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Solid-State Lighting Program and NIH:

Human Physiological Responses to Light R&D Meeting

November 2022

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Disclaimer

DOE Solid-State Lighting Program & National Institutes of Health, "Human Physiological Responses to Light R&D Meeting," November 2022.

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Solid-State Lighting Program
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Comments

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Stephanie Crowley	Rush Medical College
Charles Czeisler	Harvard Medical School
Altug Didikoglu	University of Manchester
Mariana Figueiro	Icahn School of Medicine at Mount Sinai
Erin Flynn-Evans	National Aeronautics and Space Administration
Gena Glickman	Uniformed Services University of the Health Sciences
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David Sliney	Consulting Medical Physicist
Manuel Spitschan	Max Planck Institute for Biological Cybernetics
Christopher Steele	Military Operational Medicine Research Program
Jennifer Veitch	National Research Council of Canada
Kenneth Wright	University of Colorado Boulder

Observers

Jamie Zeitzer	Stanford School of Medicine
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1 Introduction

On November 9, 2022, 16 subject matter experts from industry, national laboratories, and universities gathered at the invitation of the Department of Energy (DOE) Solid-State Lighting (SSL) Program to identify critical research and development (R&D) areas in human physiological responses to light. This small-group meeting is a forum for experts to directly provide technical input to the DOE SSL Program. This stakeholder guidance helps the Program identify critical R&D topics which may be suitable for R&D funding.

This year the human physiology meeting was held virtually. The meeting commenced with "soapbox" presentations where each participant gave a short presentation describing what they believed to be the key human physiological response challenges for SSL over the next three to five years. This was followed by a general discussion of the most critical challenges facing the industry today.

The meeting format provided an opportunity for experts across the research spectrum to exchange ideas and explore collaborative research concepts. Participants included researchers funded by the DOE SSL Program.

This report summarizes the outcome of the discussions on critical technology challenges and identifies corresponding R&D tasks within the existing task structure. Summaries of each participant's soapbox presentation and related remarks are included in Appendix A of the report.

2 Key Themes

The meeting format encouraged attendees to present their perspectives on critical R&D challenges for advancing understanding of human physiological responses to light. In the discussions that followed the soapbox presentations, several recurring themes arose (discussed in more detail below):

- Individual differences in physiological responses to light
- Clear and comprehensive light stimulus measurement and reporting
- Specific physiological effects of light
- Deliberate lighting strategies for engaging physiological effects

2.1 Individual Differences in Physiological Responses to Light

The participants noted that there can be individual differences and diversity of physiological responses to light. These differences need to be understood within similar demographics but also across demographics.

Individually different physiological responses to light in practical settings can be a function of behavioral differences, resulting in a wide range of lighting stimuli and doses. However, these responses can also be a function of unique physiological features. Various groups, like adolescents, elderly people, and health compromised individuals can have different physiological responses to light and different lighting needs. Addressing the unique needs of these different groups can mitigate health risks.

By necessity, many of the studies that have elucidated the mechanisms of physiological responses to light rely on young and healthy subjects. However, these subjects are not representative of the broader range of responses that are experienced by the population of those exposed to light. In particular, the physiological mechanisms of photo-sensitive populations need to be understood, as these mechanisms might provide more insight into the underlying physiological mechanisms. Lighting practices need to be inclusive of the needs of these individuals.

2.2 Clear and Comprehensive Light Stimulus Measurement and Reporting

It is critical to characterize light stimulus clearly and comprehensively in studies and in realistic settings. Laboratory studies can deliver a controlled light stimulus and monitor the physiological responses. In more realistic settings, it is more difficult to characterize the lighting stimulus, particularly over the range of light settings experienced in a day by an individual. There are numerous mediating factors within the environment, individual behaviors, and human physiology that affect the amount and duration of light on the retina. Environmentally, there are almost infinite light settings and the light stimulus provided in these settings is affected by an equally broad range of individual behaviors. In general, the range and predictability of individual light doses is not well understood. Physiologically, human face structures affect the field of view of light stimuli, pupils affect the amount of light reaching the retina, and the age of an individual can affect the amount of light transmitted to the retina. All of these mediating factors can make it difficult to translate the magnitude of physiological effects found in controlled laboratory studies, where gaze, intensity, pupil dilation state, and other factors are controlled to realistic, applicable settings. To account for all of these factors, clear and consistent reporting of light stimuli is necessary. Field studies require lighting dosimetry, which monitors behavioral factors, accounts for field of view, and collects and records stimuli over time.

