Perception and Representation of Urban Night Lighting Ambiances in Virtual Reality

09/10/25 Anthony Le Gourriérec

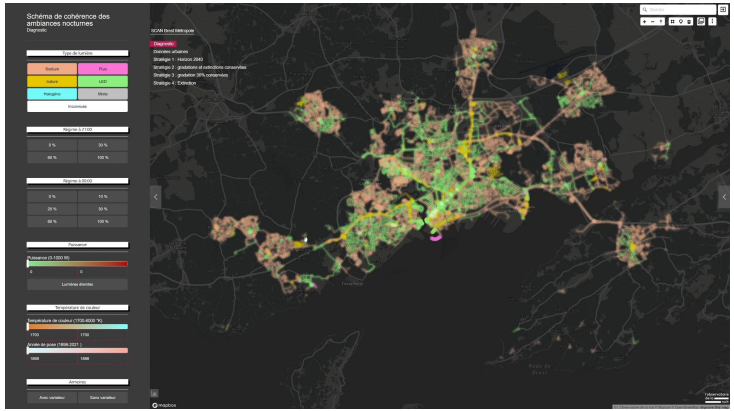
Academic Supervision: Myriam Servières, Etienne Peillard

Industrial Supervision: Nicolas Houel

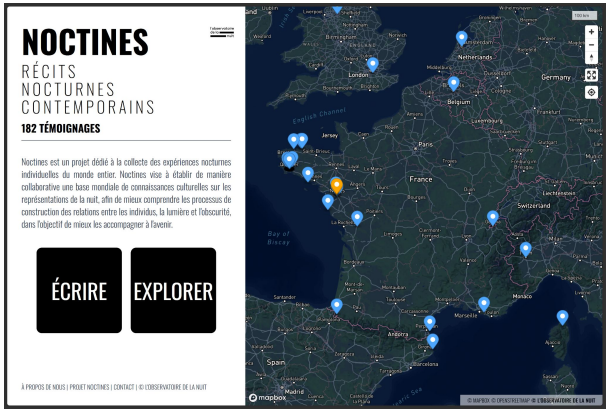
Company

l'observatoire de la nuit

Consulting agency specializing in lighting sobriety based in Nantes.



Scan - Scheme for Coherence of Ambiances at Night



Noctines - Writing the nocturnal narratives of today and tomorrow

Obscura

Obscura - Lighting simulation software

=> Work on qualitative aspect in software usually designed for quantitative outputs

Urban Lighting Philosophy

Day to Night Transfer

Historically

Today

=> Lighting used as a tool to provide security, easier mobility

Consequences

Flora and Fauna Disturbance

Circadian Clock Disruption

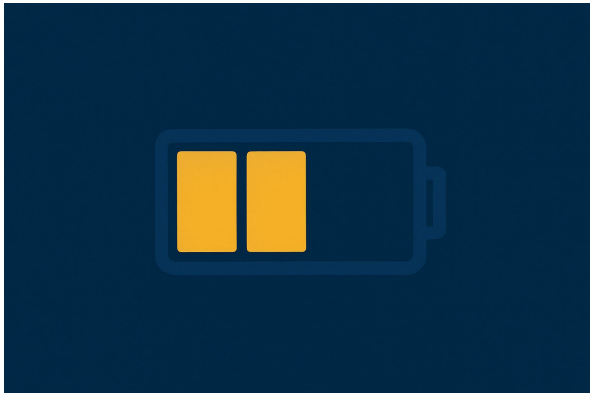
Trespassing Light

Sky Glow

80% of worldwide population lives under light polluted sky
99% of Europe and USA (Falchi et al 2016)

