Supplement A.

**Description of Assessment Measures (see Table 1 for Administration Schedule)**

## Screening

**Age Screener Item.** Participants who report being between the ages of 50 and 65 are linked to the eligibility questions.

**Eligibility Questions.** These items were investigator designed to screen out individuals who do not meet basic criteria for the study. These items included questions about being in the area for at least six months, having internet access, a webcam, being fluent in speaking and reading English, have normal hearing, willing to refrain from other behavioral health or sleep treatments for the duration of the study, and willingness to undergo the blood testing and MRI.

**Sleep Condition Indicator (SCI).**1 The SCI is a self-report measure intended to assess evaluate insomnia symptoms according to DSM-5 diagnostic criteria. The SCI is used to determine whether an individual likely meets criteria for Insomnia Disorder during screening. The SCI demonstrates good psychometric properties.1

**Informed Consent.** Once participants complete the screening items, they are routed to an online informed consent form where a signature could be provided using a finger, mouse, or stylus. Surveys and informed consent signatures are gathered on REDCap.

**Demographic Information.** Information is collected for standard demographics (e.g., ethnicity, gender, age, height, weight), health history, and home address for in-home sleep studies.

**MRI Checklist.** This checklist was designed by local bioimaging specialists to exclude participants with risk of metal in their heads or bodies, or other medical conditions that increase risk of contraindications for a 3T MRI scanner.

## Clinical Interview

**Structured Clinical Interview for DSM-5 Sleep Disorders-Revised (SCISD-R).**2 The SCISD is a semi-structured interview designed to obtain a sleep history and screen for sleep disorders including insomnia, hypersomnolence disorder, circadian rhythm sleep-wake disorders, sleep disordered breathing, and parasomnias according to DSM-5. This newly developed measure currently has no reliability or validity data. The SCISD-R Sleep Disorders Module is used to diagnose insomnia and rule out other sleep disorders.

**Montreal Cognitive Assessment (MoCA Blind Version 8).**3 The MoCA is a validated measure in assessing mild cognitive impairment (MCI). The MoCA's sensitivity for detecting MCI is 90%. The MoCA assesses multiple cognitive domains related to MCI including short term memory, visuospatial abilities, executive functions, attention/concentration/working memory, language, and orientation, time, and place. The measure is scored with a sum of all subscores. One point is added if the individual has 12 or fewer years of education. Scores range from 0-30, with a final score of 26+ to be within the normal range.

**Mini International Neuropsychiatric Interview (MINI) 7.0.2 Standard.**4 The MINI is a widely used, short psychiatric structured diagnostic interview instrument with a series of “yes/no” type questions used to determine diagnostic status on multiple common psychiatric conditions and to evaluate suicidal ideation and intent.

### Sleep Measures

**In-Home Polysomnography (PSG)*.*** Participants will be mailed an *ambulatory PSG* unit (Zmachine® Synergy5) to collect single-channel electroencephalography, pulse plethysmography (i.e., heart rate) and oximetry (i.e., oxygenation saturation), nasal airflow, and chest respiratory rate to measure sleep architecture and cardiorespiratory indicators of obstructive sleep apnea (OSA; i.e., apnea-hypopnea index). Device-specific software (i.e., Synergy Client Software) is used to autoscore the PSG-monitored night of sleep. Participants are also provided with and asked to wear a wrist-worn accelerometer used to measure sleep and activity patterns for one week, beginning the evening of Objective Baseline (see Table 1 for fuller description).

**Consensus Sleep Diary.**6 Daily sleep diaries are used to prospectively derive average sleep parameters (total sleep time [TST], sleep onset latency, number of awakenings, wake time after sleep onset, sleep quality, and sleep efficiency [TST/time in bed × 100]) over the course of a week.

***Sleep Surveys.*** These surveys are administered either during the screening, baseline, treatment, or post-treatment period. See Table 1 for administration of each survey.