2.3 Specific Physiological Effects of Light

The meeting participants also described research on specific physiological responses to light. The mechanism of photic sneezing, or sneezes induced by bright light, was brought up and indicated for further research. Temporal light modulation and the resulting visual perception as well as neurobiological and performance cognitive effects were also raised as areas for additional research. The relationship between sleep restriction, which can be a result of inadequate lighting, and plasma glucose levels, an indicator of pre-diabetes, was mentioned. The relationships between sleep health for adolescents and for Alzheimer's patients and lighting conditions was also discussed. Participants also shared recent research on the relationship between lighting and alertness, cognitive performance, and memory: lighting treatments did not affect alertness but did improve cognitive performance and memory. These discussions indicated the wide range of health impacts from lighting conditions. The positive and negative health impacts from lighting are enormous and need considerable additional research and understanding to guide optimized lighting practices.

2.4 Deliberate Lighting Strategies for Engaging Physiological Effects

The themes discussed above reinforce the need for deliberate lighting strategies in different settings to achieve desired health outcomes. For generally healthy day workers in group settings, such as offices or schools, general lighting guidance for health is becoming clearer and is most simply described as bright days and dark nights. But there is still a gap between this general guidance and practically achievable lighting target illuminance levels. In addition, vertical illuminance levels are understood to relate better to retinal illuminance. Even in general indoor settings, there can be photosensitive individuals that may require individualized lighting conditions. Deliberate lighting schemes can be deployed to support health for at-risk populations. This is particularly true in care homes, where non-sleep disrupting lights can reduce falls from nighttime bathroom visits and more attention to “bright day and dark night” lighting can mitigate symptoms of Alzheimer’s disease. Deliberate lighting designs can have significant health and well-being impacts for a range of occupants. More basic physiological research and more field-level translational studies are necessary to get the full health benefits from new lighting technology capabilities.

Appendix A: Participant Presentations

Kenneth Wright, University of Colorado Boulder: Recommendations for Indoor Light to Support Healthy Outcomes

Kenneth Wright, professor at the University of Colorado Boulder, presented the recommendations for indoor light in healthy adults from a consensus journal article published earlier this year. He, and others that attended the R&D meeting, wrote the article. Wright said that during daytime, people should have a minimum melanopic EDI of 250 lux at the eye and that the requirement should be met with daylight or electric light enriched in shorter wavelengths. Starting about 3 hours before bedtime, the recommended maximum melanopic EDI for healthy adults is about 10 lux. Finally, the sleep environment should be as dark as possible with a maximum melanopic EDI of 1 lux. Wright moved on to note that children seem to have a higher sensitivity to evening light than adults and that the recommendations may be different for children because of this. He concluded by discussing the National Institutes of Health's Sleep Research Plan. He noted that the document presented a "critical opportunity" to develop enhanced daytime lighting recommendations. The document also called for more research exploring the health effects of light exposures.

Gena Glickman, Uniformed Services University: Personalized Medicine Approach to Lighting of the Future

Gena Glickman, Director of Chronobiology at the Uniformed Services University's Light and Sleep Lab, discussed individual responses to light and how understanding the variation can result in better outcomes for occupants. Glickman began by showing results from existing studies which demonstrate that there is major variation between individuals in terms of their responses to light. She argued that this creates an opportunity for personalized approaches to lighting. Glickman said that lighting professionals can use community-based interventions first and then move on to individual interventions for more unique needs. This could be especially useful for understudied and at-risk populations. Glickman believes that the lighting industry has failed to address these populations' needs. She called for lighting professionals to design systems for everyone, not just "the average person", who she argued doesn't exist. Glickman suggested that lighting designers use a layered approach, harnessing both community and individual level interventions. In this way, she said, lighting designers can create lighting that works for everyone. Glickman concluded by stating that knowledge of individual responses to light could help create drugs to manage these responses.

