Fiscal Year:	FY 2023	**Task Last Updated:**	FY 10/27/2022
PI Name:	Brainard, George C. Ph.D.		
Project Title:	Testing Solid State Lighting Countermeasures to Improve Circadian Adaptation, Sleep, and Performance During High Fidelity Analog and Flight Studies for the International Space Station		
Division Name:	Human Research		
Program/Discipline:			
Program/Discipline--Element/Subdiscipline:	HUMAN RESEARCH--Behavior and performance		
Joint Agency Name:		**TechPort:**	Yes
Human Research Program Elements:	(1) **HFBP**:Human Factors & Behavioral Performance (IRP Rev H)		
Human Research Program Risks:	(1) **BMed**:Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders (2) **Sleep**:Risk of Performance Decrements and Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, and Work Overload		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
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PI Organization Type:	UNIVERSITY	**Phone:**	215-955-7644
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City:	Philadelphia	**State:**	PA
Zip Code:	19107-5083	**Congressional District:**	1
Comments:			
Project Type:	Flight	**Solicitation / Funding Source:**	2013-14 HERO NNJ13ZSA002N-BMED Behavioral Health & Performance
Start Date:	12/01/2014	**End Date:**	08/31/2024
No. of Post Docs:	0	**No. of PhD Degrees:**	
No. of PhD Candidates:	2	**No. of Master' Degrees:**	
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	
No. of Bachelor's Candidates:	0	**Monitoring Center:**	NASA JSC
Contact Monitor:	Whitmire, Alexandra	**Contact Phone:**	
Contact Email:	alexandra.m.whitmire@nasa.gov		
Flight Program:	ISS		
Flight Assignment:	Flight Definition NOTE: End date changed to 08/31/2024 per L. Juliette/JSC (Ed., 4/10/23) NOTE: End date changed to 08/31/2023 per NSSC information (Ed., 10/13/22) NOTE: End date changed to 08/31/2022 per NSSC information (Ed., 8/31/21) NOTE: End date changed to 08/31/2021 per NSSC information (Ed., 2/3/21) NOTE: End date changed to 12/31/2020 per D. Risin/HRP/NSSC information (Ed., 09/14/2020) NOTE: End date changed to 09/30/2020 per NSSC information (Ed., 04/27/2020) NOTE: End date changed to 03/31/2020 per NSSC information (Ed., 9/3/19) NOTE: End date changed to 11/30/2019 per NSSC information (Ed., 10/11/18)		

	NOTE: End date changed to 11/30/2018 per NSSC information (Ed., 12/13/17) NOTE: Element change to Human Factors & Behavioral Performance; previously Behavioral Health & Performance (Ed., 1/17/17)
Key Personnel Changes/Previous PI:	December 2019 - Smith Johnston, MD, retired from NASA but has stayed active on this project.
COI Name (Institution):	Barger, Laura Ph.D. (Brigham and Women's Hospital/Harvard Med Ctr) Clark, Toni B.S. (NASA Johnson Space Center) Czeisler, Charles M.D., Ph.D. (Brigham and Women's Hospital/Harvard Medical Center) Johnston, Smith M.D. (NASA Johnson Space Center (Retired 12/19, but still involved)) Moomaw, Ronald O.D. (NASA Johnson Space Center) Lockley, Steven Ph.D. (Co-PI: Brigham and Women's Hospital) Hanifin, John Ph.D. (Thomas Jefferson University) Rahman, Shadab Ph.D. (Brigham and Women's Hospital) St Hilaire, Melissa Ph.D. (Brigham and Women's Hospital)
Grant/Contract No.:	NNX15AC14G
Performance Goal No.:	
Performance Goal Text:	
Task Description:	This research addresses the NASA Research Announcement (NRA) NNJ13ZSA002N-BMED: Behavioral Health and Human Performance: "Evaluation of the Neurobehavioral Effects of a Dynamic Lighting System on the ISS." This NRA solicited both "Ground Based and Flight-Definition" research with the specific instructions that the "ground study serves as a precursor to the flight study, therefore the ground study should take place in an analog with high fidelity to the ISS. The SSLAs should be studied in a high fidelity ground analog environment, then implemented on ISS to evaluate individual crewmember outcomes related to circadian physiology, sleep, behavioral health and performance using sensitive and validated measures that are feasible in the spaceflight environment." Originally, the International Space Station (ISS) used General Luminaire Assemblies (GLAs) that housed fluorescent lamps for illuminating the astronauts' working and living environments. NASA determined that, beginning in 2016, the GLAs would be replaced with Solid-State Light Assemblies (SSLAs) containing Light Emitting Diodes (LEDs). Engineers at Kennedy Space Center developed a prototype Solid-State Lighting Assembly (SSLA) that was successfully installed