**Insomnia Severity Index (ISI).**7 The ISI is a seven-item self-report measure that assesses perceived severity of insomnia. Each item uses a four-point Likert type scale from 0 (not at all satisfied) to 4 (very much satisfied). The items sum up to produce a total score (range 0–28).

**Insomnia Identity.** This measure was investigator designed (S.E.E.)to capture the degree to which participants identified as an “insomniac.”8 Measuring insomnia identity refers to assessing an individual's identification with the experience of insomnia. This concept involves the extent to which someone sees themselves as a person who has or is affected by insomnia. To measure this, participants respond to the prompt “I am an Insomniac” by indicating their level of agreement with the statement (i.e., agree somewhat, agree, strongly agree).

**Reduced Composite Scale of Morningness (rCSM).** The rCSM is a 7-item version9 of the original 13-item Composite Scale of Morningness Questionnaire10 and is designed to classify people along a dimension of morningness-eveningness in circadian rhythms and sleep cycles.

**Sleep Need Questionnaire.**11 The Sleep Need Questionnaire is a 4-item measure which assists in CBTi treatment decision-making (e.g., how/when to change the “time in bed”).

**PROMIS Sleep Related Impairment.**12 The 8-item PROMIS Sleep-Related Impairment questionnaire (v. 1.0; 8b) measures self-reported alertness, sleepiness, tiredness, and functional impairments associated with sleep problems during waking hours within the past seven days.

**Glasgow Sleep Effort Scale (GSES).**13 The GSES is a 7-item self-report measure of sleep effort during the prior week scored on a three-point Likert scale (0: not at all to 2: very much). The scale has adequate internal consistency (Cronbach's α = .77), with evidence discriminating insomnia patients from good sleepers.

**Dysfunctional Beliefs & Attitudes about Sleep (DBAS).**14 The DBAS is a 16-item measure of beliefs and attitudes about sleep. Items are rated on a 10-point Likert scale ranging from “strongly disagree” to “strongly agree.” Strong endorsement of any of the statements is considered maladaptive. The DBAS has good internal consistency (α = 0.79) and test-retest reliability, and it converges well with the ISI.

**Self-Assessment of Sleep Survey (SASS).**15The SASS is a 9-item retrospective “whole week” questionnaire version of a prospective sleep diary. It has stronger correlations with sleep diary than the Pittsburgh Sleep Quality Index (Buysse et al., 1989).

**Multidimensional Fatigue Index (MFI).**16 The MFI is a 20-item self-report measure designed to assess fatigue across several dimensions. Total score calculation is not recommended, so the General Fatigue (GF) subscale was used in the current study to represent overall fatigue. The MFI-GF subscale consists of 4 items on a 5-point Likert scale ranging from 1 (yes, that is true) to 5 (no, that is not true). Total scores range from 4 to 20, with higher scores indicating greater general fatigue.

### Circadian Measures

**Equivital System.** Following MRI scans during Objective Baseline and Posttreatment, participants swallow a VitalSense capsule17 that captures core body temperature (CBT) and transmits data to a small device attached to a Harness18,19 worn by the participants for the following 24 hours. The Hildago Equivital ™ Physiological Monitor system was also used to measure electrocardiogram, respiratory rate, skin temperature, activity, and body position using electrodes built into the Harness.19

**Core Body Temperature**. Using the VitalSense capsule, CBT is logged in Celsius approximately every 15 seconds.

**Electrocardiography (ECG).** The Equivital Harness contains fiber electrocardiographic (ECG) electrodes on the bottom of the harness that fits around the participants’ chest, just under the breast (i.e., similar placement to a chest respiratory belt). ECG recordings are collected at a 256Hz sampling rate and inter-beat intervals (IBIs, i.e., R peak to R peak) are collected and stored automatically.

**Respiration Rate.** The belt component of the Equivital Harness (around the chest, just under the breast) is also used to capture respiration effort in the chest at a 25.6Hz sampling rate through the belt portion of the harness.

**Skin Temperature.** An infrared thermometer imbedded in the Equivital harness is used to collect skin temperature, ranging from -10°C to +50°C (±0.3°C accuracy).