Current State

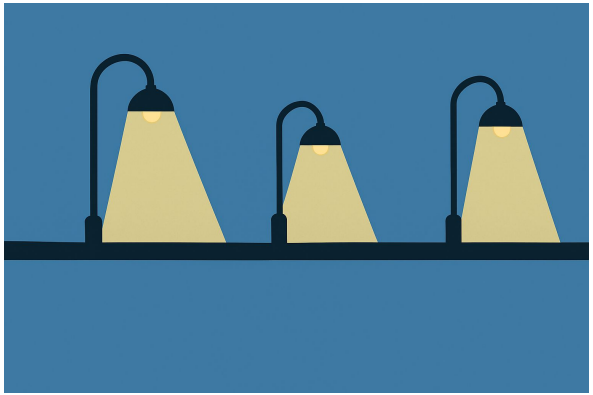
Quantitative



Energy consumption reduced

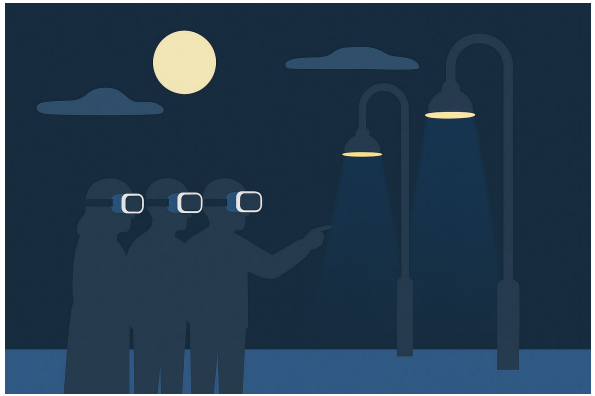
Comfort / Safety

Awareness-Raising



Quantitative & Qualitative

Stakeholders Day Meeting



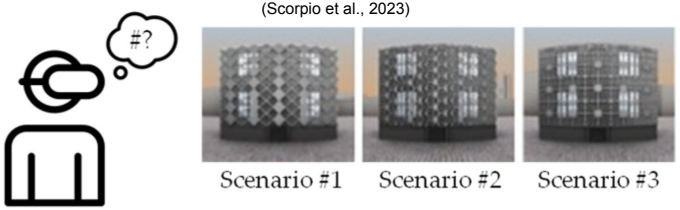
VR Lighting Scenarios

=> Raises questions about lighting representation

Virtual Reality

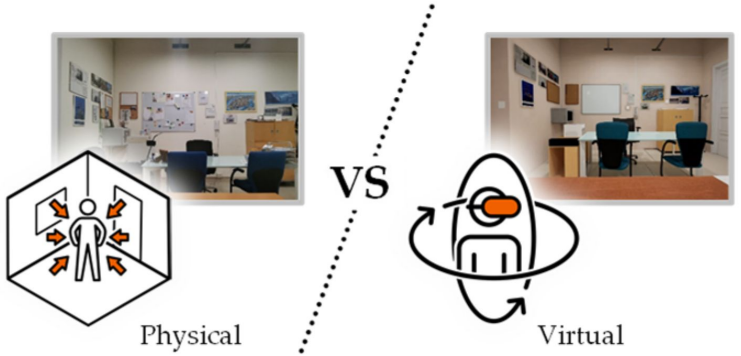
Lighting design research

(Scorpio et al., 2023)



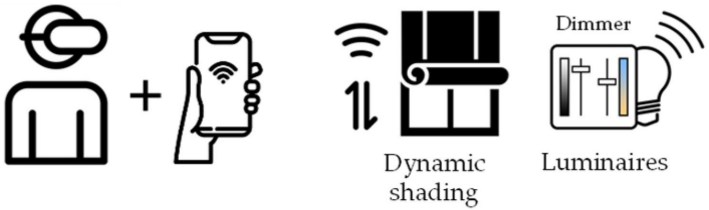
Different Lighting Scenarios

(Scorpio et al., 2023)



VR vs Reality

(Scorpio et al., 2023)