onboard the ISS during ISS Expedition 18. The Principal Investigator and Co-Principal Investigator of the intended research worked with engineers, scientists, and managers from Johnson Space Center (JSC) to revise the SSLA specifications so that the new lighting units would have dual capacity to: 1) provide illumination for crew members' working and living quarters, and 2) serve as a lighting countermeasure for crewmembers' circadian and sleep disruption. NASA ordered and received for a set of SSLAs intended to have this dual capacity. This research is comprised of a multidisciplinary collaboration between Thomas Jefferson University, Brigham and Women's Hospital, and JSC to complete a ground-based study in a high fidelity analog of the crew sleeping quarters and daily living environment of the ISS. Specifically, standardized psychometric, physiological, and neurobehavioral measures are testing the efficacy of light from the SSLAs to improve vision, circadian regulation, sleep, and performance in healthy astronaut-aged subjects. In addition, the initial SSLA was installed on ISS in 2016. Since then, a total of 82 SSLAs have been installed on ISS, bringing the total retrofit to 96% replacement of GLAs on the US portion of ISS. Since the onset of the SSLA retrofit, the investigators started the inflight ISS study to assess the acceptability, use, and impact of deployment of a dynamic lighting schedule aboard the ISS during operational flight missions on astronaut vision, sleep, alertness, circadian rhythms, and general well-being. Sleep, performance, and circadian rhythm data will be compared to those collected by their team and others during previous flight missions aboard ISS, in addition to surveillance of medical and psychological health in collaboration with mission flight surgeons. This project will generate quantitative data and knowledge for the benefit of crew health, habitability, environment, and human factors in the design of future human spaceflight vehicles and habitats. The project also will provide guidance for flight surgeons, flight psychologists, and astronauts to help optimize sleep and circadian regulation during space exploration missions. This research was designed to address NASA's Program Requirements Document (PRD) Risk: "Risk of Performance Errors due to Fatigue Resulting from Sleep Loss, Circadian Desynchronization, Extended Wakefulness and Work Overload" and Integrated Research Plan (IRP) Gap Sleep5: "We need to identify environmental specifications and operational regimens for using light to prevent and mitigate health and performance decrements due to sleep, circadian, and neurobehavioral disruption, for flight, surface, and ground crews, during all phases of spaceflight operations." The results of this research also specifically address other high priority risks of the Human Factors and Behavioral Performance Element, including the Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders, and the Risk of an Incompatible Habitat Design. Appropriately designed lighting systems will serve as a countermeasure to mitigate such risks in future Exploration missions. Importantly, this work will lead to advances in new lighting systems for civilian applications in work places and homes. As of November 2021, the Human Research Program risks and gaps have since been revised per more recent IRPs; see above for the current noted Risks and Gaps and the Human Research Roadmap: https://
Rationale for HRP Directed Research:	

Research Impact/Earth Benefits:	The sleep deficits experienced by astronauts during spaceflight along with risk of incompatible habitat design can be considered threats to the success of space missions (NASA Human Research Program Integrated Risk Plan, 2022). The resulting physiological and behavioral changes caused by sleep and circadian disruption can lead to diminished alertness, cognitive ability and psychomotor performance (Dijk et al., Amer. J. Physiol., 2001; Human Health and Performance Risks of Space Exploration Missions. McPhee and Charles, eds., 2010). As a measure to counteract sleep disruptions, crew members report using sleep promoting drugs: 71% on space shuttle flights and 75% during ISS expeditions (Barger et al., Lancet Neurology, 2014; Flynn-Evans et al., 2016 npj Microgravity). A significant portion of the global population suffers from chronic sleep loss and/or circadian-related disorders. Evidence for disease occurring due to a disruption of circadian