**Actigraphy.** Actigraphy is a measure of sleep and activity patterns, used concurrently with sleep diaries to obtain prospective objective sleep patterns. Actigraphy is recorded with the Actiwatch Spectrum (Phillips Respironics), a compact, wrist-worn, battery-operated activity monitor that looks like a small wristwatch. They use an accelerometer to capture motion as a proxy for activity. Computer software uses an algorithm to analyze activity and estimate sleep parameters such as total sleep time, sleep onset latency, number of awakenings, wake after sleep onset, and terminal wakefulness. The Actiwatch also has an event marker button, which participants press to indicate in- and out-of-bed times. In patients with insomnia, there are high correlations for total sleep time (TST) measures between actigraphy and overnight sleep studies and between actigraphy and sleep diaries.

**Data Processing and Reduction.** Using the circadian measures described above, individual cosinor values of acrophase, mesor, and amplitude will be calculated for each measure across 24-hour period collected at baseline and posttreatment. Cosinor analysis provides the acrophase, which is the time lab to the peak value from the reference time or beginning of the phase. Circadian phases of HR, HRV, skin temperature are expected to have approximately 24-hour phases 20-22.Calculations will be performed using guidelines and software for conducting cosinor analysis to examine circadian rhythms (i.e., acrophase, mesor, and amplitude) provided by Refinetti and colleagues 23,24; Cosinor software from Circadian Rhythm Laboratory).

### Blood-Based Biomarkers

The day following the in-home PSG sleep assessment, participants meet study staff at the Biosciences Research Laboratory where a staff phlebotomist (University of Arizona’s Clinical and Translational Research Services [CATS]) performed non-fasting blood draws. Six blood tubes are drawn: two serum separation tubes (SST), two EDTA tubes, one PAXgene RNA tube, and one PAXgene DNA tube. SST and EDTA tubes are centrifuged by CATS staff. One SST and one EDTA tube are immediately sent to a local laboratory (Sonora Quest Laboratories) for analysis of high-sensitivity C-reactive protein (hs-CRP), thyroid stimulating hormone (TSH), a complete blood count (CBC) panel, and a CHEM-20 panel. With the remaining SST and EDTA tubes, serum, plasma, and buffy coat are aliquoted and stored at -80°C until batch analysis. PAXgene DNA and PAXgene RNA tubes are also stored at -80°C until batch analysis.

**Inflammatory*.*** Serum is used to assay hs-CRP, a marker of systemic inflammation via Sonora Quest Laboratories. Plasma aliquots will be used to assay pro-inflammatory (IL-6, TNF-α) and anti-inflammatory (IL-6, IL-10) cytokines via Quanterix’s Simoa Accelerator Laboratory, which is equipped to run ultrasensitive biomarker assays25. Samples will be shipped and processed using Quanterix’s standard protocols.

**Neurodegenerative.** Plasma aliquots will also be used to assay neurodegenerative markers via Quanterix’s Simoa Accelerator Laboratory. The following neurodegenerative markers will be measured using ultrasensitive biomarker assays: glial fibrillary acidic protein (GFAP), tau, neurofilament light chain (NFL), ubiquitin C-terminal hydrolase L1 (UCH-L1), brain-derived neurotrophic factor (BDNF), and amyloid-β.

**Endocrine*.*** Serum is used to measure TSH, high sensitivity, which is processed by Sonora Quest Laboratories.

**Metabolic*.*** Serum is used for the CHEM-20 panel, which is also processed by Sonora Quest Laboratories. The panel included glucose, urea nitrogen (BUN), creatinine, GFR (estimated non-African American and African American), BUN/creatinine ratio, uric acid, sodium, potassium, chloride, carbon dioxide (CO2), anion gap, osmolality (calculated), protein total, albumin, globulin, albumin/globulin ratio, cholesterol, triglyceride, calcium, phosphorus (inorganic), alkaline phosphate, gamma glutamate transferase (GGT), alanine aminotransferase, aspartate aminotransferase, lactate dehydrogenase, and bilirubin total.