Manuel Spitschan, Max Planck Institute for Biological Cybernetics: New Research Group, ENLIGHT Project, and Photic Sneezing

Manuel Spitschan, research group leader at the Max Planck Institute, presented on his recently established research group, his ENLIGHT project, and photic sneezing. Spitschan's research group is focused on sensory and circadian neuroscience and will conduct laboratory studies on participants in evenings and during the day. The group will also perform field interventions to modify light exposure. Spitschan has 6 researchers working under him.

After introducing his group, Spitschan moved on to discuss his ENLIGHT project. The project's goal is to develop a comprehensive and standardized guideline for reporting light characteristics in studies using light as an intervention. Spitschan said this is important because it could enable meta-analysis of studies and make it easier to gather research results. Such a standard does not exist in the field currently. The standard will focus on laboratory-based research conducted in human participants to study the effects of ocular light exposure on non-visual physiology. The standard is in the process of being written. It will likely be revised over time. Spitschan is also working on creating a committee in the International Commission on Illumination (CIE) focused on wearable dosimetry and light logging. He hopes that CIE will vote to establish the committee soon.

Finally, Spitschan closed by discussing photic sneezing. Photic sneezing occurs when someone sneezes due to the presence of bright light. According to Spitschan, this can happen in about 20-30% of people. He also noted that there is a time-of-day effect with photic sneezes that is different to regular sneezes. He plans to investigate this phenomenon further.

Charles Czeisler, Harvard Medical School: Circadian Alignment and Metabolism

Charles Czeisler, professor at Harvard Medical School, presented on circadian alignment and metabolism. Czeisler began by discussing the results of a prior study, which showed that acute circadian misalignment is associated with elevated post-prandial plasma glucose. He moved on to a paper that he and others published in 2012, which showed that a combination of recurrent circadian disruption and prolonged sleep restriction reduced glucose metabolism. In this study, 40% of people exposed to this sleep schedule went into a prediabetic state. In general, exposed subjects had increased glucose levels and decreased insulin levels. These results motivated Czeisler to try to differentiate the impacts of circadian disruption vs. chronic sleep restriction.

To achieve this, Czeisler's team exposed one group of subjects to recurrent circadian disruption. This group was allowed to sleep for 8 hours every 24-hour period, but these 8 hours were out of sync with daylight hours. Another group was exposed to chronic sleep restriction, meaning a team member ensured they only slept for 6 hours every 24-hour period. However, these subjects were kept in the dark for 8 hours so as not to disrupt their circadian rhythms. A control group was also included. All three groups were given the same diet, which Czeisler called a "regular diet". Remarkably, no adverse effects on insulin or glucose levels were seen in either of the test groups.

Czeisler was puzzled by these results, so he set up another experiment with the same treatments. However, in this experiment, participants were given a high fat diet, which Czeisler said was closer to an average American's diet. Results from this experiment showed that recurrent circadian disruption increased subjects' glucose levels and impaired their response to insulin. Czeisler went on to say that his results imply that other studies that purportedly demonstrate the connection between chronic sleep restriction and diminished glucose metabolism may actually stem from longer exposure to light during waking hours. This is because subjects in those studies were exposed to light for the entire time they were awake, rather than only 16 hours of light as in Czeisler's experiment.

