor can be perceived positively (eustress) or negatively (distress) dependent on the person and previous experiences and coping abilities)

3) The stress/arousal response (i.e., activated HPA axis with increased cortisol levels and the sympathetic nervous system activation with increased epinephrine levels)

4) The feedback from the stress response to the brain (the psychological experience of the stress response in 3) above) (Ursin & Eriksen, 2004).

These four aspects of stress may be measured by different methods that generate the following metrics corresponding to these four stress aspects:

a) Metrics of a "stressor" (i.e. a high workload with minimal control and low social support (Ursin & Eriksen, 2004) ; please see 1) above).

b) Metrics of perceived stress or emotion or circadian vulnerability (i.e. the Perceived Stress Scale, PSS (Cohen, Kamarck, & Mermelstein, 1983) or the Positive and Negative Affect Schedule, PANAS (Crawford & Henry, 2004) or the Horne Østerberg Morningness-Eveningness-Questionnaire (Horne & Ostberg, 1976); please see 2) above)

c) Metrics of the HPA output product (i.e., bedtime salivary cortisol (Ueland et al., 2021); please see 3) above)

d) Metrics of health effects (i.e., disrupted sleep as measured by polysomnography or SOMNOFY® sleep monitor. (Toften, Pallesen, Hrozanova, Moen, & Gronli, 2020); please see 4) above).

The stress response (please see c) above) occurs when the brain perceives a discrepancy between the expected situation (set value) and what is happening in reality (actual value) (please see b) above). The discrepancy may be at the stimulus-stimulus learning level (classic conditioning) or at the response-outcome level (instrumental conditioning), and the quantified level of discrepancy is based on acquisition strength (number of the repeats of the procedure, etc.), perceived probability (subjective perception of probability by the individual) and affective value (subjective, hedonic value of the expected outcome as judged by the individual) (Ursin & Eriksen, 2004). Based on this there are three major acquired expectancies and three corresponding stress/arousal responses at the response-outcome level:

a) Coping (expected positive outcomes of the responses leading to reduced arousal level)

b) Helplessness (expected no relationship between response and outcome leading to sustained arousal level)

c) Hopelessness (expected negative outcomes of the responses leading to sustained arousal level) (Ursin & Eriksen, 2004).

Hence, stress is an adaptive response which is sustained until the reason for the arousal is eliminated. Only sustained high arousal levels constitute a health risk (Ursin & Eriksen, 2004). In summary, **positive stress** (eustress) is an adaptive response characterized by low perceived stress (PSS), positive affects (positive PANAS), a short-term elevation of cortisol levels and no adverse health outcomes. In contrast **negative stress** (distress) is a maladaptive response characterized by high perceived stress (PSS), negative affects (positive PANAS), a long-term elevation of cortisol levels and adverse health outcomes, including dysregulated sleep.

Recent studies indicate that light exposure, and in particular bright white light containing all spectral components (blue, green, red and everything else) may increase short-term cortisol secretion (as a readout of increased HPA activity) (Petrowski, Buehrer, Niedling, & Schmalbach, 2021). It has also been shown that increased access to daylight in residential areas (comparing electrochromic glass to blinds) has beneficial effects on actigraph-recorded sleep duration, the sleep regularity index and sleep onset latency as well as on measures of positive affect (Nagare et al., 2021). Furthermore, a large study of 400 000 participants identified a dose-response-relationship between the number of hours of outdoor light exposure and correspondingly reduced levels of life-time major depressive disorder, antidepressant usage, anhedonia frequency and neurotism and increased levels of happiness and ease of getting up in the morning (Burns et al., 2021). These findings in conjunction with the beneficial effects of white light therapy (but not blue light) in seasonal depression (Do et al., 2022), may indicate that light exposure may increase "positive stress" (eustress) or restore a normal circadian rhythm and hence contribute to positive health effects or at least mitigating negative health effects.

1.4 Occupational "stressors", work satisfaction and work performance

Given the potentially important roles of positive and negative stress for work satisfaction and work performance, there have been several studies of stress-lowering interventions aimed at modulating the level of occupational "stressors" in occupational settings. Slutsky and co-workers identified that 6-week-training period of mindfulness lead to increased perceived job satisfaction in the high-dose group (Slutsky, Chin, Raye, & Creswell, 2019). Fazia and co-workers assessed the effects of a 12-week mindfulness-based intervention on several self-reported well-being measures (including PANAS, PSS and the Multidimentional Assessment of Interoceptive Awareness, MAIA) and identified improvements in four of eight MAIA subscales (emotional awareness, self-regulation, body listening and trusting) (Fazia et al., 2021). Guerrier and co-workers assessed the effect of a 4-week blue light exposure on the nursing-related stress (NSS) in 84 nurses in the operating theater, identifying a significantly lower NSS score in the intervention group (Guerrier, Margetis, Agostini, Machroub, & Di Maria, 2021). McGonagle and co-workers performed a randomized controlled trial (RCT) using a six-session psychology coaching intervention in primary care physicians and identified improved job satisfaction (measured by Job Self-efficacy scale) after the intervention, an effect that was sustained for six months (McGonagle et al., 2020). Hahn and co-workers used a psychological recovery training program intervention (two sessions separated by a week) and identified improved self-reported sleep quality and lower levels of perceived stress (PSS) and lower negative affects (negative PANAS) (Hahn, Binnewies, Sonnentag, & Mojza, 2011). Although there have been several interventions aimed at addressing environmental occupational stressors, including physical exercise (Lennefer, Lopper, Wiedemann, Hess, & Hoppe, 2020), food habits, tobacco, etc. (for an overview, please see (Anger et al., 2015)) we have not identified studies correlating light exposure, meditation or other interventions with stress parameters and real-time work performance metrics. A study by Hunter and Thatcher, however, identified that increased perceived stress (as measured by the Parker and DeCotiis scale) could improve performance metrics, and more convincingly with respect to revenue metrics than to a metric of the count of products sold (Hunter & Thatcher, 2007).

Outdoor light exposure seems to be a promising occupational "stressor" with beneficial effects, improving both mood, job satisfaction (An, Colarelli, O'Brien, &

Light intervention, stress and work performance

Boyajian, 2016), employee productivity and sleep quality (Bergefurt, Weijs-Perrée, Appel-Meulenbroek, & Arentze, 2022). In addition, workers with access to windows have been reported to have better wellbeing (as measured by SF-36) and to sleep better (as measured by actigraphy) compared to windowless workers (Boubekri, Cheung, Reid, Wang, & Zee, 2014). To our knowledge it is, however, not known to which extent outdoor light exposure may improve both positive stress and work performance in an occupational setting. The beneficial effects of outdoor light exposure for health have already been outlined above in Section 1.3. If outdoor light exposure would also beneficially influence stress and work performance, it would have important consequences for occupational practice. Hence, we aimed to investigate the effects of an outdoor light exposure intervention on these outcomes (stress and work performance).

2. Beyond state-of-the-art

2.1 Scientific question

In this study we are asking the following question:

Will a thirty minute lunchtime outdoor light exposure intervention beneficially modulate different stress metrics and subsequently the metrics of actual work performance?

2.2 Definitions of the parameters in the study

We define **stress** by the stress experience measured by the PANAS positive and negative, PSS and MEQ questionnaires (explained in section 1, adapted to Microsoft form from paper formats, please see attachments to this Master Thesis), the stress/arousal response by bedtime salivary cortisol levels (measuring upward deviation from the physiological evening drop) and the feedback from the stress response to the brain using the following sleep metrics measured by a SOMNOFY sleep radar (sleep latency, total time of sleep, time of REM sleep, time of deep sleep and social jet lag).

We define **beneficial stress or positive stress** as the Coping type of adaptive stress response (please see section 1.2), characterized by relatively lower perceived stress (PSS), relatively higher positive affects (positive PANAS), a short-term elevation of cortisol levels and no adverse health outcomes, including unchanged or improved sleep metrics (shorter sleep latency, longer total time of sleep, longer time of REM sleep and longer time of deep sleep).

We define **work performance** by the following work performance metrics: Number of customers, logged hours of inbound calls, number of calls received, average calls pr time, number of products sold, sales sum and customer satisfaction score per customer reporting.

2.3 Hypotheses

To settle the above-mentioned unanswered question, we have defined three working hypotheses:

We hypothesize that positive stress correlates positively with actual work performance (hypothesis #1).

Furthermore, we hypothesize that outdoor light exposure increases positive stress (hypothesis #2).

Finally, we hypothesize that outdoor light exposure increases work performance metrics (hypothesis #3).

Hence, from an operationalized perspective, we anticipate the following results:

Main hypothesis #1 anticipation: positive stress defined by increased average scores of positive PANAS will significantly improve actual work performance, i.e. there will be a significant positive correlation of positive PANAS with measurable work performance metrics (disregarding group status, i.e., disregarding whether the group is Light or Control). Subsequently, we will also assess other stress parameters in relationship to work performance metrics, including PSS (anticipated negative correlation), MEQ (anticipated positive correlation), bedtime salivary cortisol (anticipated positive correlation) and the sleep metrics (anticipated positive correlation).

Main hypothesis #2 anticipation: Outdoor light exposure will significantly increase positive stress during the intervention week (Week 2), defined by increased average scores of positive PANAS in the light exposure group compared to the control group (unpaired analysis) and to the levels before (week 1) and after (week 3) intervention (paired analysis). Subsequently, we will assess other stress parameters, including PSS (anticipated decreased level in Week 2), MEQ (anticipated increased level in Week 2), bedtime salivary cortisol (anticipated increased level in Week 2) and the sleep metrics (anticipated increased level in Week 2).

Main hypothesis #3 anticipation: Outdoor light exposure will significantly increase measurable work performance metrics during the intervention week (Week 2) in the light exposure group compared to the control group (unpaired analysis) and to the levels before (week 1) and after (week 3) intervention (paired analysis).

2.4 Experimental design

The experimental study design constitutes a randomized controlled trial (RCT) which has been run in parallel with a study of the effects of a short-term meditation program (please see the Master Thesis by Kalgraff and Bertelsen) exploiting the same control group. Randomization to the two study groups in our experiment was performed as described below in Section 4. We recruited the study participants in a Call Center in Tryg. Exclusion criteria: persons using glucocorticoids topically or orally. Following a baseline week (week 1), nine study participants were allocated to one week (week 2) of natural light intervention consisting of being outdoor (natural daylight) for 30 minutes at lunchtime (11 am -1 pm), whereas the control group had no intervention. There was no intervention in week 3 ("washout week"). We provided written and oral information to the study participants to improve compliance with the provided instructions.