**Blood Health.** Plasma is used for the CBC panel, which is processed by Sonora Quest Laboratories. The panel includes white blood cell, red blood cell, hemoglobin, hematocrit, MCV, MCH, MCHC, platelet count, RDW (sd), RDW (cv), MPV, segmented neutrophils, lymphocytes, monocytes, eosinophils, basophils, absolute neutrophil, absolute lymphocyte, absolute monocyte, absolute eosinophil, absolute basophil, immature granulocytes, absolute immature granulocytes, and nucleated red blood cell percent.

### Genetic. PAXgene RNA and PAXgene DNA samples will be used for RNA sequencing and genomic analysis. Buffy coat samples will be used to measure telomere length. Recent research provided evidence for an association between sleep quality, sleep duration, and cellular aging. Among older adults, subjective sleep quality appears to be related to cellular aging, a potential modifiable behavior associated with adverse effects of aging. Telomere shortening has been linked with increased synthesis of proinflammatory cytokines.26

### ***Sweat-Based Biomarkers***

Sweat patches worn overnight during PSG recorded sleep will be processed and assayed for inflammatory system markers described in the Blood-Based Biomarkers section, except for hs-CRP.

**Inflammatory.** Pro-inflammatory (IL-6, TNF-α) and anti-inflammatory (IL-6, IL-10) cytokines will be assayed using the sweat extracted from the patch. Prior research has shown that cytokines can be measured using non-invasive sweat collection, which is a promising new avenue of biomarker research.27,28

### Neuropsychological Assessment

Executive functioning, visual and verbal memory, and motor skills are assessed using the NIH EXecutive Abilities: Measures and Instruments for Neurobehavioral Evaluation and Research (EXAMINER). Executive functioning was assessed using the Dot Counting, Flanker, Matching, Running Dots, Set Shifting, and Tempo. Visual and verbal memory were using an associative memory Favorites task in which participants matched face photos with information about the individual in the photo. This task included a Learning, Immediate Memory, and Delayed Memory phase.

### Magnetic Resonance Imaging

### Scans are be collected on using a research-dedicated 3T Siemens MAGNETOM Skyra (Siemens Medical Solutions, Erlangen, Germany, VE 11A) using a 32-channel head coil. Foam pads are placed around the head to limit head movement and reduce the presence of motion artifacts during scanning. A neuroimaging session is conducted at baseline and posttreatment that includes the collection of standard high-resolution T1-weighted Magnetization Prepared Rapid Gradient Echo (MPRAGE) images (structural), Blood-Oxygen Level Dependent (BOLD) resting-state and task-based functional magnetic resonance images (rs-fMRI) and diffusion-weighted tensor images (DTI).

**Gray Matter Structure.** At the beginning of every scan session, standard high-resolution T1-weighted structural images is collected. T1-MPRAGE images (TR/TE/flip angle = 2100 ms, 2.33 ms, 12°) consists of 176 slices (256x256) with a slice thickness of 1mm and voxel size of 1mm x 1mm x 1mm and will be used for standard registration of functional and structural connectivity data

**Resting-state functional MRI.** A rs-fMRI scan is collected during rest (i.e., no task), which allows for inference of functional connectivity among various brain networks.29-32 Functional scans are obtained using a T2\*-weighted gradient-echo, echo-planar imaging sequence sensitive to blood oxygen level dependent (BOLD) contrast (TR = 2000 ms, TE = 25 ms, FOV = 220 mm, flip angle = 90°, GRAPPA with acceleration factor = 2). A total of 32 transverse slices are collected in an interleaved sequence (matrix = 88 x 84, voxel size = 2.5 x 2.5 x 2.5 mm, distance factor = 40%), allowing for the collection of 300 volumes. Resting-state fMRI data are preprocessed using standard pipelines in fMRIPrep (v. 20.2.1). Functional connectivity from preprocessed BOLD time series will be conducted in CONN (v.22.a). These seed-driven analyses will focus specifically on within and between connectivity of the salience network, the executive function network, and the default mode network, as these are networks are known to be altered in disorders like insomnia and mTBI.

