Effects of Light beyond Vision
Results of a Scientific Workshop

September 12th & 13th 2023, Federal Institute for Occupational Safety and Health (BAuA), Dortmund

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Although a growing body of research concerning effects of light beyond vision exists, their exact mechanisms and effects are yet to be fully discovered. In the context of designing safe and healthy work systems, the BAuA is investigating light exposure of employees, which possible health effects they might have and whether effects of light beyond vision can be used to support employees at work or improve their labor conditions. In the workshop that took place on September 12th and 13th 2023 in Dortmund, several topics concerning these aspects were presented and future work on how to gain further insights into the topics were discussed. The participants agreed that more consensus on the planning and realization of studies is needed. By that, the usage of data and results by other research groups would be facilitated and conclusions could be drawn based on broader scientific evidence.

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Overview

The Federal Institute for Occupational Safety and Health (BAuA) is conducting several research projects dealing with effects of light beyond vision. In the research project F 2448, it was investigated whether lighting can be used to support attention of fulltime daytime workers at office workplaces. Additionally, light exposure of employees at home-based workplaces was examined. Within the scope of the project, a workshop was held in September 2023. The aim of the workshop was to support scientific exchange in order to gain knowledge about ongoing research in the field and also to discuss project results in the context of multiple research approaches with experts from various fields.

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The workshop started with a keynote by Prof. Dr. Manuel Spitschan who introduced the topic and named open questions as well as ideas how to address them. Afterwards several research projects were presented. In the workshop various topics concerning effects of light beyond vision were discussed. Those included light exposure in general, circadian effects, effects on cognition and effects on emotion. On the whole, this exchange helped to identify open knowledge gaps and enabled a discussion on possible approaches to solve them. Especially, more concrete ideas on what is needed to implement these approaches can help to create plans for future research that can adequately address these gaps.

Fig. 1 Participants listening to the introduction by Prof. Dr. Manuel Spitschan

Discussion on Circadian Effects of Light

On the first day, participants focused on the measurement, quantification, description and analysis of light exposure data as well as its effects on the circadian rhythm. Several research projects concerning these topics were presented. A permanently recurring item in the discussion was the huge variety of lighting scenes that exist, as well as the large number of influencing factors that could be taken into account. After the presentations, three different topics were discussed in more detail:

1. Phase-Response Curve for Circadian Effects

   The participants in this group dealt with the question of what would be needed to create such a response curve. At first, they stated that good (statistical) models that can include several different factors would be required. To fill these models, a need for longitudinal data was highlighted. Furthermore, the focus was set on the variability of phase-response curves between subjects, but also within subjects. In addition, the participants pointed out that one should not just focus on responses to light, but include other factors that influence the human circadian rhythm, such as meal times, exercise and others. Hence, it was concluded that during the design of studies that aim at creating phase-response curves experts from different fields, such as chronobiologists, nutritionists, professional athlete physicians and others should be included in order to pursue a more realistic and holistic approach.

2. Field Studies on Circadian Effects

   The discussion in this group highlighted the challenge posed by the huge number of factors that may influence outcomes in these studies, as well as the enormous varia-

bility within one influencing factor. Hence, the participants emphasized the need for large cohort studies. In order to facilitate the conduct of such studies, they considered the use of wearables that are easier to handle and probably less expensive, on the cost of providing less accuracy than other high-accuracy detectors that on the other hand would require more complex procedures of data gathering or could only be provided for small sample sizes due to financial restrictions. Due to the broad range of factors and also different equipment that could be considered for the conduct of such studies, the need for piloting studies was pointed out, as well as networks to share more information and enable an informed decision-making for the design of a study. In addition, this also led to the question in what way data from commercial devices, such as activity trackers or smart watches, could be used. This usage might on one hand be restricted by data protection and concerns regarding the ethical approval. On the other hand, it is not at all clear if and to which extend companies will share their data and possibly parts of their data processing algorithms. Building a network would also help to share experiences with commercial devices and different companies and hence facilitate the gathering and processing of such data.

3. Pre-Experimental Data

   This group discussed what variables should be included when data is gathered before the start of an experiment. In general, it was distinguished between data that should be acquired for a longer period and data that should be acquired once immediately before the start of the experiment. For the first type, light history, sleep-wake times and other social clues such as exercise, food or meal times, but also stress were discussed. It was emphasized that these had to be parametrized further in order to include them in the analysis of the data. For light history for example, illuminance, but also melanopic Equivalent Daylight Illuminance (mEDI) could be considered. In addition, data probably should not be averaged over whole days, since effects of light are significantly different throughout the course of a day. Regarding timespans, the participants emphasized the need for more research and agreement between researchers. In general, a trade-off between accuracy and inclusion of possible effects on one hand and realization potential on the other hand was described. If participants are not willing to gather data for a long time before the experiment, data becomes less accurate and hence it could be favored to restrict this timespan in order to generate more reliable data. As factors that should be detected immediately before the start of the experiments, arousal and health status were discussed. These could be parametrized through blood pressure, oxygen content in the blood as well as questionnaires.

Discussion on Effects of Light on Cognition and Emotion

On the second day, the workshop focused on effects of light on attention, cognition and emotion. After the presentations, the following topics were discussed in more detail:

1. Design of a Laboratory Room to study alerting effects of light

   It was discussed that on one hand the design of the room should not lead to major distractions from the experiment, while on the other hand a ‘sterile’ environment might lead to discomfort during the study, which in turn may affect outcome measures. Hence, furniture, fabrics and the usage of houseplants could be considered during the design of the room. However, it was emphasized that participants might react differently to these.