2.5 Statistical methods

We investigated differences between the two groups at baseline characteristics and during the experiments using unpaired t-test for continuous variables assuming
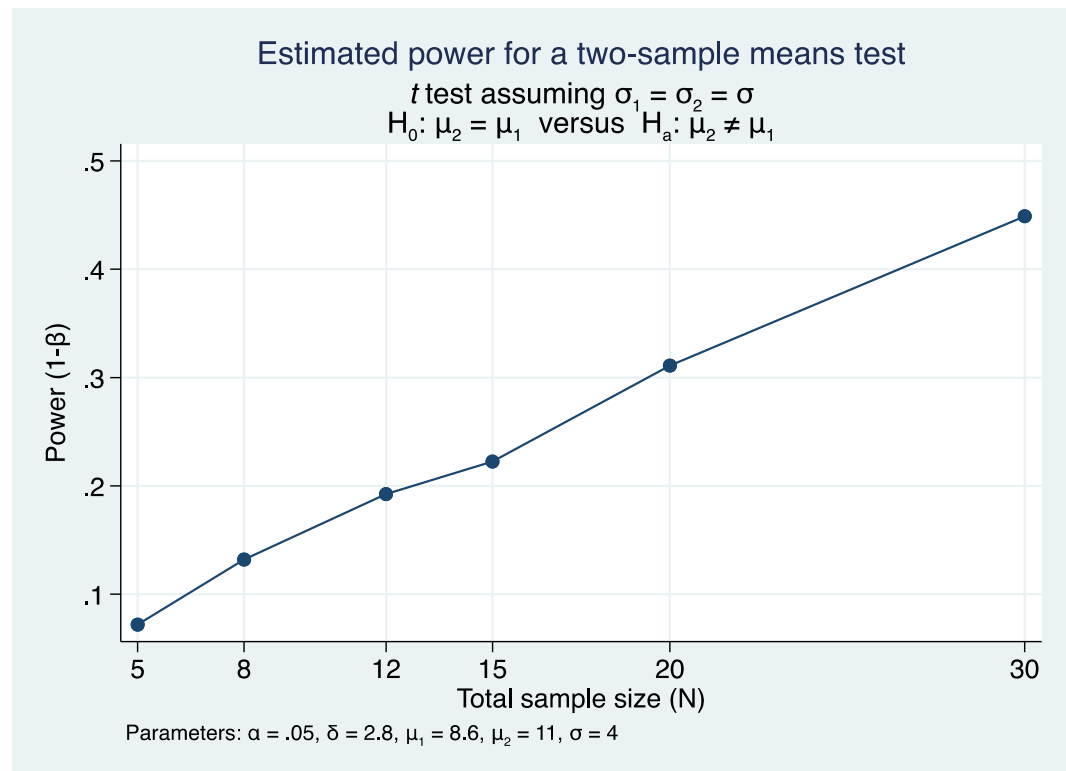
unequal variance between the two groups. We investigated differences between timepoints before, during and after interventions within each of the two groups using paired t-tests for continuous variables. We investigated correlations by estimating Pearson correlation coefficients. All data were analyzed using Stata 17 (Stata Statistical Software, Stata Corp., College Station, Texas, USA).

2.6 Power estimations and sample sizes

To estimate the required sample sizes, we extracted the reported effect sizes and variances reported in a previous comparable study by Petrowski and co-workers that reported the effects of dim vs bright light on the levels of salivary cortisol levels (Petrowski et al., 2021). Basing our power analysis on the reported metrics for salivary cortisol levels (Table 3 in (Petrowski et al., 2021)), we identified that the authors reported means ranging from 8.63 to 11.40 and standard deviations (SD) around 4. Using these metrics as input parameters, we used the following Stata syntax to calculate the power as a function of a variable number of n ranging from 5-30 (5 8 12 15 20 30):

power twomeans 8.63 11.40, n(5 8 12 15 20 30) sd(4) graph

Hence, we constructed the following power curve:

Estimated power for a two-sample means test
t test assuming $\sigma_1 = \sigma_2 = \sigma$
$H_0: \mu_2 = \mu_1$ versus $H_a: \mu_2 \neq \mu_1$

Parameters: $\alpha = .05$, $\delta = 2.8$, $\mu_1 = 8.6$, $\mu_2 = 11$, $\sigma = 4$

As illustrated in the graph we reach a power < 0.80 when including up to 30 subjects (in total) with parameters otherwise as specified in the figure. Hence, we have insufficient power with our design for the salivary cortisol data to detect meaningful differences. As for the other stress metrics (PANAS, PSS, MEQ, sleep metrics by sleep radar), there are no outdoor light intervention studies to our knowledge, from which we can extract average and SD values for power estimation. Hence, power analysis is limited by the absence of previous data. This provides an independent rationale for the study: We need to obtain pilot data for the other stress metrics and work performance metrics for future sample size calculation. Please see Section 5 for calculated Cohen d values to assess required sample size.

3 Subjects

Our experiment included 28 participants, with nine subjects in the light-exposure group, and nine and ten in each of the two control groups (Control group and Meditation group, respectively) as outlined in Figure 1 below. As the Meditation group was the subject of another Master Thesis (by Kalgraff and Bertelsen) it will not be described further. The demographic parameters of the study subjects are described in Table 1. Following a baseline week (Week 1: 14. February 2022 - 20.

Light intervention, stress and work performance

February 2022), nine employees were allocated to one week (Week 2: 21. February 2022 - 27. February 2022) of natural light intervention consisting of being outdoor (natural daylight) for 30 minutes at lunchtime (11 am -1 pm). The control group of nine people did not receive any instruction. All participants ended the experiment with a normal week ("washout week", Week 3: 28. February 2022 - 6. March 2022). The individuals were randomized in Week 1 to the groups by a randomization procedure as described in Section 4 below. We used a slightly modified consent and information form for all 28 subjects, and in addition we provided oral information meeting for these participants. The project was approved by the regional ethical committee (Project # 154991: Søvn og døgnrytme-hormoner under naturlig lys og mørke).

4   Methods

To measure the stress experience (ref 2 in Section 1.2 above), we distributed questionnaires for perceived stress (PSS (see attachment); (Cohen et al., 1983)), for emotion (PANAS (see attachment); (Crawford & Henry, 2004)) and for circadian stress vulnerability (Horne Østerberg Morningness-Eveningness-Questionnaire, MEQ (see attachment); (Horne & Ostberg, 1976)). To ensure a timely delivery of the questionnaires throughout the three-week experimental period as outlined in Figure 1 below, we developed electronic reporting systems for these questionnaires with digital prompts to ensure compliance. In short, PANAS (Positive and Negative Affect Schedule) uses a 5-point Likert scale which the study subjects use to rate 20 statements on affect and corresponding feelings. PANAS measures two general dimensions: Positive PANAS (questions 1, 3, 5, 9, 10, 12, 14, 16, 17 and 19) reflects a state of high energy and pleasure experience, whereas negative PANAS (questions 2, 4, 6, 7, 8, 11, 13, 15, 18, 20) is a state of general distress and unpleasurable engagement (Fazia et al., 2021). PSS also uses a 5-point Likert scale which the study subjects use to rate 10 items about feelings and thoughts. In general, high PSS scores reflect a greater stress perception with feeling of absent control and overload. MEQ uses a combination of a 4-point Likert scale (14 items) and time-scale questions (5 items). The lowest values of the Likert scale items indicate eveningness. Three of the time-scale items are divided into 15 minute intervals over a time period of 7 hours where each of five sections of the scale is assigned a value

of 1 through 5. Two of the time-scale items are divided into hourly intervals over a time period of 24 hours where each of five sections of the scale is assigned a value of 1 through 5. A global score is then calculated to provide the following five categories: definitely morning type (70–86), moderately morning type (59–69), neither type (42–58), moderately evening type (31–41), and definitely evening type (16–30).

To identify the internal reliability of our questionnaire data we used the Stata "alpha" command to calculate the following scale reliability coefficients (Cronbach alpha):

PANAS positive Week 1 measurement 1: 0.80

PANAS negative Week 1 measurement 1: 0.89

PANAS positive Week 1 measurement 2: 0.91

PANAS negative Week 1 measurement 2: 0.82

PANAS positive Week 1 measurement 3: 0.91

PANAS negative Week 1 measurement 3: 0.82

PANAS positive Week 1 measurement 4: 0.92

PANAS negative Week 1 measurement 4: 0.87

PANAS positive Week 2 measurement 1: 0.93

PANAS negative Week 2 measurement 1: 0.88

PANAS positive Week 2 measurement 2: 0.85

PANAS negative Week 2 measurement 2: 0.90

PANAS positive Week 2 measurement 3: 0.87

PANAS negative Week 2 measurement 3: 0.86

PANAS positive Week 2 measurement 4: 0.90

PANAS negative Week 2 measurement 4: 0.88

PANAS positive Week 3 measurement 1: 0.88

PANAS negative Week 3 measurement 1: 0.87

PANAS positive Week 3 measurement 2: 0.90

PANAS negative Week 3 measurement 2: 0.91

PANAS positive Week 3 measurement 3: 0.89

PANAS negative Week 3 measurement 3: 0.92

PANAS positive Week 3 measurement 4: 0.90

PANAS negative Week 3 measurement 4: 0.89

PSS Week 1: 0.78

PSS Week 2: 0.82

PSS Week 3: 0.86

MEQ Week 1: 0.86

MEQ Week 2: 0.81

MEQ Week 3: 0.81

To measure the stress/arousal response (ref 3 in Section 1.2 above), we measured secreted cortisol levels:

Cortisol measurement. We performed bedtime salivary cortisol hormone measurements (Ueland et al., 2021) twice a week (Wednesday and Thursday) over the three week period as outlined in Figure 1.

To measure the feedback from the stress response to the brain (ref 4 in Section 1.2 above) we measured sleep quality with a sleep radar:

Sleep radar. Sleep quality was assessed by a SOMNOFY® sleep monitor (Somnofy, Vital Things AS). The SOMNOFY® sleep monitor is a novel tool for sleep assessment, utilizing an impulse radio ultra-wideband (IR-UWB) radar and Doppler technology described in detail by Toften et al. (Toften et al., 2020). The IR-UWB radar emits radio wave pulses in the electromagnetic spectrum, which pass through soft materials (i.e., clothes or duvets), but are reflected by denser materials (i.e., the human body). As the pulses are reflected, they are returned and received by the IR-UWB radar. Time-of-flight to cover the distance between the radar to the object and back to the radar is calculated. The sleep monitor functions contactlessly and is unobtrusive to the subject. The movement and respiration rate of the sleeping person is derived from the IR-UWB radar by utilizing the Doppler effect and Fast Fourier Transform. In this way, SOMNOFY® can monitor the vital signs, movement, and respiration of the individual in bed with high precision. The raw data (movement and respiration) from the IR-UWB pulse radar are processed by algorithms built on deep neural networks machine learning to calculate relevant sleep variables. For this study, the following sleep variables were obtained during

the experimental period as outlined in Figure 1: seconds of sleep onset latency, total minutes of deep sleep, minutes of REM (rapid eye movement) sleep, sleep regularity index (Phillips et al., 2017) and social jet lag. The sleep algorithm has been validated to provide sleep stage classification with a precision close to the medical gold standard for sleep assessment: polysomnography (Toften et al., 2020).

