Chronic Sleep Deprivation Among the Poor: A Lab-in-the-field Approach

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Study Protocol

Overview. Given the potentially bidirectional relationship between sleep and the study's key outcomes of interest, and the potential for omitted factors influencing some or all of these variables, we will utilize a randomized-controlled trial (RCT) to provide rigorous identification. We will conduct the main study by recruiting approximately 450 participants to work full-time for up to 28 business days in a data-entry job. After an eight-day baseline period, participants are stratified into four cells by work productivity and sleep quantity (above vs. below median for both). Within each cell, participants are then randomized into the following three groups, with an equal number of participants in each group:

(1) *Control Group:* Participants in the control group continue to work in our lab office. They do not receive any of the below-mentioned sleep treatments, but they do receive placebo items so that any positive response from being able to take something home is similar across groups;

(2) *Night-Sleep Treatment:* Participants in the sleep treatment group receive sleep aid devices as well as feedback on their sleep, encouragement to sleep more if appropriate, and information regarding the benefits of sleep;

(3) *Night-Sleep Treatment + Incentives:* Participants in the sleep treatment + incentives group receive the same sleep aid devices, encouragement, and information as participants in the sleep treatment, but participants in the sleep + incentives treatment are also provided modest financial incentives according to how much they increased their sleep over the previous two nights compared to their average sleep during the baseline period.

Half of the participants across each of the three treatment groups will also be randomly assigned to take a half-hour nap each afternoon. The other half will be randomized into either taking a break or working during the same time slot. This results in six total experimental groups.

Sleep will be objectively measured using wristwatch-like actigraphs, which accurately infer sleep from movement. In order to estimate the labor market effects of improved sleep, productivity, labor supply, and earnings will be measured using performance on the data-entry task. Variations on the data-entry task and a savings activity will be used to understand effects on economic decision-making, as measured by intertemporal choices and reaction to the salience of work incentives. All participants will also engage in standard lab tests of aspects of cognitive function as well as surveys and measurements of health.

Sample. All participants will be low-income residents of Chennai, India. Given the importance of sleep to all genders, we will enroll both men and women.

Process and timeline. During their participation in the study, individuals will attend the study office six days per week for 6 to 10 hours per day. During each of their visits, individuals will primarily work on a data-entry task, which will create precise measures of their labor supply and productivity, but will also complete a brief daily survey to assess self-reported sleep and covariates of interest (e.g. caffeine intake), undertake a battery of cognitive tasks, and make a daily decision whether to save money at the office at a favorable interest rate. More extensive surveys are also taken at enrollment and endline and additional health measures are collected as described below. All participants will follow a thorough informed consent procedure prior to enrollment.

Baseline period. The experiment will begin with an eight-day baseline period without any experimental variation. This baseline period serves two main goals. First, it will generate baseline

information on key covariates, which will allow us to stratify treatment conditions based on baseline outcomes, boosting statistical power and reducing the danger of baseline imbalances across treatment groups along key dimensions. Second, it ensures a population with sufficiently high attendance, promoting internal validity, since only participants who complete the baseline period are entered into the main study.

Treatment conditions. Upon completion of the baseline period, experimental variation in sleep is created in two ways: (1) two interventions to improve individuals' home sleep environments and attitudes towards sleep (randomized across individuals), and (2) a napping intervention (randomized across individuals).

(1) *Night-sleep treatment.* Existing evidence suggests that environmental irritants such as noise and light markedly disrupt sleep. To help combat these irritants as well as other disruptors of sleep common to low income populations, treated participants will be provided the option to take home eyeshades, earplugs, a basic mattress and sheet, a pillow, a cot, a heavier blanket, and a table fan. Treated participants will also be provided with instructions on proper usage of sleep aids with which they are less familiar (e.g. earplugs) to ensure safety, comfort and effectiveness. Multiple varieties of some of the products such as ear plugs and mattresses are provided, so participants can choose the ones they like most. A sub-set of individuals in the control arm of the study will not receive any sleep aids, but they will be provided the option to take home "neutral" items including utensils, a flash light, a shoulder bag, a plastic chair, a table mate, a clothing drying stand, toys, or a blender. These placebo items are designed to ensure that any positive emotions that participants may feel when they receive items to take home are experienced among participants in both the treatment and control groups. Participants are not required to accept the sleep aids or the placebo items, although most choose to accept at least some.