homeostasis has mounted significantly in the past several years. In the United States, nearly 22 million Americans do shift work that interferes with a biologically healthy nocturnal sleep cycle (US Bureau of Labor Statistics, 2007). It has been shown that shift workers are more likely to suffer from a wide variety of ailments, including cardiovascular disease, metabolic disorders, gastrointestinal distress, and cognitive and emotional problems. Development of an in-flight lighting countermeasure that helps resolve circadian and sleep disruption in astronauts is likely to help optimize the use of light therapy for patient populations with affective, circadian and sleep disorders. References Dijk DJ, Neri DF, Wyatt JK, Ronda JM, Riel E, A. R-D, Hughes RJ, Elliott AR, Prisk GK, West JB and Czeisler CA (2001) Sleep, performance, circadian rhythms, and light-dark cycles during two space shuttle flights. Am J Physiol 281:R1647-R1664. McPhee J and Charles J, eds. 2010. Human Health and Performance Risks of Space Exploration Missions: Evidence Reviewed by the NASA Human Research Program. NASA SP-2009-3405 edition. Barger LK, Flynn-Evans EE, Kubey A, Walsh L, Ronda JM, Wang W, Wright KP and Czeisler CA (2014) Prevalence of sleep deficiency and use of hypnotic drugs in astronauts before, during, and after spaceflight: an observational study. Lancet Neurology 13:904-912. Flynn-Evans EE, Barger LK, Kubey AA, Sullivan JP and Czeisler CA (2016) Circadian misalignment affects sleep and medication use before and during spaceflight. npj Microgravity 2:15019; doi:15010.11038/npjmgrav.12015.15019.
	Three institutions are collaborating on this multidisciplinary research: Thomas Jefferson University (TJU), Brigham and Women's Hospital (BWH), and Johnson Space Center (JSC). The original aims were to complete a ground-based study in a high-fidelity analog of the crew sleeping quarters (CQ) and an in-flight study in the daily living environment of the International Space Station (ISS). Ground-Based Analog Study: This study aims to test the efficacy of lighting protocols for daily operations using Solid State Lighting Assemblies (SSLAs) in ISS CQs installed in laboratories at TJU. In a controlled five-day inpatient study using astronaut-aged volunteers, we tested the hypotheses that compared to the static, daily lighting of General Illumination only, the Dynamic Lighting Schedule protocol for a typical ISS work day (18 h wake: 6 h sleep) will improve visual performance, circadian entrainment, the onset of melatonin production, sleep onset, sleep duration as well as morning alertness and performance. Separate human use protocols were submitted and approved by the Institutional Review Boards (IRBs) at TJU and NASA. Previously, NASA and National Space Biomedical Research Institute (NSBRI) funded the PI and Co-PI to develop a high-fidelity, in-laboratory analog environment to study the visual, biological, and behavioral effects of the SSLAs. Specifically, a high-fidelity replica of the ISS Crew Sleeping Quarters (CQ) was developed with precise replication of CQ volume, geometry, and surface reflectance with an SSLA providing illumination. Astronaut-aged study subjects were able to be upright in this CQ and work, read, or use a computer just as crewmembers do aboard the ISS. In addition, a second CQ was developed that allows subjects to be semi-recumbent during wakefulness in SSLA lighting or fully recumbent when sleeping in darkness. Data from controlled studies in these high fidelity in-laboratory analog conditions represent the only published ground-based human data on the efficacy of the SSLAs to date (Brainard et al., Acta Astronaut., 2013; Brainard et al., Curr. Opin. Pulm. Med., 2016). The SSLAs were each adjusted for their spectral output to be as close as possible to NASA's vendor requirements for ISS (NASA Revision C, S684-13489, 2013). These specifications include Correlated Color Temperature (CCT) and luminance in candelas (cd) for three basic settings: 1) General Illumination: 4500 K SSLA white light, 210 cd; 2) Phase Shift/Alertness: 6500 K SSLA (blue-enriched) white light, 420 cd; 3) Pre-Sleep: 2700 K SSLA (blue-depleted) white light, 90 cd. Based on published and unpublished data, the Co-PIs determined that the 90 cd luminance at the crewmember's eye level inside of a CQ would be too bright to serve as an effective Pre-Sleep countermeasure. This issue was discussed with our project management team at JSC on several