Work performance data. The work performance data are already routinely collected in the Call Center, and we hence extracted the following data de-identified: the number of customers, the number of logged hours of inbound calls, the number of calls received, average calls pr time unit, the number of products sold, sales sum and customer satisfaction score (per customer reporting). The customer satisfaction score uses a value from 1 to 5, where 5 is the highest level of customer satisfaction. Tryg Forsikring provided these data at agent level for employees in the Contact Center in Bergen. The data was only delivered from Tryg when they have been deidentified and added to the research project's ID number for the individual participants. These extracts were performed by an analysis and reporting department in Tryg and the delivery did not contain names or other identifying information. Building on legislation related to GDPR and privacy, there are rules in Tryg that only the immediate manager and reporting departments have access to information at the individual level, and that this information is deidentified before forwarding, regardless of whether it is internal or external. We emphasize that the key that connects ID number and the name is stored by the researchers and was separate from the data to be analyzed, i.e., the researchers keep the file with the ID key, and do not share this information with Tryg. The research project provided a list of the participants in the project and their ID numbers in the project to Tryg. In return, the analysis and reporting department in Tryg supplied sales, satisfaction and telephony data at ID number level. It was not possible for external parties to identify anyone based on the analysis material for the project since information about ID number and associated name is stored separate from other data. The performance data retrieved here are otherwise only linked to KPIs that the employees have weekly and daily follow-up on themselves and together with the immediate manager. We also emphasize that there is no information about individual customers that has been processed by the case officers. All data has been

aggregated to day and week levels per agent so that no customers can be identified. This procedure was approved by the Regional ethical committee.

To assess the validity of the intervention we collected the following data:

Light and activity measurements. We applied the Actiwatch Spectrum (Philips), a watch-like accelerometer and photodiode sensor placed on the wrist, to continuously measure motor activity and light exposure (white and colored light) during the experimental protocol.

For the **randomization procedure**, we used the "rand" function in Excel to generate random numbers between 0 and 1. We generated 28 random numbers in the middle of Week 1 of the study corresponding to each study participant. The random numbers were then sorted in ascending order, and the first ten subjects were assigned to the meditation group, the next nine subjects to the light exposure group and the remaining nine subjects to the control (no intervention) group.

5   Results

We recruited 28 subjects from the Tryg Call Center to the randomized controlled study (**Figure 1**).
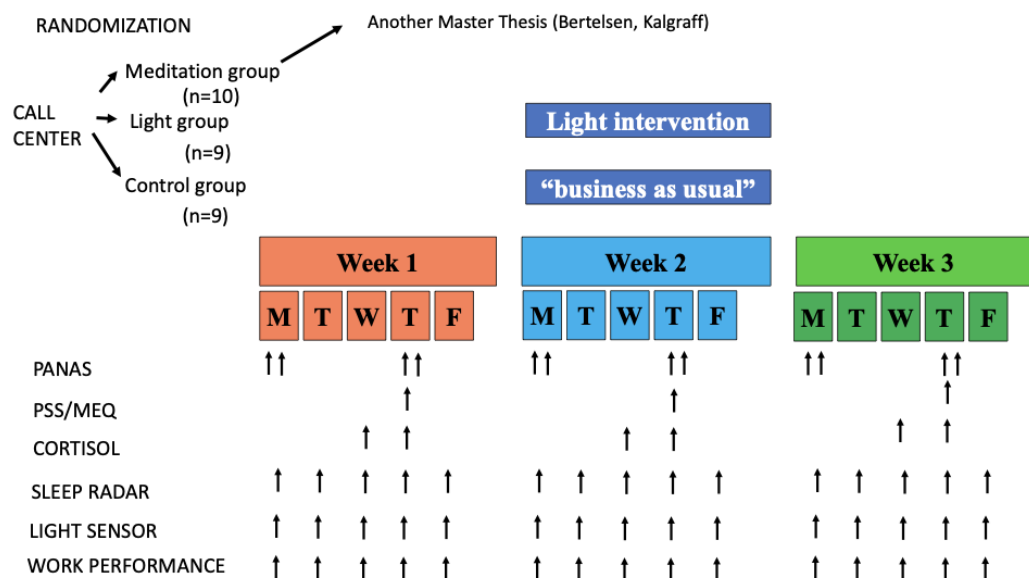

Figure 1. Design of the study. Light intervention included 30 minutes of outdoor light exposure between 11 am and 1 pm on each of the work days in Week 2. All study participants were also asked to avoid screen exposure 1 hour before sleep. Week 1 started February 14, 2022, Week 2 started February 21, 2022 and Week 3 started Februay 28, 2022. M=Monday, T=Tuesday, W=Wednesday, T=Thursday, F=Friday.

Figure 1 shows the outline of the experiment with a run-in period (Week 1, starting on a Monday), an intervention period (Week 2, starting on a Monday = day 1 of each week) and a wash-out period (Week 3, starting on a Monday). The study participants were asked to complete the PANAS questionnaire on the Monday morning (denoted with the suffix "m1"), Monday evening (denoted with the suffix "m2"), Thursday morning (denoted with the suffix "m3"), Thursday evening (denoted with the suffix "m4") for each of the three weeks of the project period. The study participants completed the PSS and MEQ questionnaires on Thursday and delivered the salivary cortisol samples on the Wednesday and Thursday of each study week at 10 pm. We observed no statistically significant differences of the baseline characteristics between the two study groups (**Table 1**).

Table 1   Baseline characteristics of the analyzed subjects

	Light group	Control group	p-value
Present age (age in years (SD))	34.6 (7.7)	31.4 (2.6)	0.28
Male (N (%))	2 (22%)	5 (56%)	
Female (N (%))	7 (78%)	4 (44%)	0.15

Age was tested using t test assuming unequal variance. Sex was tested using the Fisher exact test

In the intervention week (Week 2), we subjected the light exposure group to 30 minutes of outdoor light exposure each day between 11 am and 1 pm. The control group were not instructed to be exposed to daylight during this time period. **Figure 2** shows the light exposure of all study participants as measured in lux units (2 h between 11 am and 1 pm and 24 h) by the wristband actigraph as well as the measured activity data (24 h).
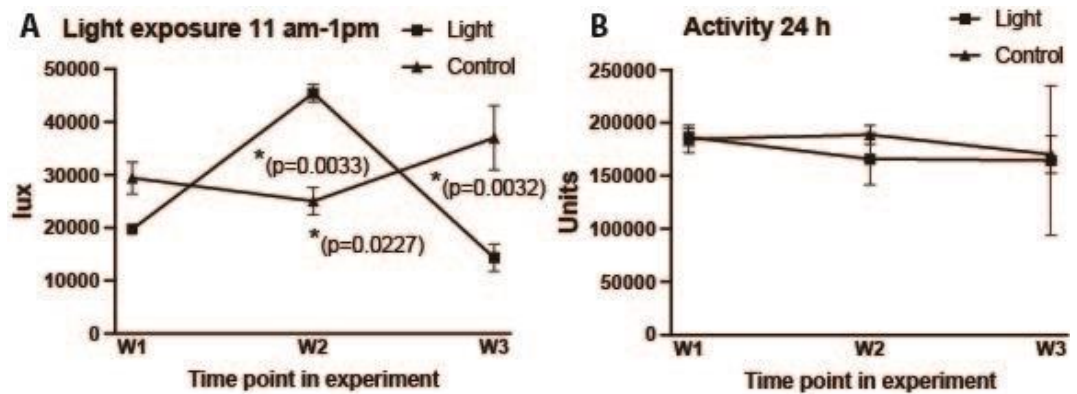
Figure2. Activity and light exposure measurements using the wrist Actigraph. A. Light exposure measured in lux, B. Activity measured in standard units. Abbreviations: W1 = week 1, W2 = week 2, W3 = week 3. . The error bars are Standard Errors. The data points were tested for significant differences between the two groups (unpaired analysis of Light vs Control; example of stata command: ttest w1l if group!=1, by (group) unequal) and for significant differences between timepoints (W1 vs W2 or W2 vs W3; example of Stata command: ttest w1l == w2l if group==2).. An asterix (*) denotes significant differences with corresponding p-values. In A. there was a significant difference between the Light group and the control group (p=0.0227) in week 2 and a significant difference in the pairwise analysis of W1 vs W2 in the Light group (p=0.0033) and in the pairwise analysis of W2 vs W3 in the Control group (p=0.0032).

Figure 2A showed as expected a significantly almost 2-fold increase in light exposure in the light exposure group (45439 lux vs 25020 lux in the control group, p = 0.0227) in week 2, whereas there were not significant differences between the light group and the control group in Week 1 and Week 3. There was also a significant 2.3-fold increase in light exposure from Week 1 to Week 2 in the light group (lux 19727 lux vs 45439 lux; p=0.0033). There were no significant differences in Activity counts between the the Light group and the Control group in any of the weeks, and the Activity counts did not change significantly in any of the groups during the three weeks (Figure 2B). Hence, our data supported the validity of the light exposure intervention.

Table 2 demonstrates overall outcomes during the course of the experiment (Week 1, 2, 3) of stress parameters (PANAS, PSS, MEQ, cortisol values and sleep parameters) and of performance parameters.

Table 2   Main Results of the intervention (95% confidence intervals)

	Week 1		Week 2		Week 3	
	Light	**Control**	**Light**	**Control**	**Light**	**Control**
PANAS-positive (score)						
-measurement #1	[26,36]	[27,35]	[26,35]	[20,34]	[25,35]	[23,31]
-measurement #2	[23,40]	[21,36]	[26,36]	[22,32]	[19,42]	[-3.2, 60]
-measurement #3	[25,35]	[24,38]	[26,36]	[21,34]	[24,40]	[23,33]
-measurement #4	[26,36]	[20,35]	[22,39]	[24,32]	[26,40]	[24,34]
PANAS-negative (score)						
-measurement #1	[12,27]	[13,22]	[11,24]	[11,22]	[14,19]	[8.7,26]
-measurement #2	[10,22]	[13,22]	[9.3,16]	[8.9,17]	[13,20]	[-54,85]
-measurement #3	[12,22]	[13,20]	[11,21]	[13,25]	[9.6,26]	[9.5,21]
-measurement #4	[10,17]	[12,19]	[13,25]	[12,28]	[9.8,23]	[9.0,23]
PSS (score)	[9.1,22]	[14,19]	[9.9,24]	[15,23]	[5.8,25]	[14,21]
MEQ (score)	[40,53]	[39,61]	[43,55]	[41,62]	[42,56]	[46,60]
Salivary cortisol (nM/L)						
-measurement #1	[0.24,1.7]	[0.47,0.62]	[0.50,0.95]	[0.096,0.76]	[0.38,0.89]	[0.25,0.70]
-measurement #2	[0.52,1.5]	[0.063,1.0]	[-0.18,4.0]	[0.34,0.69]	[0.63,1.2]	[0.35,0.53]
Total sleep (kilo s)	[22,28]	[21,29]	[22,28]	[18,28]	[21,29]	[19,29]
Deep sleep (kilo s)	[3.7,5.4]	[3.9,5.0]	[3.5,5.0]	[2.7,4.7]	[3.3,4.8]	[3.2,5.0]
REM sleep (kilo s)	[4.5,6.5]	[5.2,6.7]	[4.9,6.4]	[4.2,6.9]	[4.7,7.3]	[4.1,7.3]
Sleep onset latency (kilo s)	[1.0,1.9]	[0.67,2.3]	[1.3,2.4]	[0.33,2.5]	[0.86,3.0]	[0.29,5.4]
SRI (index score)	[74,88]	[75,92]	[66,86]	[55,89]	[66,85]	[57,76]
Social jet lag (h)	[-0.48,1.4]	[-0.97,1.8]	[-0.52,0.79]	[-0.18,1.6]	[-2.4,5.9]	[1.4,3.2]
Customer satisfaction score	[4.3,4.8]	[4.7,4.8]	[4.6,4.9]	[4.5,4.9]	[4.5,4.9]	[4.5,4.8]
Number of hours the customer service representative was logged in the phone system	[30,41]	[33,40]	[23,45]	[22,40]	[18,38]	[30,38]
Number of hours spent in conversation with customers	[9.3,13]	[12,16]	[7.1,13]	[9.1,14]	[6.3,12]	[9.2,14]
Number of calls answered						

Light intervention, stress and work performance

for the week	[119,169]	[127,173]	[89,170]	[93,171]	[70,147]	[112,157]
Number of calls per logged						
in hour	[3.5,4.7]	[3.5,4.7]	[3.4,4.3]	[3.9,4.7]	[3.5,4.4]	[3.4,4.5]
Sum of sales for the						
week (KNOK)	[47.4,119]	[56.0,132]	[26.5,105]	[37.4,107]	[42.8,86.7]	[53.4,96.7]
Number of products sold	[8.5,20]	[10,28]	[4.8,18]	[13,23]	[10,18]	[11,21]
Sales per hour logged in						
to phone system (KNOK)	[1.3,3.3]	[1.5,3.6]	[0.94,3.1]	[1.6,3.1]	[1.3,4.2]	[1.4,3.2]
Sales per hour in conversation						
with customers (KNOK)	[3.9,11]	[4.3,9.1]	[3.0,10]	[4.0,8.0]	[3.7,13]	[3.9,10]

All values at 95% Confidence intervals.