In conclusion, it was proposed to execute pilot studies in order to either find a room design that creates approximately the same impression of comfort for all different lighting scenes of a study or to find a way for a more precise quantification of perceived comfort and enable a systematic variation of that factor.

2. Dependent Variables – A Pile of Possibilities

This group emphasized that there is a huge number of outcomes that could be included in a study that focuses on alerting effects of light. In addition, it was pointed out that 'alerting effects' is an umbrella term and should be further narrowed down before a study can be adequately planned. In the discussion the following outcome measures were considered (among others):

Karolinska-Sleepiness-Scale (KSS), Stanford-Sleepiness-Scale (SSS), d2-Task, GoNoGo-Task, Heart Rate Variability (HRV), Electrodermal Activity (EDA)/ Skin Conductance Response (SCR), Psychomotor Vigilance Task (PVT)-(Reaction Time), Δ-Pre-ejection-period (ΔPEP), Electroencephalogram (EEG)-(Alpha Band, other Bands, P300).

In general, a need for a database that includes outcome measures characterized by the following factors (among others) was declared:

- Subjective or objective measure?
- How easy to assess?
- Accuracy
- Reliability
- Simplicity
- Costs
- ...

The Karolinska Sleepiness Scale (KSS) was discussed in more detail. In general, it was perceived as a relatively simple and informative measure. However, it was found that different realizations and translations for the KSS exist. Hence, it was proposed to find a consensus on the type and exact realization of the KSS for studies from different research groups.

3. Light – A Question of Emotions?

Generally, the participants highlighted the major difficulty of quantifying emotions. However, existing questionnaires such as the MDMQ (Multi-dimensional Mood Questionnaire) and the AD-ACL (Activation-Deactivation Adjective Checklist) were discussed. The participants further talked about connections between lighting related quantities, sensations and emotions that may already have been investigated (such as the impact of CRI or flicker). They also considered the possibility to gain information about the emotional state of a participant via physiological measures, such as skin conductance. In general, they recommended the inclusion of a baseline measurement in order to enable acclimatization of the participants with the situation. In addition, it was discussed whether certain points of measurements should be discarded (e. g. last measurement because people might respond differently due to a 'going-home-effect'). It was emphasized that a major task consists in the inclusion of emotion in statistical analyses.

Conclusion and Implications

Although the workshop included topics from various fields connected to effects beyond vision, the need for a consensus concerning

- Measurement and reporting of light exposure and light scenarios
- Description of participant samples
- Inclusion of influencing /interacting/ mediating factors
- Standardization and reporting of scales and tasks

and other factors that need to be considered during study design was emphasized. The participants agreed that building stronger networks and discussing these topics in more detail would help to reach such a consensus and increase comparability of studies as well as create synergistic effects that lead to a broader understanding of those effects.

Following up on this workshop, the Federal Institute for Occupational Safety and Health (BAuA) will further proceed with international cooperation and exchange in the topics discussed. Especially in the context of occupational safety and health, BAuA will foster the NoVEL network of European OSH Institutions collaborating on research in nonvisual effects of light.

Presentations

Presentations on the first day mainly focused on light exposure in general, as well as measurement and description of lighting scenes. On the second day, different studies concerning alerting effects of light as well as general questions on how to design such types of studies were presented.

September 12th 2023

Towards a roadmap for translation of non-visual effects of light into policy: Known unknowns and unknown unknowns	Manuel Spitschan (MPI for Biological Cybernetics, Tübingen)
A Data-driven, Multi-modal Approach to Characterise the Human Photoreceptorrelevant and Spectral Characterisation across Time and Space	Niloufar Tabandeh (MPI for Biological Cybernetics, Tübingen)
Binocular signal integration in neuroendocrine and circadian functions	Maydel Fernandez Alonso (MPI for Biological Cybernetics, Tübingen)
Influence of the human field of view on visual and non-visual quantities in indoor environments with a special focus on head orientations	Johannes Zauner (TU München) Karin Bieske (TU Ilmenau)
Light exposure of different occupations – an observational study	Ljiljana Udovicic (BAuA, Dortmund)
Photobiomodulation and its controversies in general lighting	Peter Veto (Pixun Technologies)

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Differences in the Effect of Light from Superior and Inferior Field of View on Measures of Alertness	Kai Broszio (BAuA, Dortmund)
Role of Electroencephalogram (EEG) as a Method in Lighting Research: Insights from a Systematic Review	Elifnaz Gecer (TU Eindhoven)
Effects of Light on Attention of Fulltime Daytime Workers – A laboratory study	Hannah Rolf (BAuA, Dortmund)
Basic research on the effect of light on cognitive function, emotional response, and mood	Nino Wessolowski (Medical School Hamburg)
The effect of a dynamic light intervention on subjective and objective vigilance in shift workers	Robert Herold (Zentralinstitut für Arbeitsmedizin und Maritime Medizin, Hamburg)

Suggested citation
Rolf, Hannah; (2023). Effects of Light beyond Vision
Results of a Scientific Workshop
September 12th & 13th 2023, Federal Institute for Occupational Safety and Health (BAuA), Dortmund. (baua: Focus). DOI 10.21934/baua:focus20231107 | November 2023

Gender-neutral language is used in this publication. Where this is not possible or would detract from the readability of the text, terms used to refer to persons include all genders.

Imprint | Publisher: Federal Institute for Occupational Safety and Health (BAuA), Friedrich-Henkel-Weg 1-25, 44149 Dortmund | Telephone: 0231 9071-2071, mail to: *info-zentrum@baua.bund.de*, Internet: *www.baua.de*, | Design: R. Grahl | DOI: 10.21934/baua:fokus20231107 | November 2023

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