Mariana Figueiro, Icahn School of Medicine at Mount Sinai: Lighting for Neurodegenerative Diseases

Mariana Figueiro, professor at Icahn School of Medicine at Mount Sinai, discussed lighting for neurodegenerative diseases through the lens of her work. She primarily discussed four studies that her group is either working on or has completed in this area. Figueiro began by showing results from her study focused on therapeutic light interventions for patients with Alzheimer's disease and dementia. The study showed that patients had fewer sleep disturbances, agitation behavior symptoms, and depressive symptoms during the intervention compared to the baseline. She then moved on to discuss an upcoming study, which will use 7T multimodal imaging to detect brain changes associated with light therapy in patients with Alzheimer's and mild cognitive impairment (MCI). Her team hypothesizes that this light therapy will cause effects that are visible on these images and that the light therapy will improve mood and sleep compared to control subjects. The next study Figueiro presented is focused on rhythmic light therapy in the 40 Hz range and sex differences in response. This study also uses elderly patients with Alzheimer's or dementia as test subjects, although healthy elderly patients are included as well. Results of the study show that males have a heightened response to the treatment compared to women. Figueiro concluded by discussing a study of nightlight use to reduce fall risk in elderly care homes. The nightlights used for the study surround residents' bathroom door frame, guiding them toward the bathroom in the dark. The study indicated that the lights reduced falls by 34% for residents of the rooms where they were installed.

Renske Lok, Stanford School of Medicine: Light Effects on Daytime Cognitive Performance and Alertness

Renske Lok, postdoctoral fellow at Stanford School of Medicine, discussed her research on light effects on daytime cognitive effects and alertness. Lok began by presenting results that demonstrated that light effects on subjective alertness are minor. She also said that her research showed that neither light intensity nor spectral composition affected subjective alertness. However, Lok noted the effects of light were more pronounced in simple mental performance: as melanopic EDI increased, cognitive performance improved. These effects were large and present in almost every participant, although they were not present in all cognitive domains. Lok concluded by noting that these performance enhancing effects can occur independent of alertness.

Stephanie Crowley, Rush Medical College: Adolescent Sleep: The "Perfect Storm" Model

Stephanie Crowley, professor at Rush Medical College, discussed the "Perfect Storm" model of adolescent sleep. Crowley began by describing the various pressures that combine to cause circadian misalignment in adolescents and prevent them from getting enough sleep. These include bioregulatory, psychosocial, and societal pressures. Crowley said that bioregulatory pressures in adolescents have to do with circadian phase delays and slowed sleep pressure rise. She explained that as children get older, psychosocial pressures arise from more bedtime autonomy and increased screen time, social networking, and academic pressures. These bioregulatory and psychosocial pressures cause adolescents to go to bed later, while societal pressures such as early school start times force them to wake up early. The circadian misalignment that results from these pressures is harmful to adolescents. The issue is especially important because this period in life is often when mental health issues start to arise and healthy habits for adulthood are formed.

In response to all this, Crowley was motivated to investigate how 24-hour light and dark patterns impact vulnerable populations, such as those in hospitals, schools, and jails. She ran a research project with juvenile justice facilities to gather information. Crowley said 75% of youth that responded to her survey say there are lights on at night making it hard to sleep. She also said 6 out of 11 night staff had experienced youth complaints from nighttime lighting in these facilities. Crowley concluded by proposing dynamic lighting systems as a potential solution to this problem. She said these systems would allow youth to sleep at night in a dimmed red-light environment while night staff monitor youth and safety. These systems would also allow youth exposure to broad spectrum light during waking hours. However, for these systems to work well, they require buy in from facility managers. Thus, systems must be cost effective and implemented easily into a complex schedule.