Treated participants will also receive daily encouragement to sleep more (if their current levels of sleep are below recommended levels) as well as information regarding the benefits of sleep and strategies to improve sleep. Half of the treated participants will also be randomly assigned to a *Night-Sleep+Incentives* group where they receive modest financial incentives according to how well they slept the previous two nights. We expect the paid out amounts to be approximately Rs 50 ($0.80) per day. To ensure that participants in the *Night-Sleep+Incentives* group do not earn more overall than other participants, the remaining participants are matched with a participant in the *Night-Sleep+Incentives* group and are paid the amount this participant receives for their sleep throughout the course of the study.

(2) *Napping.* A substantial body of evidence suggests that napping can effectively ameliorate sleep deprivation, and provides meaningful benefits in terms of improved alertness, reaction time, short-term memory, and vigilance, as well as physiological benefits (Sallinen et al, 1998). To assess whether the cognitive effects associated with napping translate into meaningful economic impacts in our context, half of all participants are randomly assigned to a workplace nap condition. These participants will be provided with the same sleep aids as those offered in the sleep intervention, and they will have a quiet gender-segregated place to lie down and take a half-hour nap. The remaining individuals will be randomly assigned each day either to take a mandatory half-hour break from work or to continue working without such a break. The randomization is constrained such that each of the non-nap participants breaks for half of the study and works for the other half. This between-person randomization greatly improves statistical power to detect the potential effects of naps and allows a comparison between the effects of naps, breaks, or working continuously.

Data-entry work task. We employ study participants in a data-entry task for three reasons. First, the data-entry task will allow us to measure productivity and labor supply at an extremely fine-grained level, while simultaneously maintaining realism and external relevance to "real-world" work environments. Second, the task allows for variation in piece rates, allowing comparison of the impact of sleep to a common metric, money. Third, by hiring participants as full-time employees, we are able to allocate time towards napping as well as to the cognitive tasks at a high frequency.

The task involves typing English words from a display into a data-entry field. The strings vary in length to mimic true data-entry work. The incentives provided vary over time; the piece rate for correct entries changes in approximatively half-hour intervals over the course of each day. All data from this task is automatically captured and stored in a custom-built database in real time.

Outcomes. A key contribution of this project is the careful construction of precise and novel outcome measures of interest, namely sleep, health, cognitive function, and economic outcomes and decisions.

(A) Sleep and sleep deprivation both constitute outcomes of interest of the study and serve as a "first stage" for the analysis of the impact of sleep on the remaining outcomes of interest. We will measure sleep and sleep deprivation via two objective and two subjective measurements. The primary measure of sleep relies on data from actigraphs, which resemble wristwatches and reliably and cost-effectively measure sleep/wake cycles via body movement. In addition, we will conduct a standard (in sleep medicine) psychomotor vigilance test (PC-PVT) on a daily basis, a reaction-time test used in sleep research as a proxy for sleep deprivation. These objective data will be complemented with self-reported sleep quantity and quality.

(B) Cognitive function is measured throughout the study period via a battery of laboratory tests conducted on a rotating basis. The tasks measure two key aspects of cognitive function, short-term memory (Corsi Block-tapping Task) and inhibitory control (Hearts and Flowers Task). The tasks are modified to cater to a low-literacy population.

(C) Health and subjective well-being. Happiness and life satisfaction reports will be elicited and anthropometric measurements taken at enrollment and exit. Additionally, participants will be asked to self-report health outcomes known to influence or be influenced by sleep including physical pain, hunger, mood, and stress. As sleep can also have an influence on self-control, we will track daily alcohol consumption through self-reports and objective measurements in the morning when participants arrive at the office. Finally, because sleep restriction has been shown to affect cardiovascular function, we will collect blood pressure readings multiple times.