**Multisource Interference Task-Based functional MRI.** Participants completed the MSIT while undergoing a functional MRI scan. The MSIT is a measure of cognitive and behavioral inhibition, which is a sub-domain of executive function.33 Participants respond to “congruent” and “incongruent” trials, which will be used as first-level conditions in the final analyses.

**White-Matter Tractography.** White matter integrity will be examined using DTI a 72 direction-weighting scheme. This acquisition has been found to provide sufficient angular resolution of the composite apparent diffusion coefficient in areas of fiber crossings for possible use in a tractography analysis, while having a short enough acquisition time (~8 min) to be appropriate for routine clinical use. Diffusion scan parameters include: b = 1000 sec/mm2, voxel size = 2mm x 2mm x2mm, TR = 9600 ms, TE = 88 ms, and 74 slices with a slice thickness of 2mm. Preprocessing will be completed using standard pipelines in QSIPrep (v. 0.12.2). Metrics of white matter integrity will be calculated using DTIFIT34 and will include fractional anisotropy (FA), mean diffusivity (MD), radial diffusivity (RD), and axial diffusivity.

***Health Measures***

**General Health Questionnaire (GHQ)*.*** The GHQ is the primary measure for collecting self-report data on age, ethnicity, height, weight, and high-risk health behaviors. It was developed in Dr. Taylor’s research lab, supplemented with established measures. Self-report health information is obtained using a series of checklists and yes/no/open-ended questions. Participants report on their use of medications (prescription, over-the-counter, dietary supplements) and substances (caffeine, illicit drugs). Body Mass Index (BMI) will be calculated based participants’ self-reported height and weight according to CDC guidelines.

**History of Head Injury Modified for Civilians (modified Defense and Veterans Brain Injury Center [DVBIC] 3-Item Screening Tool).** We use a modified version of the Defense and Veterans Brain Injury Center (DVBIC) 3-Item Screening Tool (Schwab, Baker, Ivins, Sluss-Tiller, Lux & Warden, 2006; Schwab, Ivins, Cramer, Johnson, Sluss-Tiller, Kiley, Lux & Warden, 2006) that was used in STRONG STAR. This instrument, initially called the Brief Traumatic Brain Injury Screen (BTBIS), was used as the gold standard for the diagnosis of TBI in a sample of soldiers returning from duty in Iraq and/or Afghanistan (Schwab, Ivins, et al., 2006). As recommended by the DVBIC, the 3-Question Screen will be considered positive when the participant endorses an injury (question 1) and altered consciousness (question 2, items A-E) for the worst head injury sustained while deployed. The form was modified for STRONG STAR and now CAP to capture the number of injuries, and to answer question 2 based on the worst injury; the original form does not recognize the possibility of multiple head injuries during deployment. As the 3-Question Screen does not query head injuries prior to deployment, an additional four questions have been added to solicit information about each head injury sustained outside of deployment.

**Patient Health Questionnaire-15**. The original PHQ was derived from the PRIME-MD and consisted of a three-page, self-administered questionnaire that asked about both somatic and psychological symptoms. The PHQ-15 (Kroenke et al., 2002) is an abbreviated version of the original PHQ that asks about somatic symptoms and symptom clusters that account for more than 90% of physical complaints reported in an outpatient setting. The 15-item measure asks patients to report symptom severity on a scale ranging from 0 (“not bothered at all”) to 2 (“bothered a lot”).

***Other Psychosocial Measures***

**Patient Health Questionnaire-9 (PHQ-9).**35 The PHQ-9 is a widely used and well-validated instrument for measuring the severity of depressive symptoms. It consists of 9 items that assess both affective and somatic symptoms related to depression and depressive disorders; these 9 items correspond to the diagnostic criteria for DSM MDD. Respondents also indicate the degree to which their depressive symptoms have made it difficult for them to do their work, take care of things at home, or get along with other people, from “not difficult at all” to “extremely difficult.”