Table 2. Main outcomes

To test Hypothesis #1 (testing whether positive stress correlated positively with actual work performance) we next studied the correlations (Pearson correlation coefficients) between the positive stress parameters and work performance parameters in Week 1 to avoid confounding effects of the intervention itself. We disregarded the group status (Light exposure group or Control) and pooled all subjects into one group as Week 1 was prior to the intervention. As stated in Section 2.2 we defined positive stress as lower PSS, higher positive PANAS, short-time elevated salivary cortisol and no worsening of the sleep parameters. **Table 3** shows a correlation matrix displaying the correlation coefficients for the correlations between the stress parameters (rows) and work performance parameters (columns). Significant correlations are displayed with an asterix (*). **Figure 3** shows correlation plots for the pairs of stress parameters and work parameters where we identified significant correlations. We identified positive correlations for some of the stress parameters (PANAS, Deep Sleep and Sleep Regularity Index, SRI) with some of the work performance parameters (Sum of Sales for the Week, Number of products sold, Sales per hour logged in to the phone system and Sales per hour in conversation with customers). Specifically, we identified support for Hypothesis #1 with regards to the affect part of the stress experience (positive PANAS; $R = 0.57/p=0.0137$ for Sum of Sales for the Week; **Figure 3A**, $R=0.55/p=0.0174$ and $R=0.55/p=0.042$ for the Number of products sold; **Figure 3D** and **3E** respectively, $R = 0.56/p=0.0158$ and $R=0.57/p=0.0327$ for the Sales per logged in hour to the phone system; **Figure 3F** and **3G** respectively, and $R = 0.59/p=0.0106$ and

Light intervention, stress and work performance

R=0.55/p=0.0428 for the Sales in hour in Conversation with customers; **Figure 3G** and **3H** respectively). We did not find support for the perceived stress part (PSS; **Table 3**) or the circadian vulnerability part (MEQ; **Table 3**) of the stress experience. We also did not identify support for the stress/arousal response (Salivary cortisol levels; **Table 3**). We did however identify support for the feedback from the stress response to the brain with regards to Deep sleep (R = 0.57/p=0.0161 for Sum of Sales for the week; **Figure 3B**, R = 0.52/p=0.0311 for Sales per logged in hour to the phone system; **Figure 3H**, and R=0.61/p=0.0094 for Sales in hour in Conversation with customers; **Figure 3L**) and Sleep Regularity Index (R = 0.69/p=0.0198 for Sum of Sales for the week; **Figure 3C**, R = 0.67/p=0.0254 for Sales per logged in hour to the phone system; **Figure 3I**, and R=0.64/p=0.0451 for Sales in hour in Conversation with customers; **Figure 3M**). We did not identify support for Total Sleep, REM sleep or sleep onset latency. To conclude this section, our data partly supported Hypothesis #1, warranting the further exploration of the Hypotheses #2 and #3.

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP9	WP9
PANAS pos									
-m#1	0,04	0,16	0,15	-0,40	-0,59*	0,57*	0,55*	0,56*	0,59*
-m#2	-0,09	-0,24	-0,10	-0,53	-0,47	0,49	0,55*	0,57*	0,55*
- m#3	-0,11	0,12	0,54	-0,19	-0,27	0,38	0,45	0,40	0,36
- m#4	-0,41	0,19	0,11	0,05	-0,04	0,23	0,13	0,24	0,29
PSS	0,01	-0,63*	-0,47	-0,27	0,16	-0,40	-0,30	-0,28	-0,32
MEQ	0,19	-0,04	-0,13	-0,13	-0,10	0,02	-0,24	-0,03	0,10
Cortisol m#1	-0,06	0,00	0,32	-0,24	-0,23	0,00	0,14	0,00	-0,12
Cortisol m#2	-0,19	0,02	-0,14	0,08	0,13	-0,01	0,04	0,00	0,07
Total Sleep	0,18	-0,17	-0,26	-0,17	-0,07	0,05	0,21	0,13	0,15
Deep Sleep	0,08	0,37	0,18	0,46	0,19	0,57*	0,31	0,52*	0,61*
REM Sleep	0,18	0,04	-0,05	0,24	0,22	0,07	0,04	0,06	0,09
Sleep latency	0,07	0,02	0,23	0,75	0,10	0,28	0,21	0,26	0,21
SRI	-0,11	0,26	0,36	0,45	0,24	0,69*	0,54	0,67*	0,64*
Social Jetlag	0,00	0,05	-0,11	0,27	0,30	0,06	-0,32	-0,02	0,17

Table 3. Correlation matrix showing Pearson correlation coefficients. The row headings show stress parameters. m#1 denotes measurement #1, etc. as explained in more detail in Figure 1. The column headings show work performance (WP) parameters. These WPs are defined as follows:

WP1:   Average customer satisfaction score

WP2:   Number of hours the customer representative was logged in to the system

WP3:   Numbers of hours spent in conversation with customers

WP4:   Number of calls answered for the week

WP5:   Number of calls per logged in hour

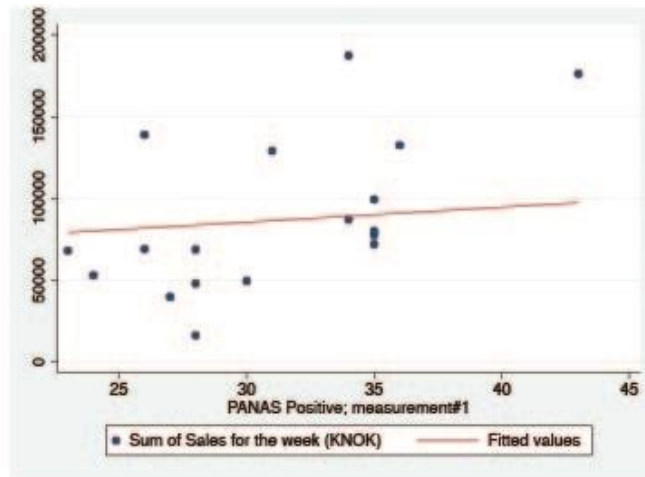*WP6:   Sum of sales for the week*

WP7:   Number of products sold

WP8:   Sales per hour logged in to the phone system

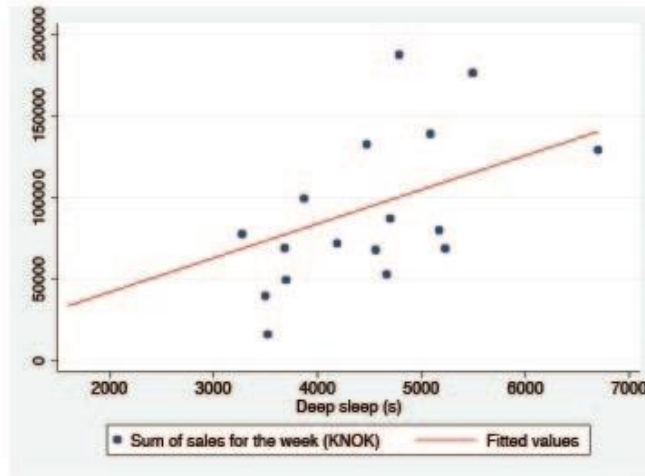*WP9:   Sales per hour in conversation with customers*

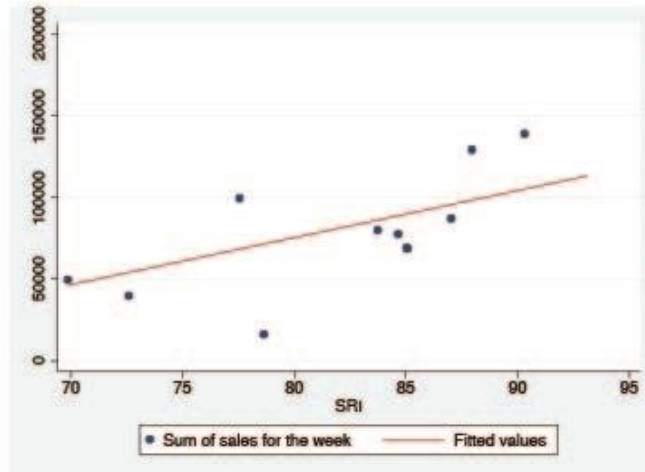*Significant correlation coefficients are shown with an asterix (*).*

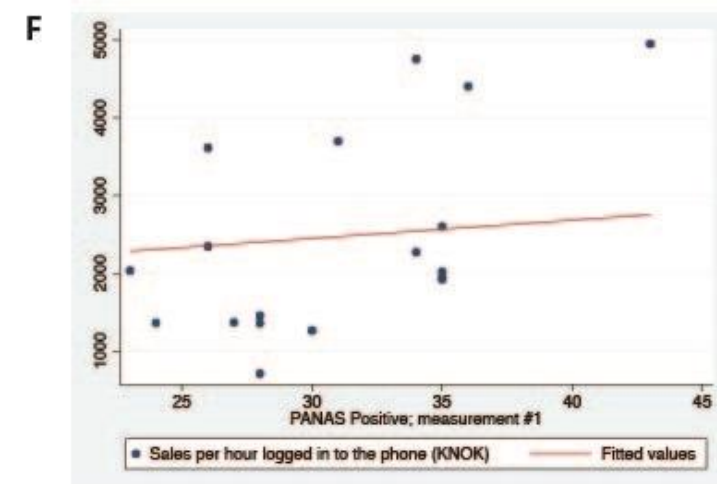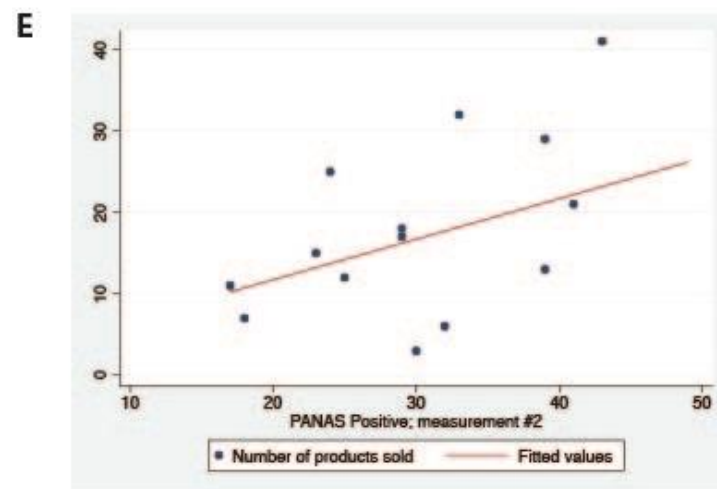*Light intervention, stress and work performance*

