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Karolinska Institutet

# *DATA COLLECTION PROTOCOL*

Exploring the Psychological, Emotional and Behavioural Effects of Artificial Lighting

***National Centre for Suicide Research and Prevention***

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## Study Objectives and Purpose

### *Study goals*

This study aims to investigate how blue light exposure affects emotions, psychic health, and behaviours, constituting one of several studies within the overall project aimed at expanding the knowledge base and uncovering underlying mechanisms. Specifically, it seeks to determine whether blue-light emitting diodes (B-LED) lamps have a calming effect or influence psychological responses through other pathways. The insights gained will help to inform the potential application of B-LED lighting in various settings.

### *Research Question*

How does blue light exposure influence emotions, psychic health, and behaviours among healthy adults?

## Study Design

### *Type of Study*

Randomised controlled trial (RCT) where participants will be allocated to either the intervention or control group using simple randomisation techniques.

### *Exposure*

Light exposure will be provided by two Pracht Luminaire TUBIS LED INDUSTRY fixtures. In the intervention group, a fixture with narrow-band blue light (λ: 469-480nm) will be used, while in the control group, another fixture with broad-spectrum white light (λ: 380-700nm) will be used. Both groups will be in a noise- and temperature-controlled room, isolated from outside interference and natural light sources.

### *Data Collection Method*

The study will take place at the Department of Psychology, in the Sleep Laboratories at Stockholm University (Albano Campus). The entire duration required for each participant will be a single 90-minute session with no follow-up appointments necessary.

First, written informed consent will be obtained from all individuals who volunteer to participate in the study by researchers trained in this process. This includes providing an information sheet containing details about the study's purpose, what participation involves, potential risks, the type of data to be collected and how it will be stored, compensation, their rights as a participant, as well as contact information for the principal investigator (sv. huvudansvarig forskare). During this time participants will also be given an opportunity to ask questions before proceeding.

Those that consent to partake will first undergo baseline assessments. This begins with measuring the resting heart rate of participants using an electrocardiogram (ECG). Participants will place the electrodes on themselves under the guidance of the study coordinator. The electrodes will remain in place throughout most of the data collection process to provide continuous monitoring. Baseline questionnaires will then collect demographic and lifestyle information, as well as measure participants' current emotional state and stress level. Next, maximum hand grip strength will be measured using the

participant's dominant hand to determine the endurance setting (30% of their maximum grip strength) for the behavioural perseverance task. This ensures that the endurance task is equally challenging for all participants. Lastly, a baseline test will be conducted to assess participants' initial proficiency in the N-back task before proceeding with the main experimental phase.

During the next phase, participants will be allocated to either the intervention or control group using block randomisation. The study coordinator will select a pre-randomized card from a set of 24 (all possible randomized orders) which states the condition, task order, and lighting exposure order the participant will receive – up until this point the study coordinator will be blind to such information. Three tasks will be completed to measure behavioural perseverance (BP) with the order of tasks varying for each participant through Latin square randomisation. *The hand grip endurance task will be carried out as follows*: Using their pre-determined endurance setting, participants will be instructed to clench the hand grip device and hold that strength for as long as possible or until they decide to give up. If the participant sustains their grip for five minutes, the study coordinator will end the task. Perseverance is measured by how long the participant maintains their grip. *The N-back task will be carried out as follows*: The initial baseline assessment will have determined the appropriate starting level of difficulty to ensure that each participant faces an equal challenge. Participants will be instructed to complete the task on a computer and continue until they either choose to quit or reach a predetermined duration (five minutes). Perseverance is measured by how long the participant persists through the task. *The thread and needle task will be carried out as follows*: Participants will be instructed to simply thread a needle. They will not be informed beforehand that the task is intentionally designed to be frustrating. The width of the thread will make it impossible to complete, especially within the given time limit and under the rules, which state that participants cannot use their mouth or the other hand and must only hold the thread beyond a knot located approximately 5 cm from the tip. Participants will be asked to carry out the task until they decide to give up or until the study coordinator ends the task (if they reach 5 minutes). The level of performance will be assessed by how long participants persist in trying to thread the needle. After each task, participants will complete a single-item stress scale and a single-item effort scale. Participants will continue under either the intervention or control lighting condition and then fill out a brief questionnaire assessing their current emotional state, depression, anxiety, stress, suicidal ideation, as well as a hope scale. The study coordinator will then change the lighting back to the normal room lighting condition (ending the experimental lighting exposure).

The post-experimental phase comprises two final components. First, the participant will complete the single-item stress scale one last time, before removing the electrodes from themselves, and then complete another questionnaire measuring psychological symptoms and transportation habits. Lastly, associations to both lighting conditions will be assessed for all participants through free recall of up to five words associated with each condition, along with an estimation of the perceived strength of the association in relation to the light. The order of exposure to the lighting conditions will be randomised using block randomisation, alternating between blue-first and white-first for each participant.

### *Study Population*

The study population will be healthy adults aged 18 years and older that do not have any severe vision impairments which would prevent them from perceiving light differences or carrying out the tasks. The aim is to collect a sample of 500 participants. The inclusion criterium is adults (over 18 years old). The exclusion criteria are severe vision impairment (unable to read written text) which would not allow them to solve the tasks and influence how they perceive the light.

### *Sampling Method*

We aim to recruit a diverse sample to represent the general population in Stockholm, including a variety of age ranges and backgrounds, using a self-selection recruitment technique. While achieving this level of diversity is ideal, it may not be attainable due to the nature of volunteer sampling. Recruitment will take place through advertisements on Karolinska Institute's website and bulletin boards around Stockholm. Participant booking will be done via phone and email, primarily during daytime hours, but evening slots may also be available if it is more convenient for the participants.

