

Multilevel dynamics of human and animal sleep: mathematical models meet data
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University of Surrey

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In 2015 we co-organised a meeting with Daniel Forger at the Lorentz Center in Leiden with the aim of bringing biologists and theoreticians together to discuss sleep and circadian rhythms. We felt it was about time that we again brought people together, to further strengthen interdisciplinary collaborations, discuss the open questions in the field and how we might tackle them.

The event was originally planned as a two-day in-person event that was to be held at the end of March 2020. The COVID pandemic led to a last-minute postponement, and the workshop was subsequently re-structured as a series of on-line discussion sessions which ran over two weeks in July 2021.

Event themes

We targeted the general theme of multilevel dynamics of human and animal sleep, focusing on models and data for real life sleep restriction, performance and circadian rhythmicity, models and data for the dynamics of the NREM, REM, wake cycle, effects of homeostasis and circadian rhythmicity and omics-based biomarkers for sleep and circadian status. In each session, two speakers set out the current state-of-the-art and open questions, one from the angle of mathematical / statistical models and one from the biology / data angle.

In the first session, Derk-Jan Dijk (Surrey) and Anne Skeldon (Surrey) set the scene for the meeting. Derk-Jan outlined the challenges of combining models and data and raised some fundamental questions: How do we model interactions and feedbacks across many different scales? How do we make models more quantitative and predictive at the individual level? How do environmental and societal factors interact with our biology? Anne gave three different illustrative examples of the ways that models have been used.

The second session gave us a nice overview of where we are modelling sleepiness and performance in the real world, with Svetlana Postnova (Sydney) outlining some of the recent modelling successes and Steve Lockley (Surrey/Harvard) highlighting the challenges. It was evident that models still have some way to go before they can capture individual differences and chronic and variable sleep deficiency.

In the third session we turned to REM sleep, with Paul Franken (Lausanne) giving the biologists take, discussing how research across species brings insights on the role and importance of REM sleep for learning, memory and cognition. Cecilia Diniz-Behn (Colorado School of Mines) gave an overview of models of REM sleep, from the early reciprocal interaction model of McCarley and Hobson to the more recent sophisticated models of REM-NREM and wake. Accounting for REM homeostasis and circadian variation in REM sleep stood out as a questions that it will be important for models to address in future.

In the fourth session, we tackled genomics with Simon Archer (Surrey) discussing biomarkers for circadian rhythmicity under different sleep challenges and the question of whether it is possible to identify if someone is sleep deprived from a single blood sample. Meanwhile, on the theoretical front, Rebecca Richmond (Bristol) described what can be extracted from genome wide association studies (GWAS) using Mendelian randomization

The fifth and final session of the meeting was an invited presentation from Victoria Booth (Michigan). Victoria took us back to the cellular level and talked about the state-of-the-art in coupled oscillator models of the suprachiasmatic nucleus.

Next steps – Outcomes

While we greatly missed the opportunity to meet in person and continue some of the lively discussions over a drink, the online format did enable us to make the meeting even more international than originally planned, with participants joining from Monash and Sydney in Australia as well as from the USA and Europe. It provided a rare opportunity to bring together quite a few of the people who have made significant contributions to the mathematical modelling of sleep and circadian rhythms in the last few years, with some of those at the forefront of collecting data.

The meeting initiated and further expanded on links between participants, and there are future online events planned including bilateral discussions between individuals and participation in online reading groups. There was much enthusiasm for a future in-person event.

Acknowledgements

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