A

R = 0.57

p = 0.0137

B

R = 0.57

p = 0.0161

C

R = 0.69

p = 0.0198

Light intervention, stress and work performance

D

$R = 0.55$

$p = 0.0174$

E

$R = 0.55$

$p = 0.042$

F

$R = 0.56$

$p = 0.0158$

Light intervention, stress and work performance
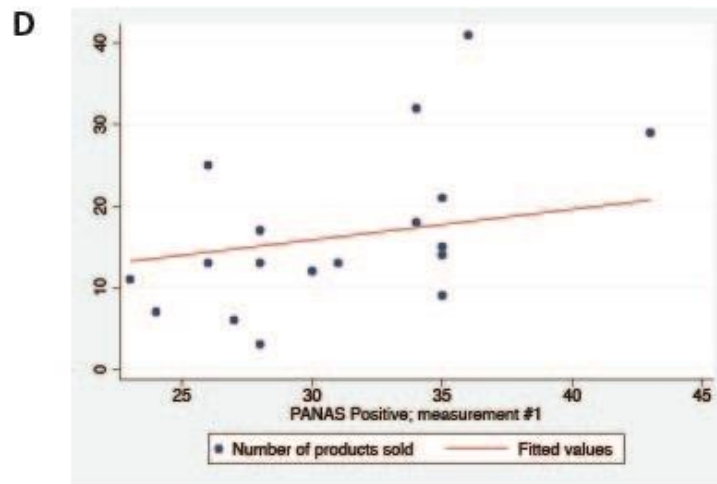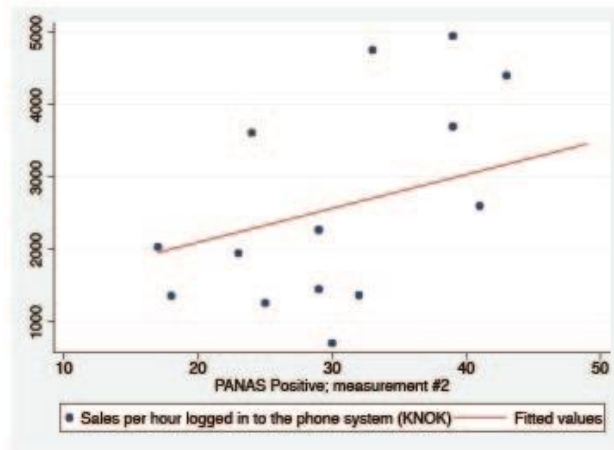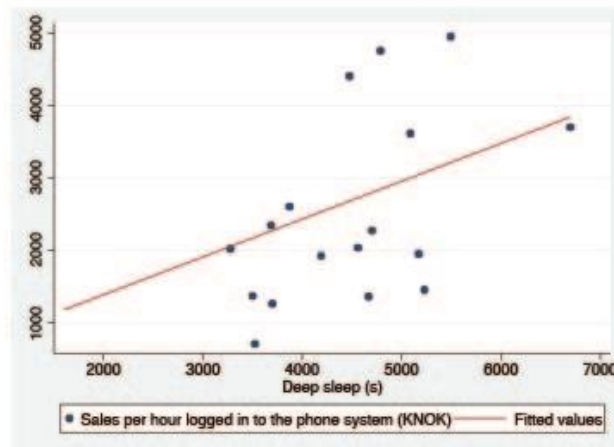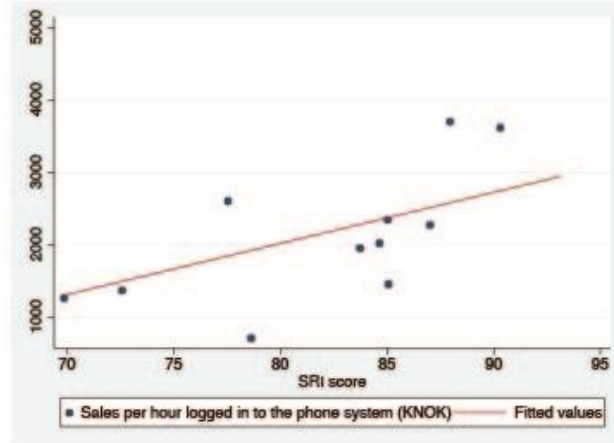
G

R = 0.57

p = 0.0327

H

R = 0.52

p = 0.0311

I
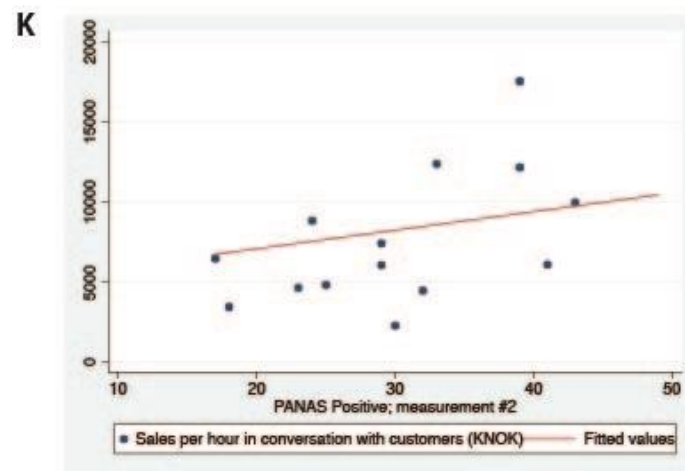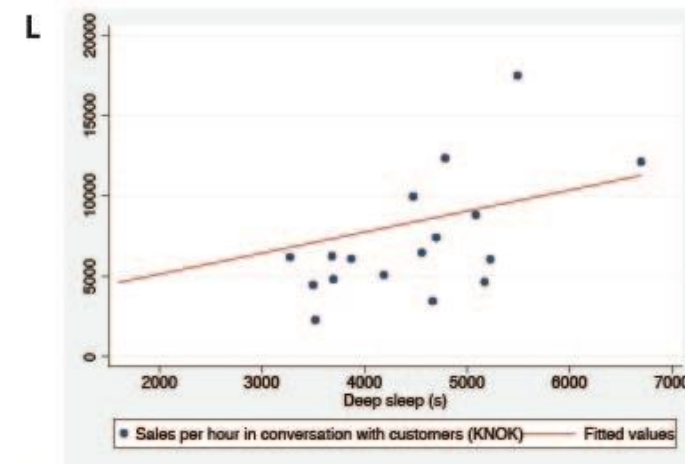

R = 0.67

p = 0.0254

J

$R = 0.59$

$p = 0.0106$

K

$R = 0.55$

$p = 0.0428$
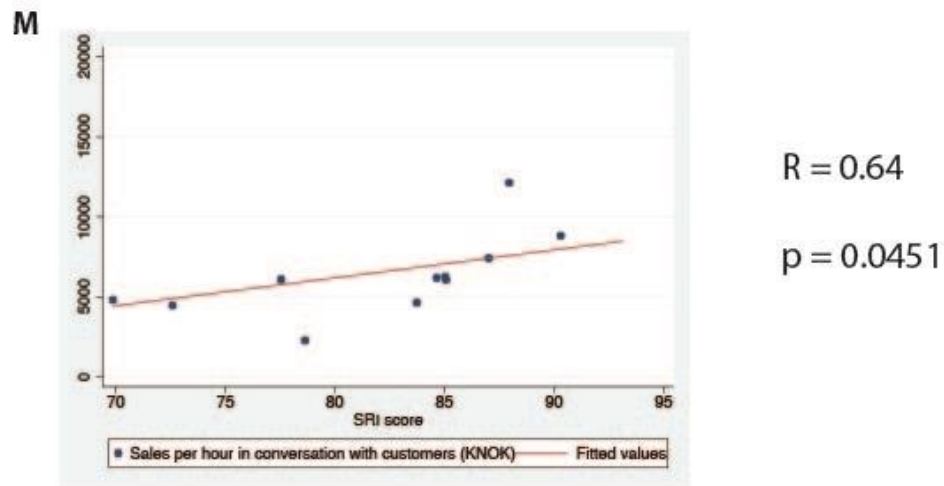
L
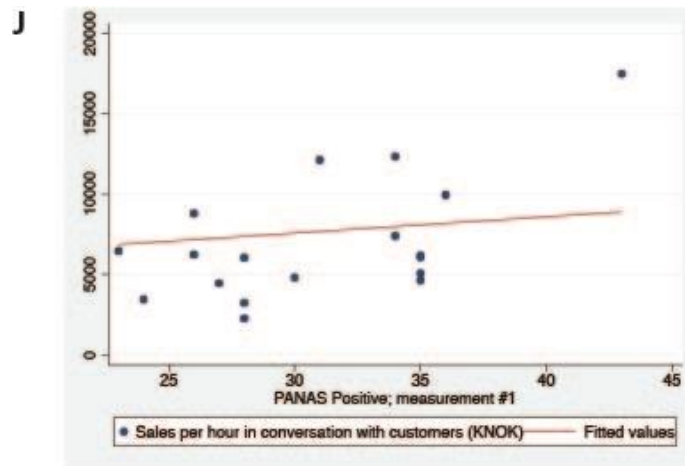
$R = 0.61$

$p = 0.0094$

Figure 3. Correlation plots with Pearson correlation coefficients and p-values for the selection of correlations that were significant. The stress parameters are displayed on the x-axis, whereas the work performance parameters are displayed on the y-axis.   A. Sum of Sales of the week vs PANAS positive measurement #1. B. Sum of Sales of the week vs Deep sleep. C. Sum of Sales of the week vs SRI (Sleep regularity index). D. Number of products sold vs PANAS positive measurement #1. E. Number of products sold vs PANAS positive measurement #2. F. Sales per hour logged in to the phone system vs PANAS positive measurement #1. G. Sales per hour logged in to the phone system vs PANAS positive measurement #2. H. Sales per hour logged in to the phone system vs Deep sleep. I. Sales per hour logged in to the phone system vs SRI (Sleep regularity index). J. Sales per hour in conversation with customers (KNOK) vs PANAS positive measurement #1. K. Sales per hour in conversation with customers (KNOK) vs PANAS positive measurement #2. L. Sales per hour in conversation with customers (KNOK) vs Deep sleep. M. Sales per hour in conversation with customers (KNOK) vs SRI (Sleep regularity index).