(D) Stationary biking task. A significant portion of our population of interest faces employment opportunities that involve physical labor, from working as a rickshaw driver to a construction worker. In order to gather policy-relevant information on whether sleep also improves productivity on such tasks, we want to measure the impact of sleep on physical activity by having participants ride a stationary bike for up to 30 mins at the end of the study. We will collect information on the total distance participants cover while biking (in kilometers) and the maximum speed the participant reaches. Participants can always opt not to participate in this task. The incentives for task completion are relatively low—participants are offered Rs. 10 per kilometer biked, with expected average earnings of roughly Rs. 90. To ensure that participants are not overexerted, the participants can set their own cycling speed, the bike tension will be set at a low level, participants are welcome to take breaks, and we provide participants with water. We will also screen out participants whose blood pressure is over 200 or who show other signs of cardiovascular disease. From this task, we hope to estimate the impact of sleep deprivation on potential productivity in jobs that require physical labor. This task is a simplification of one previously implemented by PI Schofield with a similar study population in the

same local setting, in a project on the economic effects of nutrition also approved by Harvard CUHS (Schofield 2014; IRB #21201).

(E) Productivity, labor supply, and earnings. Individual's' work performance on the data-entry task, the primary work activity for participants for the duration of the study, will be precisely tracked. This task is compensated according to performance, and workers may choose the number of hours they work (i.e. their labor supply). Every day, the study office is open from 9.30 am till 8.00 pm. In order to disentangle the labor supply effect from the productivity effect, on some days, participants have "short days" during which they can only type from 11am to 5pm, and will receive a bonus if they type during this full period. Key outcomes of interest are (i) labor supply, defined as the number of hours worked, (ii) productivity, as determined by variable payments, (iii) overall earnings, a function of both hours worked and productivity, and (iv) quantity and quality measures in terms of the number of submitted entries and the percent of correct entries.

(F) Attention to non-salient features. An important topic of study in behavioral economics is attention to non-salient features of pricing (DellaVigna, 2009). For example, individuals do not pay enough attention to taxes that are not directly incorporated in the prices of goods (Chetty et al., 2009). To measure this, the pay structure of the typing task is salient on some days and non-salient on others, determined by the color of the payment box and signals on the screen, which are varied in terms of salience. We hypothesize that sleep deprived individuals are less likely to attend to the incentive scheme on non-salient days.

(G) Intertemporal choice: self-control. There is ample reason to hypothesize that sleep influences self-control, and thus inter-temporal choice. Sleep deprivation has been shown to worsen inhibitory control and affect the functioning of the ventromedial prefrontal cortex, the region of the brain implicated in the exercise of self-control. We will measure the impact of sleep on intertemporal choice using a savings task. To study savings behavior, all individuals are given the opportunity to save money daily at an interest rate of 0% or 1% in an individual savings box at the study office.

(H) Susceptibility to present bias. The tendency to prefer immediate gratification to receiving the same consumption bundle in the future is well known in behavioral economics. What is less known is whether sleep deprivation affects the extent of this preference. Sleep, by increasing self-control, could help individuals to make less present-biased decisions when allocating effort. We intend to address this question by following a standard procedure used in behavioral economics (e.g. Augenblick et al., 2015) wherein we ask participants how many pages (which are similar to those they work with in the data-entry task but shorter) they would be willing to type when offered different piece rates. Participants make two decisions, first one or two days before the work task, and then again right before the work task. One of the two decisions is randomly chosen to be implemented and the participant is asked to type the number of pages he or she selected in that choice. We will compare the difference in the number of pages participants are willing to enter across the two days. We hypothesize that participants choose higher work task goals in the future than the present, and that this difference will be lower among those with better sleep. Participants will always have the choice to not type any pages, and to go home instead.

(I) Risk and social preferences. Another outcome of interest is the influence of sleep on risk aversion, loss aversion, and social preferences. To measure these outcomes, we use standard lab experimental techniques outlined in the literature with modest stakes (e.g. Eckel and Grossman, 1996; Gneezy and Potters, 1997). For the risk or loss aversion activities, participants choose between an amount of money for sure or playing a lottery in which they can earn different amounts of money or nothing (with the

chance of losing negative amounts in the case of loss aversion.). For the social preferences activities, participants play the standard dictator, ultimatum (sender and receiver), and trust (sender and receiver) games. Participants are paired with another participant in the study, but we ensure that it is impossible for participants to know who they are paired with. Participants are asked to make these decisions twice in the study, once in the baseline period and once on the last day of treatment.

Note: Only health related outcomes were considered in the clinicaltrials.gov pre-registration. Economic outcomes were registered and analyzed according to the AEA clinical trials registration.