occasions. It was determined that in spaceflight, the SSLA luminance could be lowered from 90 cd using a combination of SSLA dimming buttons and a cloth shade system that is currently used on the fluorescent lighting system in the CQs aboard ISS. Based on a series of SSLA lighting measures and our prior pilot study in the CQs, we chose a Pre-Sleep luminance of 7.7 cd (20 lux at eye level) for our Pre-Sleep setting. This study included male and female volunteers in good physical and mental health with normal color vision. Volunteers were selected in the age range of astronauts (range 26-54 years). Prior to admission to the laboratory, subjects were asked to maintain a regular 8:16 h, sleep:wake schedule and wear a wrist-borne, non-invasive activity and light monitor for at least 10 days. Twenty-eight subjects completed the screening process and were randomly assigned into a lighting condition of either dynamic (N=16) or static (N=12) lighting. Among those subjects, 19 were male, and 9 were female (age range 26 – 53 years). Twenty-five of these subjects successfully completed the entire five-day study. The data gathered from this first study run include a successful collection of complete pre-study actigraphy and inpatient study actigraphy from each subject. A total of 268 neurocognitive and performance tests were collected from each subject across the five-day inpatient study (over 6,700 total). In addition, 95 Karolinska sleepiness scales (KSS) were collected from each subject across the inpatient study (2,375 total). Complete sets of blood, saliva, and urine samples were collected from each subject for the measurement of melatonin and 6-sulfatoxymelatonin. Melatonin contents of 548 plasma samples from 25 participants who completed a full study run have been analyzed. Polysomnography (PSG) was used to monitor sleep states and wakefulness using electrodes placed on the scalp, face, chin, and chest. Electrodes were positioned according to the International 10-20 System. The actigraphy, neurocognitive, and performance tests and urinary 6-sulfatoxymeltonin measures match similar or identical tests that were used aboard ISS during the flight study. Portions of data from this study have been uploaded to the NASA Large File Transfer service.

Task Progress:	The testing of visual performance and color vision under different SSLA light settings has been done separately from the five-day studies. Two separate cohorts of 8 healthy male and female astronaut-aged subjects have completed within-subjects study designs that test their visual performance and color vision. Complete reporting on the three analog studies has been made to NASA. Data analysis and development of manuscripts is ongoing. ISS Flight Study: The aims of this study were to test the efficacy of lighting protocols for daily operations using SSLAs for inflight crewmembers aboard ISS missions. Specifically, we assessed the acceptability, use and operational impact of deployment of the Dynamic Lighting Schedule protocol on astronaut vision, sleep, alertness, circadian rhythms, and general well-being during ISS flight missions. This inflight study tested the hypotheses that, compared to current static daily fluorescent lighting of General Illumination only, the Dynamic Lighting Schedule protocol would maintain acceptable visual performance and color discrimination for operational tasks, improve circadian entrainment, improve circadian adaptation following a sleep shift challenge such as a "slam-shift," improve sleep duration and efficiency, and enhance wake-time alertness and cognitive performance. Ethical approvals were obtained from NASA and Partners Healthcare for the flight study. The flight study successfully went through an ISS Medical Project (ISSMP) feasibility assessment. Subsequently, the Human Research Program (HRP) Science Management Panel selected this study for flight on 9/3/15. A total of eight crew members consented to participate in the flight study. Seven astronauts have completed pre-flight, in-flight, and post-flight testing. As of September 2022, 82 SSLAs have been successfully installed, providing a 96% retrofit of the ISS. This ISS flight study on crewmembers is a sophisticated human photobiological study. All photobiological studies, whether in spaceflight or on Earth, rely on precise characterization of the independent variable of the study: light. For this study, the relevant light stimulus is light emitted by the new SSLAs and