To address Hypothesis #2, we next studied the effects of the outdoor light exposure intervention on the parameters of the stress experience (PANAS, PSS, MEQ; **Figure 4**), the parameters for the stress/arousal response (salivary cortisol; **Figure 5**) and the parameters for the feedback from the stress response to the brain (sleep parameters; **Figure 5**) during the three experimental weeks. As for parameters of the stress experience we found no significant differences in positive (**Figure 4A**) or negative (**Figure 4B**) PANAS (positive and negative affection) levels between the Light group and the Control group before (Week 1), during (Week 2) or after (Week 3) intervention. There were also no significant differences from Week 1 to Week 2 or from Week 2 to Week 3 within these two groups. We found no significant differences in the Perceived Stress Scale (PSS) levels (**Figure 4C**) between the Light group and the Control group before (Week 1), during (Week 2) or after (Week 3) intervention. We found, however, a significant reduction in the PSS score from Week 2 to Week 3 in the Light group (p=0.0255), but not in the Control group. We found no significant differences in the Horne-Östberg Morningness Eveningness

Questionnaire (MEQ) levels (**Figure 4D**) between the Light group and the Control group before (Week 1), during (Week 2) or after (Week 3) intervention. There were also no significant differences from Week 1 to Week 2 or from Week 2 to Week 3 within the two groups.
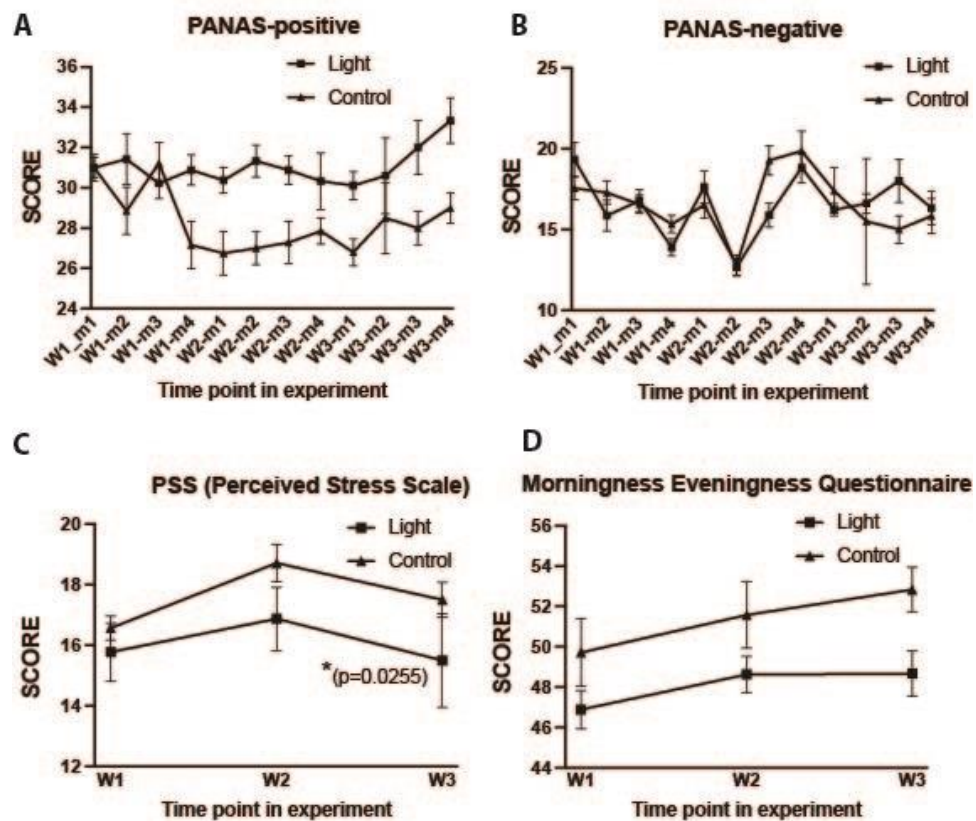

Figure 4. Levels of subjective stress during the experimental period for the Light group compared to the Control group. A. PANAS -positive, positive and negative affection scale, summed for the positive attributes, B. PANAS -negative, positive and negative affection scale, summed for the negative attributes, C. PSS (Perceived Stress Scale), D. MEQ (Horne-Östberg Morningness Eveningness Questionnaire). The error bars are Standard Errors. Abbreviations: W1 = week 1, W2 = week 2, W3 = week 3. m1 = measurement #1 (Monday morning), m2 = measurement #2 (Monday evening), m3 = measurement #3 (Thursday morning), m4 = measurement #4 (Thursday evening). The error bars are Standard Errors. The data points were tested for significant differences between the two groups (unpaired analysis of Light vs Control; example of stata command: test panas_w1_m1positive if group!=2, by (group) unequal) and for significant differences between timepoints (W1 vs W2 or W2 vs W3; example of Stata command: test panas_w1_m1positive == panas_w2_m1positive if group==1). For the paired PANAS analyses, we compared W1-m1 vs W2-m1, etc. An asterix (*) denotes significant differences with corresponding p-values. In C. there was a significant difference in the pairwise analysis of W2 vs W3 in the Light group.

Light intervention, stress and work performance

As for the parameters for the feedback from the stress response to the brain, we found no significant differences in Total sleep (**Figure 5A**), Deep sleep (**Figure 5B**), REM sleep (**Figure 5C**), Sleep onset latency (**Figure 5D**), Sleep Regularity Index (SRI, **Figure 5E**) or Social Jet Lag (**Figure 5F**) between the Light group and the Control group before (Week 1), during (Week 2) or after (Week 3) intervention. There were also no significant differences from Week 1 to Week 2 or from Week 2 to Week 3 within the two groups for these sleep parameters, except for Total sleep (**Figure 5A**) and Deep Sleep (**Figure 5B**) between Week 1 and Week 2 in the Control group. For the stress/arousal response metrics, we found that nighttime salivary cortisol levels showed no significant differences between the Light group and the Control group before (Week 1), during (Week 2) or after (Week 3) intervention, except for a significantly increased level at measurement #2 in week 3 in the Light group (**Figure 5G;** p=0.0067). There were no significant differences from Week 1 to Week 2 or from Week 2 to Week 3 within the two groups.

To conclude this section, our data did not sufficiently support that outdoor light exposure increased positive stress (Hypothesis #2). The only exception was a significant reduction in perceived stress (PSS) from Week 2 to Week 3 in the Light exposure group (which was not observed in the Control group). The significant increase in measurement #2 of cortisol in week 3 was not identified in measurement #1 of week 3 and could represent a spurious finding (Please see Section 6 Discussion).

As an alternative means to assess the sample size, we estimated the Cohen d values based on salivary cortisol levels in Week 1 (measurement #1) using the Stata command:

```
cohend cort_w1_d1 group if group!=1
```

We identified a Cohen's d of 0.64 and a Cohen's d corrected for uneven groups of 0.65. The Cohen´s d for other time points of salivary cortisol were as follows: Week 1 measurement #2: 0.80; Week 2 measurement #1: 0.96; Week 2 measurement #2: 0.82; Week 3 measurement #1: 0.72; Week 3 measurement #2: 2.19 These Cohen d values corresponds to a medium to large effect size.
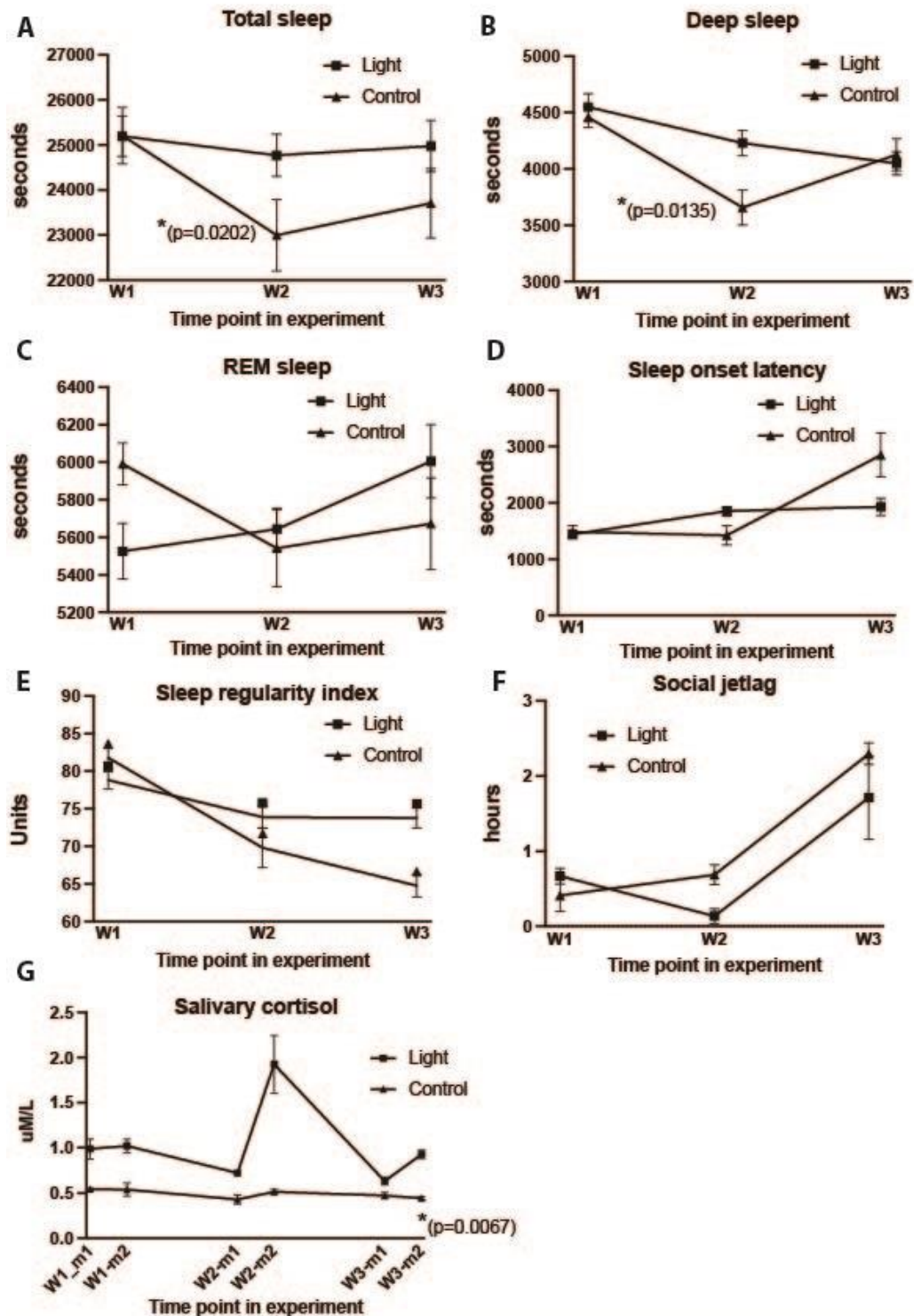
Figure 5. Levels of objective stress during the experimental period for the Light group compared to the Control group. A. Total sleep, B. Deep sleep, C. REM sleep, D. Sleep onset latency (I.e., time from intended sleep to sleep onset), E. Sleep regularity index. This index calculates the percentage probability of an individual being in the same state (asleep vs. awake) at any two time points 24 h apart, averaged across the study. The index is scaled so that an individual who sleeps and wakes at the same times each day scores 100, whereas an individual

Light intervention, stress and work performance

who sleeps and wakes at random scores 0, F. Social Jetlag is calculated as difference between the averages of midsleep with regards to midnight comparing weekdays (Monday-Friday) with Weekends (Saturday-Sunday). G. Salivary cortisol levels at 10 p.m. measured in mikromolar per liter. Abbreviations: W1 = week 1, W2 = week 2, W3 = week 3. m1 = measurement #1 (Wednesday evening), m2 = measurement #2 (Thursday evening). The error bars are Standard Errors. The data points were tested for significant differences between the two groups (unpaired analysis of Light vs Control; example of stata command: ttest sleep_onset_latency_w1_sum if group!=2, by (group) unequal) and for significant differences between timepoints (W1 vs W2 or W2 vs W3; example of Stata command: ttest sleep_onset_latency_w1_sum == sleep_onset_latency_w2_sum if group==2). For the paired salivary cotisol analyses, we compared W1-m1 vs W2-m1, etc. An asterix (*) denotes significant differences with corresponding p-values. In A. there was a significant difference in the pairwise analysis of W1 vs W3 in the Control group. In B. there was a significant difference in the pairwise analysis of W1 vs W2 in the Control group. In C. there was a significant difference in the analysis of Light vs Control group in W3-m2.