## Variables

### *Primary and Secondary Variables*

*Primary outcomes*

- Present emotional states
- Behavioural perseverance
- Stress (physiological and self-reported)
- Hope
- Psychological health
- Suicidal ideation

*Other variables of interest, including covariates*

- Age
- Sex
- Colour vision deficiency (colour blindness)
- Education
- Income
- Lifestyle
- Transport habits
- Associations to the light conditions

### *Definitions*

### *Measurement tools*

*Behavioural perseverance measures: 1) The hand grip task* to be used in this study was designed and tested as an experimental behavioural measure to study perseverance in unpleasant, difficult, or adverse situations and deemed physically demanding (Määttänen et al., 2021). Jamar hand dynamometer devices will be used, which are considered the gold

standard (Roberts et al., 2011). The baseline max hand grip strength will be measured using the Jamar digital SMART hand dynamometer device, providing precise readings to the nearest 100 grams. While the original Jamar hydraulic hand dynamometer with an easy-to-read gauge will be used for the hand grip task. Both devices feature an adjustable handle to fit various hand sizes and measure grip strength ranging from 0 to 90 kilograms. *2) The thread and needle task* will be used as a measure of cognitive and physical behavioural perseverance, also designed, and tested by Määttänen and colleagues (Määttänen et al., 2021). *3) The N-back task*, developed to assess working memory (Kirchner, 1958) and widely-used (Gilmour et al., 2019), will serve as a measure of behavioural perseverance by evaluating how well individuals maintain focus and performance over time as task difficulty increases. Broadly speaking, the N-back task is a type of continuous performance test in which participants are shown a series of stimuli and must determine if the current stimulus is correct according to an "N-back rule". This means they need to assess whether the current stimulus corresponds to one that was presented n steps earlier in the sequence. For example, in a 1-back task, participants compare the current stimulus to the one immediately preceding it, while in a 2-back task, they compare it to the stimulus presented two positions before (Gilmour et al., 2019).

*Present emotional states* will be measured with the Circumplex Model of Affect, as originally developed by Russell (Russell, 1980), organises emotions along two primary dimensions: valence (pleasant-unpleasant) and arousal (high-low). In this study, participants will report their affective states using a validated scale derived from this model, which has been widely used in psychological research to assess emotional experiences in a systematic and structured manner. Specifically, we will be using a Swedish Core Affect Scale that comprises 24 unipolar adjectives (Västfjäll et al., 2002).

*Stress (physiological and self-reported):* *1) Physiological stress responses* will be assessed using medical-grade heart rate monitors (Zenicor FLEX-EKG), equipped with three electrodes. The monitor will provide accurate and real-time data on heart rate variability, enabling the measurement of participants' physiological stress levels during the experimental phase. 2) The study will also assess *2) self-perceived stress* using the Borg CR Scale (CR10) (Borg et al., 2010; Borg & Borg, 2002). Participants will rate their stress levels on a scale from 0 (no stress) to 10 (maximum stress). This scale provides a reliable and intuitive method for participants to quantify their perceived stress levels, enabling a detailed evaluation of individual stress responses during the experimental phase.

*Hope* will be measured with the Adult Hope Scale, measures the construct of hope by assessing two key components: agency (the belief in one's ability to achieve goals) and pathways (the perceived ability to find routes to those goals) (Snyder et al., 1991). In this study, participants will complete this validated scale, which has been extensively utilized in psychological research to systematically evaluate individuals' hope levels. The scale consists of 12 items scored on a Likert-type format, allowing for the calculation of separate agency and pathways scores, as well as a total hope score, providing a comprehensive assessment of hope in various contexts.

*Psychological health* will be measured with a Swedish translation of the Depression, Anxiety and Stress Scale-21 (DASS-21) will also be used to measure psychological symptoms and distress. Multiple studies have assessed the psychometric properties of the 21-item scale, yielding consistent and satisfactory results (Alfonsson et al., 2017).

*Suicidal ideation* will be measured with the Suicidal Ideation Attributes Scale (SIDAS). The SIDAS is a web-based instrument designed to measure various dimensions of suicidal ideation, including frequency, intensity, and associated attributes (Van Spijker et al., 2014). By employing this scale, we aim to obtain comprehensive data on participants' suicidal thoughts and behaviours, contributing to a deeper understanding of their mental health status.

*Self-perceived effort and persistence* will be measured with Borg CR Scale (CR10) (Borg & Borg, 2002) will be used to assess participants' self-perceived effort and persistence during the behavioural tasks. After completing each task, participants will be asked to indicate how hard they tried on a scale from 0 (no effort) to 10 (maximum effort). Since the BORG-10 is a general intensity scale, it is applicable across a range of perceptions, experiences, and emotions.

*Psychiatric symptoms* will be measured with the SCL-90 (Symptom Checklist-90) questionnaire (Fridell et al., 2002) will be employed to measure psychological symptoms among participants. This well-established self-report instrument assesses a range of psychological symptoms across nine domains, including anxiety, depression, and interpersonal sensitivity. Participants will respond to items reflecting their experiences over the past week, allowing for a comprehensive evaluation of their psychological well-being. The data collected from the SCL-90 will provide valuable insights into the psychological symptoms present in the study population. A Swedish-translated version that has been standardized and validated will be used in this study (Fridell et al., 2002).

*Transportation habits* will be measured with questions assessing participants transportation habits (mode and frequency) will be based on those used by the Swedish Transportation Analysis (Trafikanalys) agency, the designated authority responsible for Sweden's official statistics in Transport and Communications (Trafikanalys, 2023).