the remnants of the original ISS fluorescent lighting system. A spectrophotometer/irradiance meter is an essential tool for ensuring that consistent emission of light spectrum and light intensity is maintained during the inflight ISS research. The key measures for this flight study are light irradiance, illuminance, and spectral power distribution of the four settings of the SSLAs, as well as the single setting of the current fluorescent lights. Working with the study collaborators, ISSMP selected and deployed the meter for the flight study on ISS. A total of 37 sets of lighting measures have been taken by crewmembers and transmitted from ISS to the study team on Earth. Considerable work between the study collaborators and the hardware group of ISSMP has gone into making flight-worthy versions of visual performance and color vision tests. Those tests were used successfully on the ISS. The Lanthony Desaturated 15-Hue test is the method used for testing crewmember color discrimination under the different SSLA light settings compared to that of the current fluorescent lighting on ISS. Historical data of actigraphy, sleep logs, cognitive testing, and urine samples were identified from previous flight studies and used as the control data in the flight study. Seven crewmembers have completed all post-flight data collection, including actiwatch/sleep logs, cognition, urine sampling, and visual testing. The urine samples were returned to Earth and analyzed for 6-sulfatoxymelatonin. After the completion of their flight mission, each of the seven crewmembers met personally with one or two representatives from BWH and TJU for debriefing at JSC. Complete reporting on this ISS flight study has been made to NASA. Data analysis and development of manuscripts are ongoing. New Analog Study: As described above, the original objectives of doing an analog ground study and an ISS flight study have been successfully completed and reported to NASA. The analog study data showed that the new SSLA developed for re-lamping the ISS can facilitate the onset of evening melatonin secretion, an important component of sleep physiology. This benefit of the Pre-sleep SSLA light setting, however, comes at the cost of significantly reducing color vision. Data from the analog study demonstrated that color vision was significantly reduced under the Pre-sleep setting. Similarly, data collected ISS flight study also showed color vision was significantly reduced under the Pre-sleep setting. There are many color-sensitive tasks during space flight, such as the hydrazine test, electrical wiring, and the like. Further, color coding is used in warnings, reminders, and crewmember manuals. Crewmembers often read manuals during the pre-sleep period to prepare for the next day’s operations. Human Factors and Behavioral Performance Element provided augmentation funding to support a small study (N=8) to test the hypothesis that, compared to the current ISS Pre-sleep light intensity, a modified spectrum and/or an increased Pre-sleep light intensity will still permit an earlier melatonin onset while improving crewmember color vision. The COVID-19 pandemic, however, caused a cessation of our program’s human subject testing for two and a half years. Rcently, we have successfully restocked expired medical supplies, restaffed, and are recruiting participants for this new analog study. Enrollment of our first NASA participant is poised to start no sooner than November 2022. This study specifically addresses high-priority risks of the Human Factors and Behavioral Performance Element, including the Risk of an Incompatible Habitat Design. Appropriately designed lighting systems will serve as a countermeasure to mitigate risks in programs such as Artemis and Gateway. If successful, the study will inform the NASA Technical Standard 3001 for the lighting of future space vehicles and habitats. References: Brainard GC, Coyle W, Ayers M, Kemp J, Warfield B, Maida J, Bowen C, Bernecker C, Lockley SW, and Hanifin JP. Solid-state lighting for the International Space Station: Tests of visual performance and melatonin regulation. Acta Astronaut. 2013 Nov;92:21-8. Brainard GC, Barger LK, Soler RR, and Hanifin JP. The development of lighting countermeasures for sleep disruption and circadian misalignment during spaceflight. Current Opinion in Pulmonary Medicine. 2016;22:535-44. NASA. ISS Interior Solid State Lighting Assembly (SSLA) specification, revision C. May 2013;S684-13489.