Finally, we studied the effects of the intervention on work performance parameters during the three experimental weeks (**Figure 6**). We found a significant difference in Customer satisfaction score (**Figure 6A**) and Number of hours spent in conversation with customers (**Figure 6D**) between the Light group and the Control group before (Week 1), but not during (Week 2) or after (Week 3) intervention. There were no significant differences in Number of calls answered for the week (**Figure 6B**), Number of calls per logged in hour (**Figure 6C**), Number of hours that the customer representative was logged in the phone system (**Figure 6E**), Number of products sold (**Figure 6F**), Sum of Sales for the Week (**Figure 6G**), Sales per hour logged in to the phone system (**Figure 6H**) and Sales per hour in conversation with customers (**Figure 6I**) between the Light group and the Control group before (Week 1), during (Week 2) or after (Week 3) intervention. There were also no significant differences from Week 1 to Week 2 or from Week 2 to Week 3 within the two groups for any of the work performance parameters. To conclude this section, our data did not support that outdoor light exposure increased work performance (Hypothesis #3).

A Customer satisfaction
B Number of calls answered for the week
C Number of calls per logged in hour
D Number of hours spent in conversation with customers
E Number of hours the customer service rep was logged in the phone system
F Number of products sold
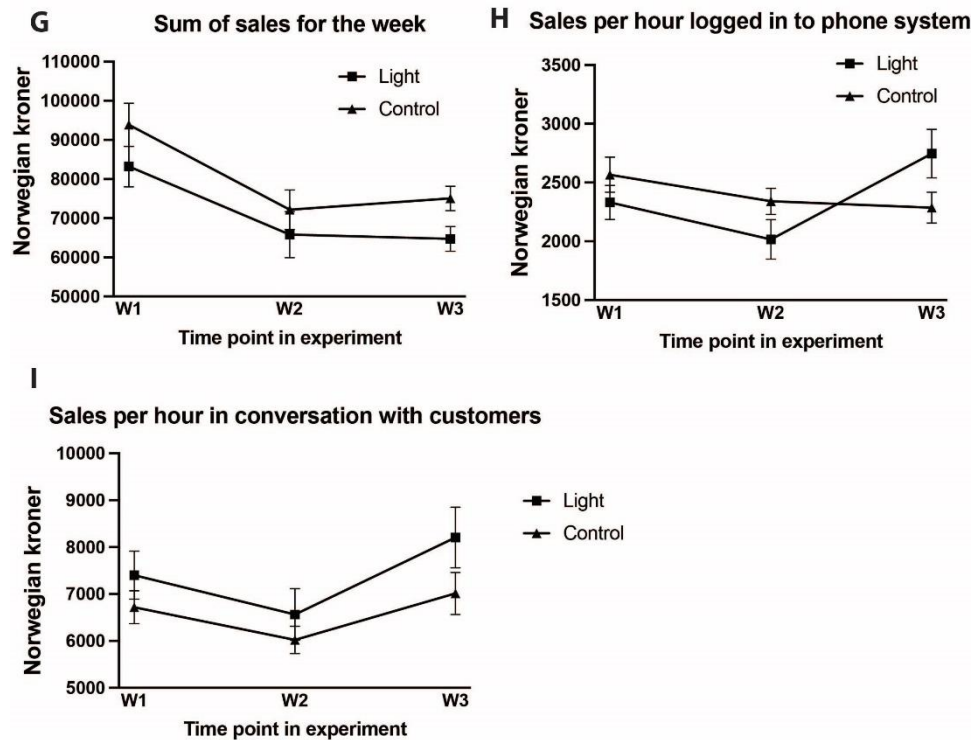
Light intervention, stress and work performance
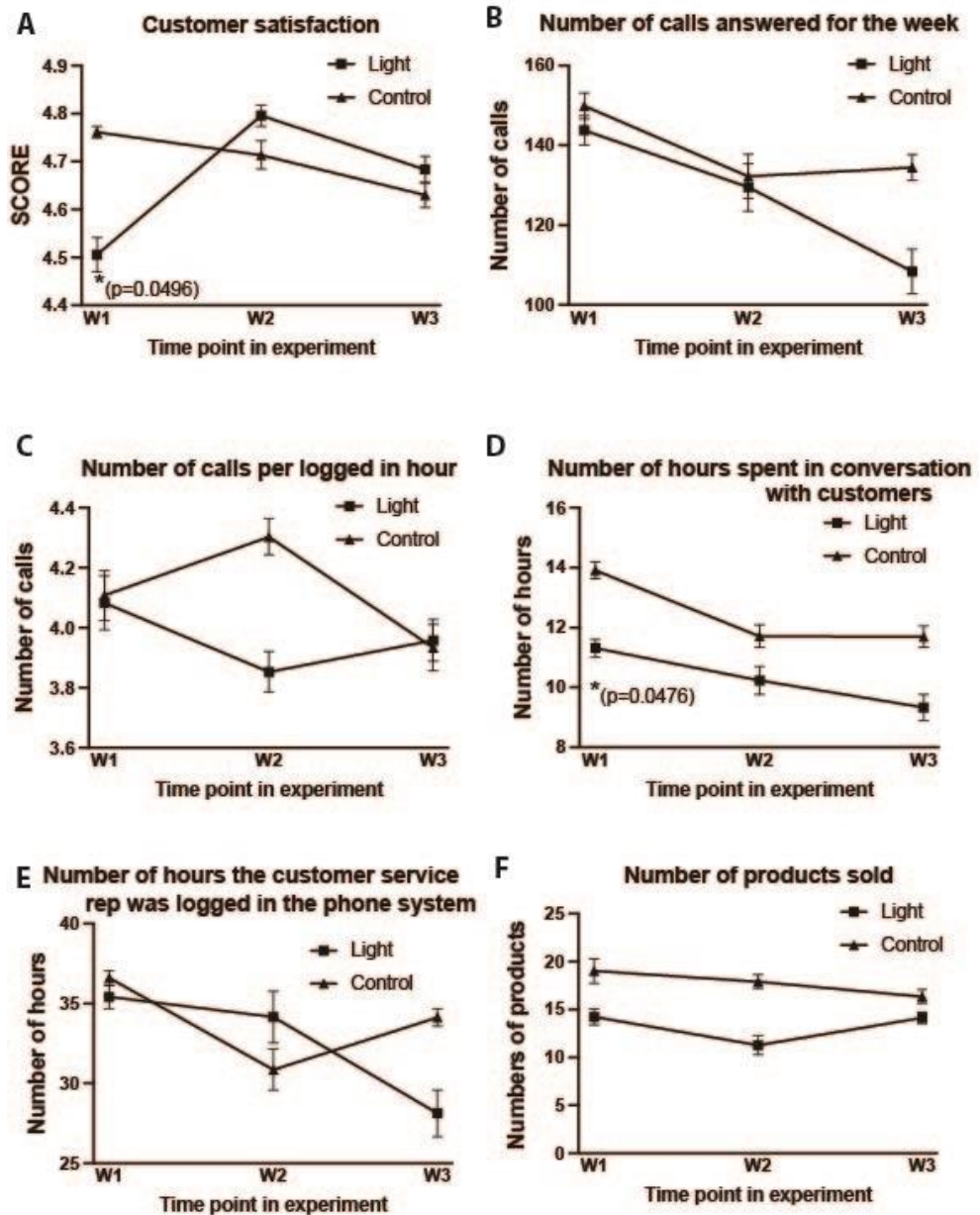
Figure 6. Work performance during the experimental period for the Light group compared to the Control group. A. Customer Satisfacton Score, B. Number of Calls answered for the week, C. Number of calls per logged in hou, D. Number of hours spent in conversation with customers, E. Number of hous rthe customer sevice representative was logged in the phone syste, F. Number of products sold, G. Sum of sales for the week, H. Sales per hour logged in to the phone system, I. Sales per hour in conversation with customers. Abbreviations: W1 = week 1, W2 = week 2, W3 = week 3. The error bars are Standard Errors. The data points were tested for significant differences between the two groups (unpaired analysis of Light vs Control; example of stata command: ttest tmk_avg_score_w2 if group!=2, by (group) unequal) and for significant differences between timepoints (W1 vs W2 or W2 vs W3; example of Stata command: ttest tmk_avg_score_w1 == tmk_avg_score_w2 if group==2). An asterix (*) denotes significant differences with corresponding p-values. In A. there was a significant difference in the analysis of Light vs Control group in W1. In D. there was a significant difference in the analysis of Light vs Control group in W1.

6. Discussion, Limitations and Directions for Future Research

6.1 Main findings

In this Master Thesis, we have explored the relationship between positive stress and work performance (**Figure 7**). To our knowledge, there are no previous studies assessing the effects of an outdoor light exposure intervention on the combination of stress parameters and detailed real time, company-relevant work parameters.
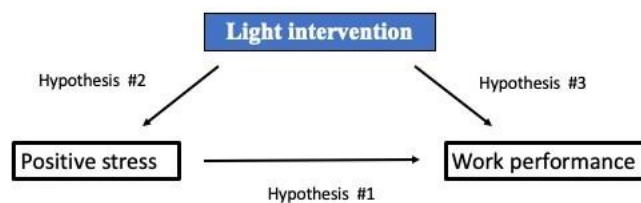
Figure 7. Model in relation to hypotheses.

We hypothesized that positive stress would improve work performance (Hypothesis #1), and indeed, by correlation studies, we identified a significant positive correlation between some of the stress parameters measured (PANAS positive, Deep sleep and Sleep Regularity Index) and work performance parameters (Sum of Sales for the week, Number of Products sold, Sales per hour logged in to the phone system, Sales per hour in conversation with customers). Interestingly, we identified a positive correlation between work performance parameters and the affect part of the stress experience, but not with the perceived stress part or the circadian vulnerability part of the stress experience, nor with the stress arousal response. A better powered study could have identified several more significant correlations between stress and work performance parameters as we discuss in more detail below. Also, we identified a positive correlation between work performance parameters and deep (non-REM) sleep, but not with REM sleep, and with sleep regularity which is interesting provided that more deep (NREM) sleep and improved sleep regularity (SRI) could represent a lower allostatic load/less stress (Le Bon, 2020) contributing to a higher performance level.