Luc Schlangen, Eindhoven University of Technology: Light is a Problem and a Solution for Health and Sleep

Luc Schlangen, senior researcher at Eindhoven University of Technology, explained why he believes light is a problem and a solution for health and sleep. Schlangen began by discussing health and sleep problems associated with light exposure. He said that people with little daytime light exposure have later sleep timing, increased interindividual differences in sleep timing, decreased sleep quality, and higher risk of lifetime depression. He went on to describe how research shows that people exposed to more indoor light at night have impaired cardiometabolomic function, higher incidence rate for diabetes, increased sleep onset latency, and increased BMI, LDL cholesterol, sleep disturbances, and depressive symptoms. After explaining this, he showed that there is a dose response relationship between melanopic EDI of evening light and sleep. Schlangen noted that UL recommendations for light for human health are insufficient to meet the most recent research recommendations for healthy light. He concluded by reiterating that low light levels during the day and high light levels at night are both associated with poor health and sleep. He also said that recommendations for bright days and dim nights are currently specified using light level, duration, and timing of exposure. Schlangen proposed that future research evaluate healthy light recommendations and develop recommendations for different groups, such as shift workers, the elderly, and children.

George Brainard, Thomas Jefferson University: Influence of Daytime LED Light Exposure on Circadian Regulatory Dynamics of Metabolism and Physiology in Mice

George Brainard, professor at Thomas Jefferson University, presented results from a study conducted by his group. During the study, the research team exposed one group of mice to LED lights with short wavelength enabled and the other group to cool white fluorescent light. Both groups were exposed to their corresponding light for 12 weeks. When C3H mice were tested at the end of the exposure period, their melatonin nighttime levels were six times higher under LED than fluorescent. The C3H mice exposed to LED also exhibited lower dietary and water intake and slower rates of animal metabolism and growth. These results were not observed in other strains of mice that were tested (C57BL/6 and BALB/c).

Brainard's group wants to see if these findings could be replicated in humans, so they have developed an experiment using a multiday live-in test facility. They hypothesize that compared to built-in CWF light, SSL tunable lighting will: advance onset of melatonin production; increase the amplitude and duration of melatonin production; optimize glucose, insulin, leptin and cortisol levels; and shorten sleep latency and improve sleep efficiency. The group will perform two studies, one in which participants are exposed to light for 16 hours a day only in the laboratory, and one in which participants will be exposed to the light condition for 8 hours a day in the laboratory and then return home.

Rob Lucas, University of Manchester: Measuring Personal Light Exposure in Everyday Life

Rob Lucas, professor at the University of Manchester, discussed measuring personal light exposure in everyday life. Lucas began by discussing the existing body of research on the effect of light on things like alertness, cognitive performance, and sleep. He pointed out that these studies have most often been done in controlled settings and that the field is lacking real-world data. Lucas said that the field needs large scale data collection in everyday life. He suggested that to perform population-level studies, researchers need a device to measure personal light exposure and good methods to collect health data.

Lucas and his team set to solving this problem by creating a new wearable device that could record and store a lot of data. The device, called "Spectrawear", can be worn on the wrist. It has a multisensory chip with 10 spectrally distinct sensors. Spectrawear is made of components that are widely available or 3D-printable and its design is open access, making it suitable for big data.

After describing Spectrawear, Lucas presented a study that his colleague, Altug Didikoglu, performed to test the device. The study examined sleep and sleepiness over seven days. 59 healthy participants were asked to wear Speactrawear on their wrist or leave it face-up in their bedroom while they slept. They used a smartphone app associated with the device to complete an initial health questionnaire, a daily sleep diary entry, and subjective assessments of sleepiness three times per day. The study successfully demonstrated the device's ability to reveal associations between light exposure and sleepiness with minimal disruption to participants' daily life.

Altug Didikoglu, University of Manchester: Measuring Cognitive Task Performance and Illuminance in Everyday Life

Altug Didikoglu, research associate and Rob Lucas' colleague at the University of Manchester, presented his work on measuring cognitive task performance and illuminance in everyday life. Didikoglu began by reiterating some of the issues with existing light exposure studies that Rob Lucas had discussed in his presentation. He then moved on to the main subject of his presentation, which focused on a method to collect data on cognitive performance in everyday life. Didikoglu developed the BrighterTime smartphone app to allow research subjects to submit data and answer questions easily. He described the app as engaging and said submitting responses was quick. The app can record responses to baseline surveys on things like demographics, health, and sleep quality. It can also record responses to daily surveys, like sleep diaries, work schedule, and other indicators. Finally, participants can use the app to submit certain data, like sleepiness, alertness, and cognitive task data, whenever they want. The app can also collect light measurements using an intrinsic light sensor, but this feature is only available on Android phones. Researchers can set the app to send the data to any computer. Didikoglu used the app to run a study in which 91 individuals were asked to play games at least 3 times per day for 1 week. He concluded by saying that BrighterTime works well for collecting data on ambient light exposure, cognitive performance, and alertness on a large scale.

