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Opinion: The need for intensive longitudinal data to advance translational research in the domain of light and health

Light is a strong determinant of our sleep-wake rhythm. To enable healthy entrainment of our circadian system with the external 24-h day, it is beneficial to be exposed to a clear temporal profile of light and darkness. Research has shown that a weak contrast between light and darkness or ill-timed exposure to light inhibits a healthy sleep-wake rhythm.[1–3] Circadian rhythmicity is strongly tied to a person's health status, and persistent disruption of circadian rhythms can result in a higher risk of mental diseases (such as depression) and an increased incidence of chronic non-communicable diseases (such as cardiovascular disease and diabetes).[4–6] Yet, adopting healthy light hygiene is seriously challenged in our modern society; we typically spend most of our time indoors during the exogenous photoperiod and are exposed to relatively high light levels in the evening and at night due to screen usage and engagement in social activities. It is therefore important to increase awareness of the potential impact of light on health (beyond vision) among the general public and to develop and implement intervention strategies to leverage the health-promoting potential of light. But what is the right light for the right person at the right time?

Recently, recommendations have been formulated by an expert panel for daytime, evening and nighttime exposure to light to foster sleep, mental health and physiology.[7] Although a great initiative, it is important to realize that most of the evidence on the health-promoting potential of light is derived from laboratory studies contrasting static light settings under well-controlled conditions (with limited sample sizes). Hence, to what extent and how the effects of light beyond vision manifest in the daily dynamics of everyday life and whether the recommendations require person-tailored and context-dependent tuning largely remain open questions. To address these gaps and foster the implementation of tailored interventions and accurately inform decision support in the domain of light and health, there is an urgent need to collect and model *intensive longitudinal data* on luminous exposure and key health indicators.

Intensive longitudinal data can be collected using ecological momentary assessment (EMA), an approach in which sensor data are combined with repeated self-reports to sample subjects' momentary behaviours and experiences in real life, under naturalistic conditions.[8] While studies have used this research approach to map light to specific health indicators (such as vitality or sleep),[9–11] they are more scarce than laboratory studies and oftentimes collected data among a limited and rather homogeneous sample. Collecting datasets on luminous exposure and health among large and more heterogeneous samples in the context of everyday life using EMA will accelerate the translation of insights obtained in the laboratory to everyday practice and will contribute to three important innovations. First, large-scale field assessments enable validation of the recently developed recommendations for luminous exposure[7] in the field and can provide answers to questions like: Is a melanopic equivalent daylight illuminance (melanopic EDI) of 250 lx at the eye indeed an accurate

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threshold for regular daytime hours in real life? To what extent can we deviate from the recommendations without compromising health? How can we best compensate for deviations from the recommended thresholds?

Second, intensive longitudinal data collected among large, diverse and more inclusive samples can aid the modelling of inter-individual differences in luminous exposure profiles and their associations with key health indicators. This allows acknowledging and accounting for the fact that the 'average person' does not exist. Most studies to date have rendered results at the group level, potentially masking the effects of light at the user level.[12,13] Insights into inter-individual differences can inform questions regarding for whom interventions are most beneficial and to what extent the recommendations for healthy luminous exposure need to be person-tailored.

Third, intensive longitudinal data will enable the use of machine learning (ML) models to move from descriptive to predictive models. While AI has been adopted in many research fields, its use in the domain of light and health is scarce (likely due to the lack of large-scale datasets). Yet, AI and in particular explainable AI (XAI) can be a powerful tool, complementing the current use of statistical and mathematical models, to map light sensor data to human behaviour and experiences and advance our knowledge of person-specific and contextual dependencies. For example, ML models can facilitate feature selection, user profiling, and time series forecasting and help us answer questions like: How well can we predict light-induced moderations among unseen samples? Which personal and contextual characteristics do we need to know to improve the accuracy, sensitivity, and precision of the predictions? Which set of light-related features and aggregations of continuous light data are most effective in reliably predicting key health indicators in the field?

In summary, collecting and modelling intensive longitudinal data will offer new avenues for research on the impact of light on health. Given the prevalence of burnout and sleep problems, I would argue that novel research strategies to render and model intensive longitudinal data (such as EMA and XAI) are urgently needed: They can advance the translation of research insights gained in the laboratory into effective, evidence-based strategies to leverage the health-promoting potential of light in the dynamic everyday situations at large scale.

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