*Demographics* will consist of several questions adapted from the European Social Survey (ESS); a reputable source known for its rigorous data collection across diverse European populations. The survey includes standardized questions on key demographic variables such as sex, age, education level, and income (European Values Study, 2017). Utilizing the ESS framework ensures consistency and comparability in the data collected, allowing for meaningful analysis of the participants' demographic profiles.

*Colour vision deficiency (colour blindness)* will be assessed with two questions developed specifically for this study. The first question refers to whether the participant has some form of colour vision deficiency and the second question is to clarify which type of colour vision deficiency.

*Lifestyle* related factors will be assessed using several questions developed specifically for this study. These are included to control for variables that may influence participants' reactions, responses, or performance during the experiment – such as wake time, caffeine intake, food consumption and nicotine use.

*Associations to the light conditions* will be assessed through a questionnaire created specifically for this study. Participants will be asked to freely provide up to five words they associate with each of the two lighting conditions. They will then rate the strength of their association with each word, allowing us to assess the perceived connection between the lighting conditions and associated terms.

## Data Collection Procedures

### *Recruitment*

Participants will express their interest in participating either via the Accindi website, email (nasp-research@ki.se) or by telephone. The first action should always be sending the interested person the pre-drafted email that includes the information sheet in both languages (PDF version in English and Swedish) and the Microsoft bookings link (to limit back and forth communication). If none of the available time slots are suitable for the participant, you can ask more specific questions about their availability. The pre-drafted email can be found in the Microsoft Teams folder 1. If the individual makes contact by telephone, then ask for their email address to be able to send these details to them. Once a time slot has been decided upon, send the pre-drafted email confirmation with the instructions on how to get to the campus (PDF version in English or Swedish). The pre-drafted email can be found in the Microsoft Teams folder 2.

### *Scheduling Participants*

To ensure all processes run smoothly, follow the below set of instructions for scheduling participants for data collection.

- Do not book more than four participants per day.
- Book 90-minute slots for each participant to allow time for preparations beforehand (information and consent) and follow-up and questions afterwards.
- Ensure there is at least a 30-minute gap between participants. This provides flexibility in case data collection runs over time and allows for sufficient time to clean up and prepare for the next participant. Ideally, a 1-hour gap is preferable to ensure the process between participants is not rushed, allowing everything to be done properly.
- It is okay to schedule a participant's visit outside of normal working hours (9am – 5pm) if necessary. However, this is at the discretion of the study coordinator and shouldn't be any later than finishing at 7pm to minimise participant sleep disruptions.
- Participants' bookings must always be logged in the shared Google calendar with the sleep laboratory.

### *Withdrawal or no show*

If the participant has booked a time to participate and then decides to no longer partake or does not turn up to the session, then note this here: ID_numbers_datacollection excel file, tab called "withdrawals or no show".

### *Step-by-Step Instructions for Participant Data Collection*

***Data uploads once a week***

- All N-back task data should be uploaded onto Microsoft Teams folder 3.

***Deleting communication***

- After participants have completed the experiment, you must delete all previous communication threads.
- Clear the calendar of previous bookings at the end of each week.

***Start of day checklist***

- Ensure that the ECG device has full battery
- Ensure the tablet has enough battery for the first participant

***Pre-data collection checklist for each participant***

- Set the lighting conditions to the standard room setting (white colour/half sun)
- Have a physical copy of the information and consent form ready on a clipboard with a working pen (both Swedish and English)
- Attach the electrodes to the leads via the stud connection, ensuring that they are securely connected. Then, attach the device to an electrode and place everything on the bedside table, ready for the participant
- Put a new case on the pillow
- Make sure the laminated written instructions for the experimental tasks, as well as the emotion-adjective descriptions are placed on the desk
- Make sure the following items are placed are also placed next to the bed:
    - Shaver (ensure this is charged and clean)
    - Alcohol wipes for cleaning (before and after)
    - Laminated written instructions for applying the electrodes
- Prepare the N-back task: This requires inserting the participant's ID number and setting the version number (both of which can be found in the ID_numbers_datacollection excel file) – these values should be in red within the citation marks.

***Pre-experimental phase***

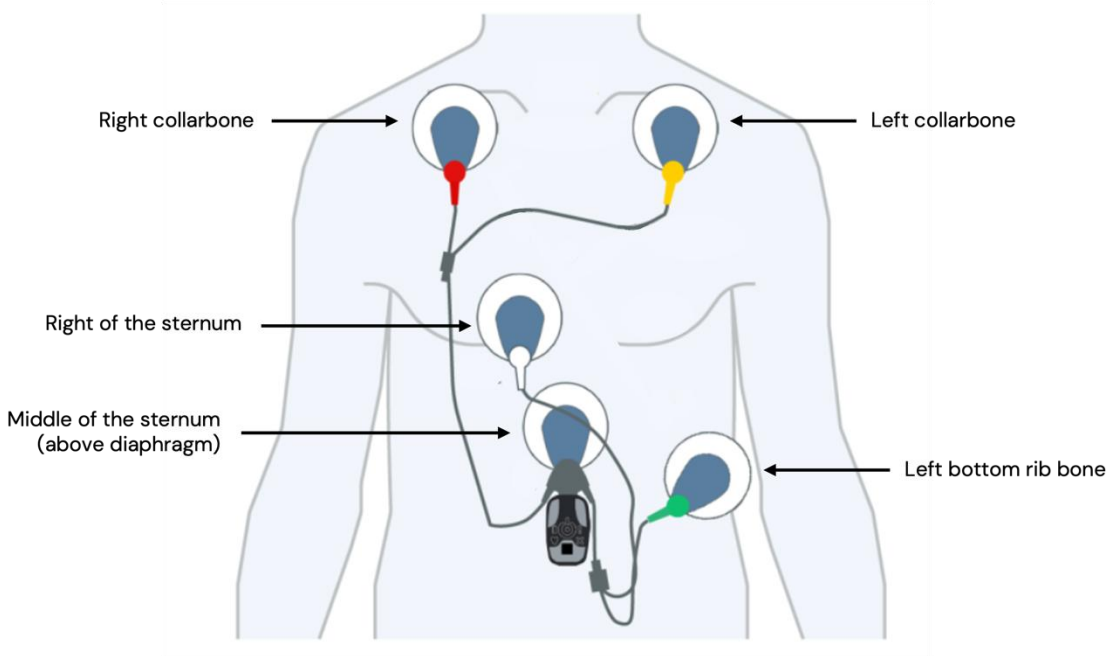
*Information and obtaining consent:* The study coordinator will meet the participant in the foyer next to the sleep laboratory. Here, the participant will be provided with a review of the study information to ensure understanding and given the opportunity to ask any questions. If everything is clear and the participant agrees to proceed with the experiment, they should provide written consent.