Shadab Rahman, Harvard Medical School: Impact of Upgraded Lighting on Falls in Care Home Residents

Shadab Rahman, Professor at Harvard Medical School, discussed the impact of upgraded lighting on falls in care home residents. Rahman began with some background on falls in adults over the age of 65. He noted that the problem is especially severe in care homes. According to the Centers for Disease Control and Prevention (CDC), care home residents have about 2.6 falls per year on average and account for 20% of fall deaths despite making up only 5% of the elderly population. Rahman described how risk factors are broad and complex, and they include intrinsic and extrinsic factors. However, he said that lighting interventions could benefit several risk factors. To test this, Rahman and his colleagues ran a study on a lighting intervention in care homes. The intervention involved greatly increasing light levels during the day and decreasing light levels at night. The daytime light was blue-enriched, while nighttime light was blue-depleted. The study involved 758 residents at 4 care homes, 2 of which were treated as controls. The team collected 12 months of pre- and post-intervention fall data. At the end of the study, Rahman compared the experimental care homes to the control homes and found that the experimental homes had a 43% lower fall rate.

Christopher Steele, Military Operational Medicine Research Program: Department of Defense's Lighting, Health, and Performance Needs

Christopher Steele, U.S. Navy Commander and Director of the Military Operational Medicine Research Program (MOMRP), presented on the Department of Defense's (DoD) lighting, health, and performance needs. Steele began by outlining the DoD's research needs. He said that DoD does not understand how to identify sleep and circadian dysfunction in military service members, nor does DoD understand how sleep dysfunction affects service members. Consequently, DoD does not understand how their policies improve or exacerbate members' sleep dysfunction. Steele noted that managing service member fatigue is crucial for DoD, but said that the department does not understand the risks and benefits of methods to combat fatigue. On a broader scale, Steele stated that DoD needs a better understanding of the effects of sleep disruption or dysfunction on physical and mental health, including the use of various coping mechanisms. He also said that the DoD needs to find optimal work/rest/sleep schedules for service members in many operational environments.

After defining these areas of uncertainty, Steele discussed ways in which meeting participants could contribute. He started by saying that although DoD has good investigators doing the research, the department could always use partners or advisors. He called for more data showing that health and sleep are inextricably linked, especially evidence that is easy for DoD leadership to comprehend. However, he noted that DoD prioritizes acute, urgent health impacts over chronic issues, so evidence of acute issues stemming from sleep dysfunction would be most persuasive to leadership. Next, he urged experts to focus on developing pragmatic solutions for health and performance improvements. He described how DoD's size and its long-term approach to procurement means any purchases require serious deliberation. Additionally, since the military operates in so many different environments, it is difficult to come up with solutions that will work across the entire force. Finally, he argued for the development of DoD product-based requirements that drive the need for procuring circadian-improved lighting opportunities.

Steele closed his discussion by talking through DoD research program managers' priorities when deciding whether to fund a research opportunity. First, program managers must decide why a project is worth funding over other projects. This is difficult because competing projects may also be linked to performance and health. Program managers must also identify how an opportunity has changed compared to similar proposals that may have been submitted previously. Additionally, program managers must determine whether other government agencies are funding research on the issue and, if so, whether DoD can simply wait for those results.