**Generalized Anxiety Disorder-7 (GAD-7).**36 The GAD-7 is used to assess generalized anxiety symptomology. Respondents also indicate the degree to which their anxious symptoms have made it difficult for them to do their work, take care of things at home, or get along with other people, from “not difficult at all” to “extremely difficult.”

**Perceived Stress Scale (PSS).**37 The PSS is a self-report measure that assesses several domains of stress including unpredictability, lack of control, burden overload, and stressful life circumstances in the past month. The measure consists of 14 items on a 5-point Likert scale ranging from 0 (never) to 4 (very often). Total scores range from 0 to 56, with higher scores representing greater perceived stress.

**Dimensions of Anger Reactions-5 (DAR-5).**38The DAR-5 is a short form version of the original Dimensions of Anger Reactions39. It addresses anger frequency, intensity, duration, aggression, and interference with social functioning. Respondents indicate the degree to which each of 5 items describes their feelings or behavior over the last 4 weeks, from 1 (“none or almost none of the time”) to 5 (“all or almost all of the time”). The items are summed for a score ranging from 5 to 25; a cut-point of 12 is recommended to indicate a level of anger that may warrant clinical attention.38

**Alcohol Use Disorders Identification Test (AUDIT).**40 The AUDIT is a 10-item self-report screening measure, developed by the World Health Organization (WHO), with three subscales (alcohol consumption, drinking behavior, and alcohol-related problems) designed to identify people with hazardous or harmful patterns of alcohol consumption. The AUDIT assesses the past year.

**Brief Inventory of Psychosocial Functioning (B-IPF).**41The B-IPF is a 7-item self-report instrument measuring respondents’ level of functioning in seven life domains: romantic relationship, relationship with children, family relationships, friendships and socializing, work, training and education, and activities of daily living.

**Ten-Item Personality Inventory (TIPI).**42The TIPI is a ten-item measure of the Big Five personality dimensions, openness, conscientiousness, extraversion, agreeableness, and neuroticism.

**PTSD Checklist for DSM-5 (PCL-5)**.43The PCL-5 is a 20-item self-report measure designed to assess PTSD symptoms as defined by the DSM-5. Specifically, the checklist captures severity of symptoms within each symptom cluster, except for criterion A, which is the index trauma.44 Clusters include intrusions, hyperarousal, negative mood and cognitions, and avoidance.

**McArther Scale of Subjective Social Status.45** This instrument uses a visual aid of a ladder to prompt participants to determine where they perceive their position is in their community and in society, regarding their education, money, and occupation. Participants provide their perceived position using a sliding scale via REDCap. Positions on the ladder corresponded to values ranging from 1 to 10.

**Resting Online Technology Questions.** The ROTQ is composed of questions gauging participants’ comfortability with online tasks and interacting with mobile, tablet, and computer devices. These questions were developed as a part of a similar clinical trial evaluating the effectiveness of online-delivered therapies.

# *Therapy Process Measures*

**Credibility and Expectancy Questionnaire (CEQ).**46 The CEQ is widely used measure of treatment credibility and patient expectancy. The credibility subscale is rated on a 1-9 scale, with higher scores indicating more credibility. The expectancy subscale measures how much improvement the patient “thinks” or “feels” they will achieve on a 0% to 100% scale. The scale has high internal consistency in both factors and good test-retest reliability across different populations.

**Homework Adherence (Clinician rated).** Homework compliance forms will assess the extent that participants completed assigned treatment protocol provided each session. Each assignment given the previous week is then rated on completeness from 0-100%.

**Post-Intervention Qualitative Interviews.** The items used in the post-intervention interviews were investigator designed to better understand participant experiences within aspects of the study and the different treatment conditions.

**Treatment Fidelity Ratings.** Treatment fidelity describes the degree to which treatments are delivered competently and as intended. Modified CBTi treatment and fidelity rating scales were adopted from Lichstein and colleagues.47 Fidelity ratings were performed by a consultant who has performed this task for other studies.

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