*Enter the laboratory setting:* Before entering the laboratory, offer the participant an opportunity to use the bathroom in the foyer. The study coordinator and participant must enter the laboratory through the entrance next to the foyer, which leads into the hallway. Inform the participant that other experiments are taking place in the laboratory and to refrain from speaking with anyone else (say this even if that is not the case, as this is a measure to increase safety). Show the participant the bathroom available within the laboratory in case they need to use it during the experiment. Upon entering the experiment room, inform the participant that only this room and the bathroom will be used during the procedure. Ask the participant to take their shoes off and leave them by the door. Show the participant where they can place their belongings out of the way and take a seat at the experiment desk while you set up the tablet to begin data collection.

*Set up the tablet for the new participant:* Begin the survey on the tablet and enter the participant's ID number. The list of ID numbers can be found in the excel document titled ID_numbers_datacollection. Please select the next available ID number from that list.

*Self-perceived stress measurement 1:* Next, the participant will rate their self-perceived stress after reading the instructions and checking the scale. The study coordinator should enter this data into the survey on the tablet (Stress 1).

*Apply electrodes:* Instruct the participant to sit on the bed where they will apply the electrodes (already pre-attached to the leads and device) on themselves. Go over the electrode application process with the participant, making sure they understand each step. Emphasise the important of placing the electrodes on the bone, ensuring there is no air between the electrode gel and the skin for proper adhesive adherence. Direct the participant to the visual aids on the wall for placement guidance of the electrodes and the necessary equipment on the bedside table. Inform the participant that you will step outside while they place the electrodes on themselves and ask them to call out when they're ready or if they need assistance. If the participant prefers, you can place the electrodes for them, but only with their explicit verbal consent.




*Record resting heart rate measurements:* Check with the participant whether they think they've securely and correctly placed the electrodes. You may need to double check the placement if they're unsure, asking them for their verbal consent before proceeding. Explain to the participant that, from this point forward, you will be measuring their heart rate for the majority of the experiment, beginning with an initial resting assessment. Ask the participant to lie down on the bed with their arms lying by their side, ensuring they're relaxed and comfortable, as they will need to remain in that position for three-minutes with minimal movement. Make sure you have the stopwatch in hand ready to begin timing. Press the pushbutton on the device listening for the start sound (one beep) and looking to see that the green indicator is lit and blinking every five seconds – this means that the measurement has started and is running. If everything is working as it should, you can begin the three-minute timer immediately. Once the three-minutes is up, instruct the participant to carefully move from the bed and take a seat at the experiment desk.

*Self-perceived stress measurement 2:* Next, the participant will rate their self-perceived stress for the second time. If necessary, allow them time to review the instructions again and then proceed with the rating. The study coordinator should enter this data into the survey on the tablet (Stress 2).

*Collect baseline questionnaire data:* Hand the participant the tablet and ask them to proceed with the baseline questionnaire. Before they begin, let them know that there is a list of definitions available (on the desk) for the present-state emotions should they need further clarification on the meaning of words. They are also able to ask any questions throughout if necessary. Once they are finished, take back the tablet, as you will need it to log the following baseline measurements.

*Identify maximum handgrip strength:* Still seated at the experiment desk, the participant will next complete the baseline handgrip strength measurement. First, go through the seating instructions so that they are familiar with the position they should maintain throughout all handgrip-related measurements and tasks. This may take a few minutes to make all the necessary adjustments. Then read through the task instructions for identifying their maximum handgrip strength, ensuring they understand and giving them an opportunity to ask questions. Before beginning, the participant should follow the short warm-up exercises according to the set instructions. Next you must prepare the digital dynamometer for testing. The grip handle may be placed in 5 positions to accommodate the size and comfort of the user's hand – for most people, setting two will be suitable. Turn the device on with the [ON/OFF] button. Select the desired test with the [SELECT TEST] button to either L1 (left hand) or R1 (right hand) depending on which hand is being used in the test (dominant hand only). Finally, select the [TEST] button (the "1" will begin flashing if it is ready to test) before beginning. Proceed with the first test and then record the participant's strength measurement in both the excel document (id_numbers_datacollection) and the survey on the tablet – you will do this after every measurement. Prepare the device for the next round by selecting the [RESET] button and then selecting the [TEST] button again. Once all three rounds of measurements are complete, compute 30% of the maximum handgrip strength (this will be automatically calculated in the excel document), and round the result to the nearest even 2kg increment for the endurance task. Set aside the digital dynamometer, as you will not need it anymore.