A correlation is however not causation, and in our efforts to address causality we conceived a randomized controlled intervention trial design (**Figure 1)** where we decided to use a 30 minute lunchtime outdoor light exposure as the intervention in the dark months (February, March) to assess whether this light intervention would both increase both positive stress (Hypothesis #2) and work performance (Hypothesis #3). Our reasoning was that we needed an intervention that would correlate simultaneously with both of our primary study parameters (positive stress and work performance) to assess the effect on the primary study parameters by the absence and presence of this intervention. Hence, if light intervention was able to influence both positive stress and work performance only during intervention (Week 2) but not prior (Week 1) or after (Week 3) the intervention, we would be able to conclude that not only would outdoor light exposure cause more positive stress and better work performance outcomes. We would also be able to suggest by indirect reasoning that Positive stress caused improved work performance. This would however require that positive stress emerged before improved work performance, i.e., a specific timing of events would need to be demonstrated. We have, however, studied the parameters at a weekly and not a daily level, precluding such analyses (as discussed in more detail below). Unfortunately, we did not identify significant improvements in the stress experience, the stress/arousal response, the feedback from the stress response to the brain, or work performance parameters during the light intervention. The only exception was a significant reduction in perceived stress (PSS) from Week 2 to Week 3 in the Light exposure group and a significant increase in measurement #2 of cortisol in week 3 that was not identified in measurement #1 of week 3. Both findings are probably spurious as discussed below in the paragraph on the role of chance and multiple testing.
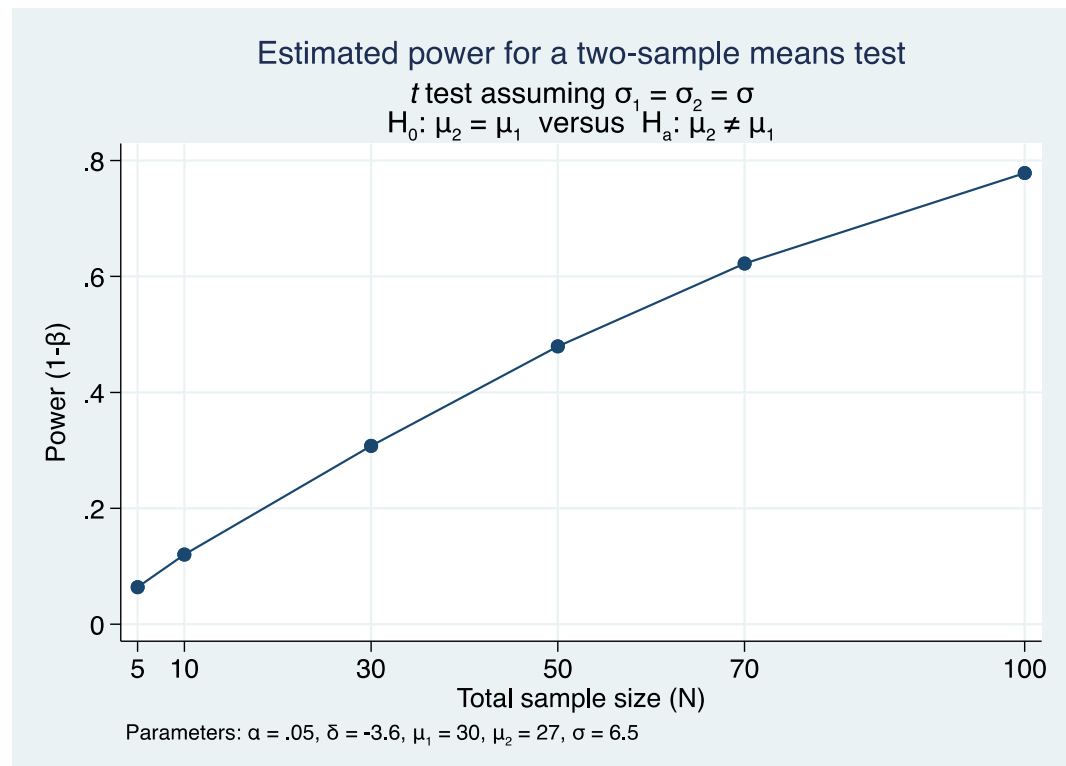
Hence, we cannot conclude that there is a positive causative relationship between Positive stress and work performance using our study population and methods of investigation. Absence of evidence, however, is not evidence of absence, and further studies are warranted that address several of the limitations of our studies. We will now review these limitations.

6.2 Limitations of the studies and implications for practice

Several factors may have influenced the results of our studies. To assess the validity of an observed statistical association we need to exclude alternative explanations such as chance, bias and confounding before we can judge the cause-effect relationship. Starting with the role of chance, our primary aim is to exclude type I errors (rejecting a true null hypothesis, i.e., the opposite hypotheses of hypotheses #1,2,3) and type II errors (rejecting a true alternative/study hypothesis, i.e., hypotheses #1,2,3). To avoid type I errors, we used a p-value of 0.05 as the significance threshold to reject the null hypothesis, but we did not perform correction procedures for multiple testing (i.e., using Bonferroni corrections or false discovery rates). Hence, there is a chance that our positive findings are false positives and that the statistically significant associations (i.e., in Table 3) are alternatively explained by chance. The aggregation of positive findings for the sales and PANAS measurements, however, increases the likelihood that these findings are indeed true. In addition, we designed our studies to further explore the putative positive findings in Week 1 (Hypothesis #1) in subsequent independent studies (Week 2 and 3; Hypotheses #2 and 3), which reduces the risk of type I errors. We also provided confidence intervals for the main outcomes (Table 3) as confidence intervals are more informative than p-values alone providing both information to decide significance but also the information to assess sample size from the width of the confidence interval. To avoid type II errors, we performed sample size calculations using a power of 0.80 as the threshold. Based on estimates derived from previous studies of salivary cortisol levels, we did not reach a power above 0.80 with the size of our study population. We did, however, not have access to effect sizes for the stress experience (i.e., PANAS, PSS, MEQ) or the feedback from the stress response to the brain (i.e., Sleep parameters) due to non-existent literature. Hence, our pilot data provide a starting point for future related studies using the mean and SD values obtained in our study. As an example, we observed a mean (and SD value) of intervention (Week 2; measurement #1) positive PANAS of 30.38 (5.2) and 26.8 (8.6) in the Light intervention group and Control group respectively. Using these input parameters and the Stata command

power twomeans 30.38 26.8, n (5 10 30 50 70 100) sd(6.5) graph

we can construct the following power curve illustrating the need for n=100 subjects (in total) to reach a power of 0.8 in future experiments:

Estimated power for a two-sample means test
t test assuming $\sigma_1 = \sigma_2 = \sigma$
$H_0: \mu_2 = \mu_1$ versus $H_a: \mu_2 \neq \mu_1$

Power $(1-\beta)$

Total sample size (N)

Parameters: $\alpha = .05$, $\delta = -3.6$, $\mu_1 = 30$, $\mu_2 = 27$, $\sigma = 6.5$

Continuing with evaluating the role bias, there are possibilities for both selection bias (study participant inclusion and exclusion procedures) and observation bias in our studies. As we recruited 28 subjects consecutively for our studies, we believe there is a low risk that we recruited an unrepresentative population of people at the Tryg Call Center. Hence, our study population consisted of both men and women with a mean age slightly above 30 years which reflects the general age distribution in the Call Center. Age may bias results as subjects in other age strata may be more or less vulnerable to the light intervention effects, so later studies may include other age strata. We studied our subjects in the dark months of February and March, but effects may have been different in the even darker months of December and January. Also, seasonal effects throughout the year could be subject to studies in future trials. Turning to observation bias, we used previously established validated methods for the stress experience (i.e. the PANAS, PSS, MEQ questionnaires have been robustly validated in previous studies) and the feedback from the stress response to the brain (SOMNOFY® sleep data have been validated against the gold standard polysomnography (Toften et al., 2020)). Also, the questionnaires were

Light intervention, stress and work performance

distributed to the study subjects as close as possible to the relevant time point using digital reporting to reduce recall bias and was furthermore encouraged by digital reminders to ensure compliance. There is the risk that study subjects in the Light group may have talked to study subjects in the Control group which may have influenced the subjective stress reporting. We tried to minimize this bias by using multiple overlapping data sources, i.e., different metrics for the stress experience (PANAS, PSS, MEQ), the stress/arousal response (salivary cortisol), the feedback from the stress response to the brain (several sleep metrics) and for work performance (customer satisfaction, number of phone calls and sales data). The work performance data is routinely collected by the employer and, hence, was used by us without modifications. To ensure the validity of the light intervention itself, we used objective measurements of light exposure by the actigraph wristband as demonstrated in Figure 2A. The figure showed that the Light group was indeed exposed to at least twice as much light (measured in lux) during the lunchtime hours (11 am – 1 pm) as the Control group in Week 2, but not in Week 1 or in Week 3. We did, however, not restrict participants to light exposure or other exposures at other time points (except for 1h with absent screen time before bedtime) that may have influenced the stress experience. We also did not record other exposures or the lighting conditions at the workplace such as the proximity to windows and other light exposures. Also, the light intervention may have biased the work performance as this mandatory break of thirty minutes may have reduced the work performance compared to a shorter break in the Control group.

Continuing with evaluating the role of confounding, the demographic composition (sex, age) may have confounded the results, but the randomization procedure of our randomized controlled trial mitigates such confounding. Notably, the age and sex in the Light and Control group was not significantly different, even when we did not apply restriction (limiting the participants to certain age strata) in our inclusion procedures. We have, however, not controlled for age and sex in our analyses (which we could have done in a regression analysis model). Most of the subjects were of Norwegian ancestry, although we did not assess ethnicity specifically. Although relevant for the stress and performance outcomes, we did not collect information on marital status and socioeconomic factors (education and income levels) and personality type which should be addressed in future studies to exclude the role of confounding by these factors. Such factors could be studied using

multiple linear regression models (generalized linear models). Second, the size of the study population is small (n=9 in each group) as discussed above. An even larger population would have increased the likelihood that we would be able to identify significant differences between the Light and Control group in the Intervention study. Thirdly, a longer duration of the studies would have in increased the likelihood that we would be able to identify significant differences. In a similarly designed meditation intervention, Fazia and co-workers used a 12 week intervention to identify significant differences in stress parameters (PANAS, PSS) (Fazia et al., 2021). Fourthly, we studied the parameters at a week-level, missing the higher granularity of studying the parameters at a daily level. Studying the parameters at a daily level would have not only increased the sensitivity of detecting significant differences between the Light group and Control group in the intervention study. A time-series analysis at a daily level would also have enabled us to distinguish between the possibility that positive stress causes improved work performance from the possibility that improved work performance causes positive stress. This would be enabled as the time of occurrence after light intervention of the parameters would mark the first parameter to emerge as the primary parameter (i.e., if positive stress emerged before increased sales parameters, we would suggest that stress causes increased sales parameters).

Finally, our studies may have implication for practice. We believe our studies constitute an important first pilot with regards to finding relationships between occupational stress and employee-level performance. We tested an intervention with outdoor lunchtime light exposure as a simple measure that can be easily adapted in work environments if supported by data. Hence, although our light intervention data did not confirm the partially beneficial effects of light exposure from our initial exploratory studies (Hypothesis #1), further studies of this exciting relationship is warranted, building on the framework suggested in this Master Thesis.

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