Bibliography Type:	Description: (Last Updated: 10/30/2023)
Abstracts for Journals and Proceedings	Brainard GC, Hanifin JP. "Light and health: From space flight to patient care." 10th Annual Conference of inVIVO Planetary Health, December 6, 2021. Proceedings of the 10th Annual Conference of inVIVO Planetary Health, December 6, 2021. , Dec-2021

Abstracts for Journals and Proceedings	Brainard G, Rahman S, Clark T, St. Hilaire M, Garcia D, Norwood K, Kemp J, Disoke F, Hanifin J, Warfield B, Maida J, Johnston S, Moomaw R, Barger L, Czeisler C, Lockley S. "Testing solid state lighting countermeasures to improve circadian adaptation, sleep, and performance during high fidelity analog and flight studies for the International Space Station." NASA Human Research Program Investigators' Workshop, Virtual Meeting, February 8, 2022. NASA Human Research Program Investigators' Workshop, Virtual Meeting, February 8, 2022. , Feb-2022
Abstracts for Journals and Proceedings	Rahman SA, Kent BA, Grant LK, Clark T, Hanifin JP, Barger LK, Czeisler CA, Brainard GC, St. Hilaire MA, Lockley SW. "Lighting protocols for exploration – HERA campaign." NASA Human Research Program Investigators Workshop, Virtual Meeting, February 8, 2022. NASA Human Research Program Investigators Workshop, Virtual Meeting, February 8, 2022. , Feb-2022
Abstracts for Journals and Proceedings	Rahman SA, Kent BA, St. Hilaire MA, Clark T, Hanifin JP, Barger LK, Czeisler CA, Brainard GC, Lockley SW. "Lighting protocols for exploration – HERA campaign." NASA Human Research Program Investigators Workshop, Virtual Meeting, February 4, 2021. Abstracts. NASA Human Research Program Investigators Workshop, Virtual Meeting, February 4, 2021. , Feb-2021
Abstracts for Journals and Proceedings	Hanifin J, St. Hilaire M, Kemp J, Warfield B, Disoke F, Glodjo T, Jasser S, Ayers M, Panepinto L, Kanumilli S, Nelson N, Hasher D, Vadalia S, Balaicuis J, Byrne B, Pineda C, Gerner E, Rahman S, Lockley S, Brainard G. "Solid state lighting countermeasures to improve circadian adaptation, sleep, and performance during a high fidelity analog study for the International Space Station." 33rd Annual Meeting of the Society for Light Treatment and Biological Rhythms, Manchester, United Kingdom, June 23-25. Abstracts. 33rd Annual Meeting of the Society for Light Treatment and Biological Rhythms, Manchester, United Kingdom, June 23-25. , Jun-2022
Abstracts for Journals and Proceedings	Brainard G, Rahman S, Clark T, St. Hilaire M, Garcia D, Norwood K, Kemp J, Disoke F, Hanifin J, Warfield B, Maida J, Johnston S, Moomaw R, Barger L, Czeisler C, Lockley S. "Testing solid state lighting countermeasures to improve circadian adaptation, sleep, and performance during high fidelity analog and flight studies for the International Space Station." NASA Human Research Program Investigators' Workshop, Virtual Meeting, February 4. Abstracts. NASA Human Research Program Investigators' Workshop, Virtual Meeting, February 4. , Feb-2021
Articles in Peer-reviewed Journals	Rahman SA, Kent BA, Grant LK, Clark T, Hanifin JP, Barger LK, Czeisler CA, Brainard GC, St Hilaire MA, Lockley SW. "Effects of dynamic lighting on circadian phase, self-reported sleep and performance during a 45-day space analog mission with chronic sleep deficiency." J Pineal Res. 2022 Nov;73(4):e12826. https://doi.org/10.1111/jpi.12826 ; PubMed PMID: 35996978 , Nov-2022
Articles in Peer-reviewed Journals	Rahman SA, St. Hilaire MA, Grant LK, Barger LK, Brainard GC, Czeisler CA, Klerman EB, and Lockley SW. "Dynamic lighting schedules to facilitate circadian adaptation to shifted timing of sleep and wake." J Pineal Res. 2022 May 2;73(1):e12805. https://doi: 10.1111/jpi.12805 ; PubMed PMID: 35501292 , May-2022
Articles in Peer-reviewed Journals	Vetter C, Pattison PM, Houser K, Herf M, Phillips AJK, Wright KP, Skene DJ, Brainard GC, Boivin DB, Glickman G. "A review of human physiological responses to light: implications for the development of integrative lighting solutions." LEUKOS 18. 2022;387-414. https://doi.org/10.1080/15502724.2021.1872383 , Feb-2022
Articles in Peer-reviewed Journals	Brown TM, Brainard GC, Cajochen C, Czeisler CA, Hanifin JP, Lockley SW, Lucas RJ, Munch M, O'Hagan JB, Peirson SN, Price LLA, Roenneberg T, Schlangen LJM, Skene DJ, Spitschan M, Vetter C, Zee PC, Wright KP. "Recommendations for daytime, evening, and nighttime indoor light exposure to best support physiology, sleep, and wakefulness in healthy adults." PLoS Biology. 2022 Mar 17;20(3):e3001571. https://doi.org/10.1371/journal.pbio.3001571 ; PubMed PMID: 35298459; PubMed Central PMCID: PMC8929548 , Mar-2022