*Run baseline N-back task:* Provide the task instructions to the participant for them to read through and then answer any clarifying questions. Inform the participant that the test is sensitive: they must press 'SPACE' only after the letter disappears, as pressing too early may lead to an incorrect response. Once they are ready to proceed, you will begin the training round and the baseline test. After each round of the baseline tests (1-4), you need to enter the hits, false alarms, and d-prime number for the corresponding n-back in the excel file. To determine the level for the n-back perseverance task in the experimental phase (which needs to be entered into the excel file and the survey data), follow these instructions: The task should not be too easy for each participant. Therefore, you want to examine the testing rounds to identify the point at which their performance began to decline, while ensuring they still demonstrated relatively good sensitivity in identifying correct responses, indicating that their performance was not merely due to chance. To determine the appropriate level, refer to both the number of hits and the d-prime value. Identify the first round in which the hit rate is 50% (0.5) or below, while the d-prime value remains above 0.6 – this level will be used for the n-

back perseverance task. Even if the participant improves their hit rate in a following round, you still choose the first round in which the hit rate is 50% or below. If the participant has a hit rate of above 50% but a d-prime value below 0.6, then the previous level should be selected for the perseverance task. Lastly, if the participant performs well across all testing rounds, demonstrating a hit rate above 50% and a d-prime value greater than 0.6 on the 4-back task, then level 5 will be selected for the perseverance task.

*Randomisation:* Before moving into the experimental phase, the study coordinator should select the card on the top of the pile that has the randomisation order assigned to the participant. Enter this information into the excel document (id_numbers_datacollection) and the survey on the tablet before proceeding.

***Experimental phase***

*Set the lighting exposure:* Inform the participant that you are now going to change the lighting condition which may cause temporary discomfort as their eyes adjust and should therefore be seated comfortably. Do not comment on the lighting exposure or disclose whether the participant is being exposed to the control or intervention condition – they should remain unaware.

*Carry out behavioural perseverance tasks*: You will now proceed with carrying out the behavioural perseverance tasks. The order of these tasks will vary each time based on randomisation.

*Self-perceived stress measurement (3, 4 and 5) self-perceived effort measurement (1, 2 and 3):* After each task is completed, ask the participant to rate their self-perceived stress level and effort and enter that information into the survey on the tablet.

*Handgrip endurance:* Review the task instructions with the participant, ensuring they understand and giving them an opportunity to ask questions. Prepare the dynamometer by placing a sticker on the dial to indicate the target range where they should keep the needle. Give the dynamometer to the participant and ask them to resume the handgrip testing position (holding the device in their dominant hand). Then place the mirror in front of them so they can clearly see the dial and the target range. Seat yourself so that you are behind the participant and can clearly see the dial and target range to monitor the task. This means ensuring the participant remains in the same seated position, with their unused hand resting on the armrest, and if they fall outside the target range for more than 5 seconds, the task be stopped. Once you and the participant are ready, start the stopwatch and begin recording the time. Make sure to record the participant's perseverance time in the survey on the tablet before moving on to the next task (must be entered in the following format MM:SS).

*Thread and needle:* Review the task instructions with the participant, ensuring they understand and giving them an opportunity to ask questions. You can demonstrate how they should hold the thread and needle if necessary. The participant should still be seated at the experiment desk to carry out the task. Start the stopwatch and begin recording when the participant starts trying to thread the needle until they give up or until they reach 5 minutes in which you will then terminate the task. Make sure to record the participant's perseverance time in the survey on the tablet before moving on to the next task (must be entered in the following format MM:SS). No comments can be given about whether the task is possible – if the participant asks, you must state that you cannot give them that information.

*N-back:* Inform the participant that they will now to the N-back task again, however this time, they will only do one level and carry out the task for as long as possible, until they decide to give up. To begin, enter the level which the participant will carry out the perseverance task (1-5). Once the participant has decided to end the task or has reached the maximum timepoint (5 minutes), enter the time (in seconds) into the excel document (id_numbers_datacollection) which will be converted into the correct formatting so that you can then enter the data into the survey on the tablet (MM:SS).
*Collect mid-point questionnaire data:* Hand the participant the tablet for them to complete the questionnaire on present state emotions, suicidal ideation and hope.
*End the lighting exposure:* Inform the participant that you are now going to return to the normal lighting condition. Remind them that the change in lighting may be temporarily unsettling.

***Post-experimental phase***

*Self-perceived stress measurement 6:* Immediately after returning to the normal lighting condition, ask the participant to rate their self-perceived stress level one last time. Enter this data into the survey on the tablet.
*Disconnect the electrodes:* Stop the ECG device recording by holding the power button for 5 seconds (three beep-sound indications means that the measurement has ended). The participant is now able to remove the electrodes from themselves. Refer them to the cleaning wipes if they have any sticky residue from the electrode pads and ask them to leave the device and leads on the bedside table. Leave the room to give them privacy and ask them to shout out when they're ready for you to return.
*Collect questionnaire data:* Hand the participant the tablet for them to complete the questionnaire data on psychological symptoms and transportation habits.
*Measuring lighting associations:* Inform the participant that this is the final component of the study. Read through the task instructions with the participant, ensuring they understand and have an opportunity to ask any questions. Before proceeding, you must set the lighting condition to the appropriate setting based on the randomisation order (either blue-white or white-blue) – ensure the participant is ready, comfortably seated and prepared for the lighting change. The participant will complete the same questionnaire twice, each time under a different lighting condition. Once they have finished the questionnaire in the first exposure setting, switch to the other lighting exposure and have them complete the questionnaire again. Ensure that they are answering the right questionnaire that corresponds with the lighting exposure.