David Sliney, Consulting Medical Physicist: Research Needs for Improved Retinal Dosimetry for Healthy Lighting Applications

David Sliney, a consulting medical physicist, talked about what he views as research needs for improved retinal dosimetry for healthy lighting applications. Sliney began by asking ‘How can we estimate the light exposure of intrinsically photosensitive retinal ganglion cells (ipRGCs)?’ He argued that the current metrics are inappropriate because they tend to measure light output from sources, not the light actually entering the eye. This can introduce errors and lack of reproducible results in research. Sliney went on to note that the difference between source light output and retinal dose can manifest in strange ways. A person could be sitting outside in sunlight and get the same retinal illuminance as someone sitting inside because of differences in pupil size. Eyelid position also changes based on scene illuminance. Studies show that field of view decreases as scenes get brighter. Because of this, he reasoned, lighting designers and researchers must keep in mind the spatial distribution of light. Sliney concluded by suggesting some research topics that he believes could improve retina-based dosimetry. First, researchers should develop new dosimeters for field studies, including meters with baffles. He also said researchers should develop an imaging camera with a field of view for spectral measurements or with melanopic EDI response. He laid out some field of view recommendations for the camera and meter: outdoor vertical +20° to -70°, indoor vertical +45° to -70°, lateral +/- 70° to 90°. For laboratory studies, Sliney first recommended researchers examine spatial ipRGC responses in the inferior and superior retina by measuring pupil size and upper-lid position. He then advised that researchers study time-weighted averaging of responses.

Erin Flynn-Evans, NASA Fatigue Countermeasures Laboratory: Outline of the Laboratory’s Work and Research Needs

Erin Flynn-Evans, head of the NASA Fatigue Countermeasures Laboratory, discussed what the laboratory works on and its research priorities moving forward. Flynn-Evans said that the laboratory does research in three main areas: space flight, aeronautics, and laboratory research. In the past, the laboratory has done studies on sleep inertia, the translation of effects demonstrated in the laboratory to the field, lighting for airline pilots, and more. Flynn-Evans explained that sleep inertia is an important topic at NASA, because people like astronauts, pilots, first responders, and doctors all frequently have to wake up quickly to respond to emergencies. However, they also need to be able to fall back asleep quickly after the issue is addressed. She said that her laboratory has seen a sleep inertia benefit from a lighting condition in one circadian phase, but they are not sure if this will persist to other times, phases, etc. They also don’t know the circadian impact of using this lighting for sleep inertia. Flynn-Evans called for more translation research, since not all laboratory studies translate to the real world. Thus, large studies in operational environments are needed to validate laboratory results. After discussing these research needs, Flynn-Evans moved on to more advanced research suggestions. She first delved into field-deployable tools. On-call workers need technology that can be used in operational environments such as hospitals or military settings. Next, Flynn-Evans pointed out passive lighting tools as an important research need. This term describes technology that could aid in phase shifting without user input. Finally, Flynn-Evans called for improved technology to provide lighting that can reach consensus recommendations for circadian health in everyday settings.

Jennifer Veitch, National Research Council of Canada: Four Research Priorities for Human Physiological Responses to Light

Jennifer Veitch, Principal Research Officer at the National Research Council of Canada, presented what she views as four research priorities for human physiological responses to light. First, Veitch called for more accessibility in lighting research and more diverse samples. She argued that current guidance and standards are mostly written for an average person based on research demonstrating effects on young, healthy, neurotypical people. But Veitch believes that lighting should work for everyone, not just the average person. Next, Veitch discussed the effects of temporal light modulation as a research priority. She said research should move beyond visual perception and revisit effects on brain activity and cognitive function. She also recommended that the field consider light-sensitive people to be the “canaries in the coal mine”, warning lighting professionals of hidden broader impacts. Third, Veitch suggested additional investigation of the acute effects of daytime light exposure. She noted that there is a long way between recommendations of “bright days and dark nights" and design guidance. She argued that evidence is weak that the intensity or spectrum of architectural light can improve cognition or reduce sleepiness during daylight hours. Finally, Veitch advocated for additional research on lighting quality and its effects on health. She mentioned that there is a pilot study underway to investigate this further.

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