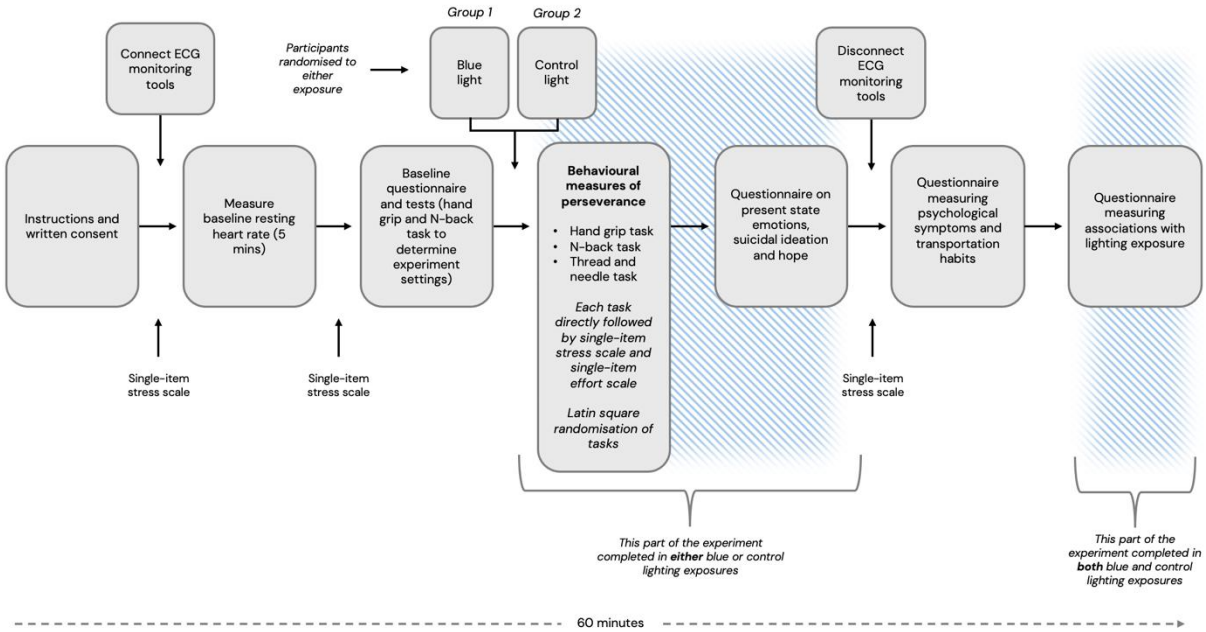



*Figure 1. Visual representation of the data collection procedure*

## ***End of data collection***

*Acknowledge participation:* Inform the participant that this is the end of the study. Express appreciation for their time and effort and acknowledge their contribution.

*Provide mental health brochure:* Give the brochure to the participant and explain that it's something you provide to everyone - Let them know that even if they don't feel they need it, it might be helpful for someone else.

*Explain what happens next:* Remind the participant that no further action is required from them and that they can refer to the information sheet for details on how to access the study results.

*Opportunity for final questions or feedback:* Ask the participant if they have any final questions, or feedback regarding the processes.

*Compensation:* Give the participant the vouchers totalling 150 SEK (~13€) as small compensation for their time.

*Take participant out of the laboratory:* Once all the above has been completed, walk the participant out of the laboratory and back into the common area outside the Psychology department. You may need to accompany them back to the meeting point if they feel are unsure about how to find their way out of the building.

## ***Post-data collection checklist after each participant***

- Place the signed consent form in the holder
- Clean the ECG device and leads with the alcohol-free wipes
- If used, clean the shaver with the alcohol-based wipes
- Place the tablet on charge if necessary
- Wipe the hand dynamometers with the alcohol-free wipes
- Put pillow cover in the rubbish
- Clean the tablet with the screen wipes
- Clean the mouse and keyboard with the alcohol-free based wipes

- Put the randomisation order card in the used pile
- All ECG data should be uploaded onto Microsoft Teams >> BLISP >> Study 1 (RCT) >> Experiment documents >> Data uploads >> ECG data. Saved in the following format: ecg_IDnumber_Date (ecg_id111_20250613).

***End of day checklist***

- Put tablet on charge
- Ensure you have enough information sheets and consent forms for participants for the next day, otherwise print more
- If the ECG device battery is running low, then place it on charge (blue indicator blinks twice and two beep-sound indications every five seconds)
- Wipe down the experimental desk with the alcohol-free based wipes
- Clean the mirror
- Upload ECG data onto Microsoft Teams if you did not have time after the participant finished the experiment: BLISP >> Study 1 (RCT) >> Experiment documents >> Data uploads >> ECG data. Saved in the following format: ecg_IDnumber_Date (ecg_id111_20250613).

***Manually collecting and entering data***

If any technical issues arise (i.e., REDCap crashes or the internet connection is lost) you must manually collect the data using the paper printouts (both Swedish and English versions available). It is possible that this could occur midway through the process of data collection and then you should resume wherever the interruption took place. You will then need to manually enter the data into REDcap (redcap.ki.se). This should be done immediately afterwards or as soon as possible.

If all the data for one participant has been collected manually, you will need to add a new record. On the left hand panel under 'Data Collection' you will see a tab entitled 'Add / Edit Records' which you should select. Then you must enter all data into the relevant sections. Take extra care when entering the questionnaire data that have multiple response options as it is easy to accidently click the wrong response. Once all data has been entered, click 'Save & Mark Survey as Complete'. The paper printout does not need to be stored and can be thrown away.

If technical issues arise midway through the data collection process, you will need to edit the record (as the record has already begun but will be incomplete). On the left hand panel under 'Data Collection' you will see a tab entitled 'Record Status Dashboard' which you should select. There you will find the Record ID that is incomplete, marked by an orange coloured circle with a tick inside – if you are doing this immediately afterwards it should be the last option. Click on the Record ID which will take you to a new page. Then you will see record the in question underneath 'Data Collection Instrument' and to the right of this is a tab called 'Status'. Click on the orange circle with a tick inside underneath the 'Status' tab which will take you to a new page. Here, you can change the language to either English or Swedish by clicking on the option on the righthand side above the orange box – It is recommended choose whatever language

the participant used to ensure correct entering of the data. To begin editing the record you must first click on the option in the orange box called 'Edit response'– then proceed with entering the data. Once finished click 'Save & Mark Survey as Complete'. The paper printout does not need to be stored and can be thrown away.

***Safety risks and procedures***

In case of fire, you should take yourself and the participant out via the exit closest to the laboratory. From there you should head to the safe meeting point, which is the grass area past the stream, located outside the front of the campus.

Should you feel unsafe with a participant, and you no longer want to continue, you can terminate the session immediately. Depending on the severity of the situation you have several options. In less serious situations, you can simply tell the participant that the technology is not working and so you must stop the session there and then escort them out of the laboratory. In more serious circumstances, you can remove yourself from the room, leaving the participant behind, and call security to manage the issue. There is also the option of activating the alarm (device located in the laboratory) to divert attention and force immediate evacuation of the room. If any of these instances occur, report this to Jesper immediately afterwards.

## Data Management

***Data Recording***

The raw data collected during the experiment will be transferred to computers for processing and analysis at KI (Karolinska Institutet). All data collected in this study will comply with the guidelines of Karolinska Institutet (KI) and national legislation. Data will be collected digitally using secure KI-approved systems, which protect against unauthorized access. These systems ensure compliance with all relevant rules and guidelines. Immediately after collection, the data will be stored on KI's central servers, which are regularly backed up to prevent data loss.

All collected data will be anonymous, with no possibility of linking personal information to the collected data. The signed informed consent forms will be stored in a disordered manner, so that the time of collection cannot be used to identify individuals. According to current legislation, a data management plan will be written and continuously updated. This plan will be based on the information provided in the ethical application. Metadata will be maintained to ensure the data's reusability and traceability.

Access to the data will be limited to active researchers in the project. Secure login credentials and access controls will be used to prevent unauthorized access. The research data will be archived for at least ten years after publication or the end of the project. The data will be migrated to archival-grade formats to ensure long-term availability. After the storage period, the data will either be preserved for future research in de-identified formats or completely erased, based on ethical considerations and project needs.

All procedures for data handling and storage will comply with the GDPR, Swedish legislation, and KI's information security guidelines. Any applications for data sharing will undergo a confidentiality and privacy assessment; however, as previously described, the data will remain anonymous throughout the study.

### *Quality Control*

Karolinska Institutet uses KI ELN (Electronic Lab Notebook) to document investigation procedures. This platform ensures accurate documentation of research activities, promotes collaboration, and maintains data integrity. However, no audio or video recordings will be collected in this study to document the procedure at the individual level.

### *Confidentiality*

All researchers in the project will continuously have full access to the collected anonymized data. Since the data is stored in Karolinska Institutet's ELN system, it will also be available to the principal investigator and can be released after a confidentiality assessment.

## Ethical Considerations

### *Informed Consent*

When booking participation, all individuals will receive the information from the informed consent, either digitally or, if they prefer, read aloud. Upon arrival at the laboratory, participants will be given the opportunity to read the informed consent in a separate room and ask questions to the experiment leader. The booking of participants will be arranged so that there is time for each participant to also reflect on the information on-site.

### *Confidentiality*

The data is fundamentally anonymous and does not contain any personal information, which provides basic protection for participants' privacy. Privacy concerns related to indirect identification are minimized by presenting all results in an aggregated form at the group level, which makes it impossible to identify individual participants.

### *Ethical Approval*

The study has been approved by the Ethical Review Authority (reference number: 2025-00418-01).

## Data Analysis Plan

### *Statistical Methods*

For all analyses Bayesian approaches will be used. The goal of the project is to provide a mechanistic description of the effects of B-LED exposure. This necessitates a generative model that can be compared with collected data. The result of the evaluation of the model in relation to data is the point of the analysis. Bayesian analysis provides this option whereas frequentist approaches only allow for evaluation of data in relation to the model. The modelling will be done in accordance with best practice in the analysis field (van de Schoot et al., 2021),

focusing on collecting informative priors from previous research, elicited priors in case there is unpublished knowledge that can be gathered and weakly informative priors for associations that have not been investigated thus far. Model testing will be done iteratively throughout the data collection to allow for continuous model development and provide checks for consistencies and inconsistencies in the data. Extensive prior and posterior predictive checks for all model components, and the complete models, to ensure that the models are stable both before and after posterior sampling. All sampling will be done with Hamiltonian Monte Carlo (HMC) in Stan through R interfaces to the programming language, such as Blavaan for Structural Equation Models (Merkle & Rosseel, 2018) and BRMS for linear mixed models (Bürkner, 2017). Prior sensitivity will be analyzed by iteratively changing priors for each parameter and in groups to assess the effect of using non informative priors (van Erp et al., 2018), thus moving assessing associations closer to a frequentist maximum likelihood estimation. Results will be presented as posterior distributions for the parameters but point estimates and HPDI intervals will also be computed and presented for all posterior distributions.

Because of the use of Bayesian methods null hypothesis-based power calculations are not appropriate (Kruschke & Liddell, 2018) to assess sample size. Instead, simulations were conducted based on the two larger main models, one focused on shorter time dynamic state variation, and the other on trait variables with longer (i.e. more stable) time dynamics. For each model 20 independent samples each were drawn (R, Lavaan, simulateData v. 0.6-19). The samples simulated differences in slope coefficients between the control (white light) and experimental groups (blue light). The samples were analyzed using two Bayesian structural equation models (BSEM) (R, blavaan, v. 0.5-6). Three MCMC chains were used in each model, (5000 "warmups" and "samples"). The goal was to find a sample size where at least 80 percent of the difference between the distributions for the control and experimental groups differed from zero. A-priori factor loadings were set based on previous research (Blalock et al., 2015; Rogers et al., 2024; Sinclair et al., 2012; Van Spijker et al., 2014; Västfjäll et al., 2002) and were assumed to be equal and normally distributed between the groups. A-priori slope coefficients were assumed to be normally distributed and were set to .8/.4 (sd=0.2) for model 1 ("state"), and .6/.4 (sd=0.2) for model 2 ("trait"). All latent covariances were set to 0. A-priori variances were assumed to be gamma distributed (k=1, $\theta$=0.5). All a-priori values except the variances can therefore be considered informed (van Erp et al., 2018; Winter & Depaoli, 2023). Both models examined differences in the distribution of latent slope coefficients in MCMC samples between the control and experimental groups.

The simulations showed that a sample of 500 participants, with 250 in the control and experimental groups, would imply an average probability of 92.5 percent (range, 83-100) that the slope coefficients identified the a priori effects. This was judged to be sufficiently precise and that a smaller number of participants in the samples would imply too great an uncertainty in being able to identify the effects. These two analyses are the most sample size demanding, thus analyses based on models with less variables or stronger effects will be eligible based on these computations too. All analyses done will be pre-registered before being conducted.

### *Software*

Several software applications are used in this study. REDcap (Research Electronic Data Capture) is used for collecting all survey data, self-perceived stress and effort measurements, and behavioural perseverance measurements (including baseline). Python version 3.12.4 and Spyder version 5.5.5 have been used to develop the N-back tasks and will be used to collect data. R version 4.4.3 (2025-02-28 urct) will be used to analyse all collected data.

### *Handling Missing Data*

Given the Bayesian framework, prior information will inform the treatment of missing data.

## Timeline

### *Start and End Dates*

Pre-planning: November 2024 – May 2025
Data collection: June 2025 – December 2026
Analysis: June 2025 – May 2027 (The Bayesian analysis will continue throughout data collection)
Writing, reporting and disseminating results: January 2027 – December 2027

## Risk Management

### *Potential Risks*

In general, participation in the study involves low risks. Examples of risks in the experimental situation include participants potentially experiencing temporary discomfort or skin irritation from electrodes being placed on the skin. However, the experiment will be conducted following the same procedures as in healthcare settings, where similar data collection is done continuously. Participants may also experience some discomfort when answering questions related to health. To minimize this risk, there will always be an experiment leader in the room to answer questions, and all questions are voluntary. During handgrip tests, mild discomfort or muscle fatigue may occur, but the participant will be encouraged to stop if discomfort arises, and the experiment leader will monitor all tests and stop them if the participant expresses discomfort. The length of the study and the variation in the types of tasks may lead to some mental and physical fatigue. However, the experiment is only 60 minutes long and includes several natural breaks, which minimizes the risk of this. Since no personal information is collected in the data, the risk of privacy violations is considered non-existent. However, participants will be clearly informed that their responses cannot be corrected or erased after they have left the experiment room, as it is not possible to trace them as individuals in the data. The experimental group with the B-LED lamp may experience the blue light as intense, which could lead to visual discomfort. Although the experiment lasts 60 minutes, the exposure will only occur for a little over half of the time; the remaining time is used for electrode application and answering questions under normal room lighting. If any participant finds the light too intense, the experiment will be stopped by the experiment leader.

***Mitigation Strategies***

Participants will be informed about the details of participation and can ask questions before voluntarily agreeing to take part. They will be informed that they can withdraw from the study at any time without explanation and may leave questions unanswered if they prefer not to share certain information. Participants will also be reassured that all information will be anonymized in the data and will only be used for research purposes. All participants will be provided with contact information for support services in case they experience any emotional discomfort. Since their responses are anonymous, their answers cannot be linked to them as individuals. All results will also be reported only at the group level. To reduce discomfort during the application of the electrodes, participants will place the electrodes themselves under the guidance of the experiment leader. All equipment will be clinically approved, with individually packaged electrodes for each participant. Unscented cleansing oils will be provided for skin preparation and electrode removal to minimize irritation. To minimize risks associated with the handgrip endurance test, we will limit the number of tests in the preliminary grip strength evaluation to avoid overexertion. Clear instructions on correct gripping technique will be provided, and participants will be encouraged to communicate any signs of discomfort. The grip resistance will be adjusted to suit individual capabilities, ensuring that everyone feels comfortable and supported throughout the process. For participants in the intervention group, exposure to the blue light will only occur during the daytime, allowing time for recovery and minimizing the risk of sleep disturbances. Participants will be advised not to look directly at the light source, and exposure will be limited to approximately half an hour.

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