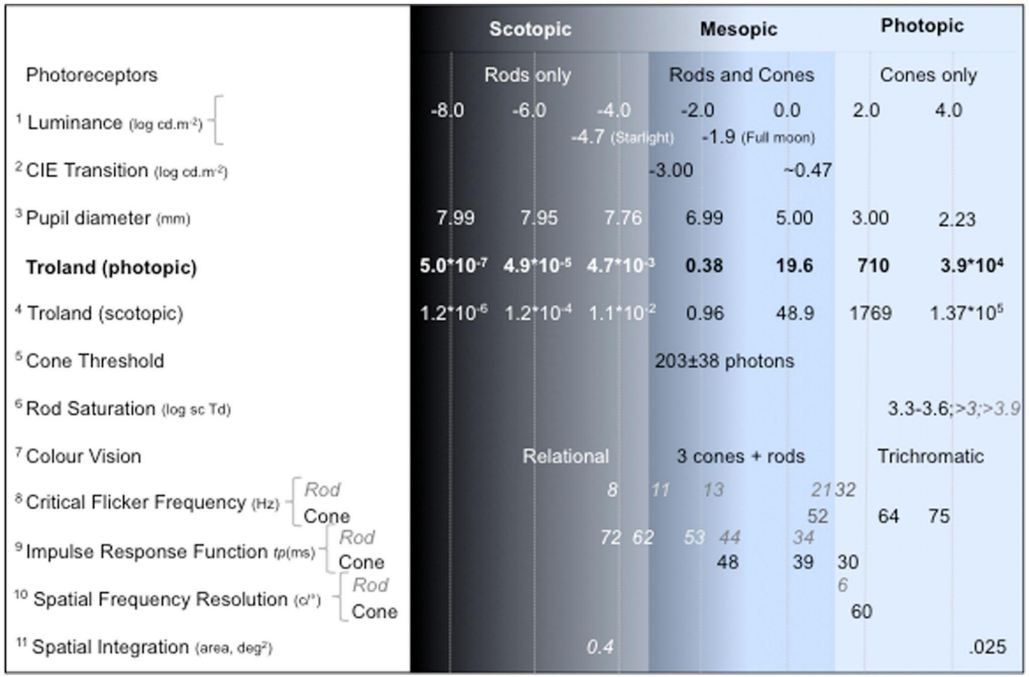


User Interaction

VR has its limitations and most study focused on indoor or daylight situations

Photopic, Mesopic and Scotopic Vision

(Zele & Cao, 2015)

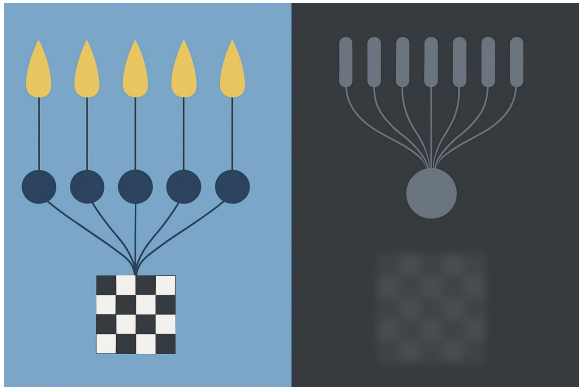


Street lighting regulation
(NF EN 13201-2)
~ 0.30 => 2.00 cd/m²

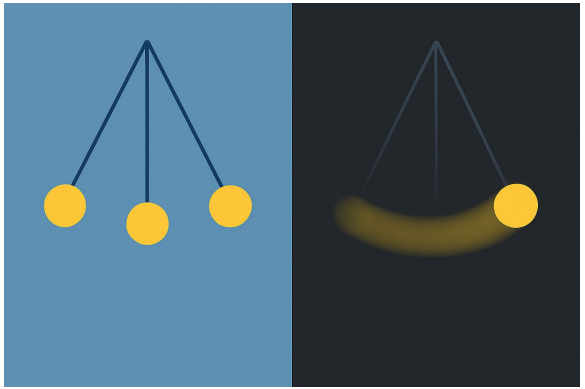
Mesopic Vision
~ 0.01 to 3.00 cd/m²

Photopic, Mesopic and Scotopic Vision

Color perception

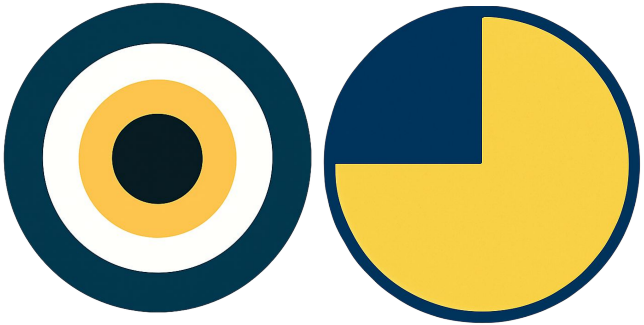


Visual accuity



Temporal resolution

Adaptation process



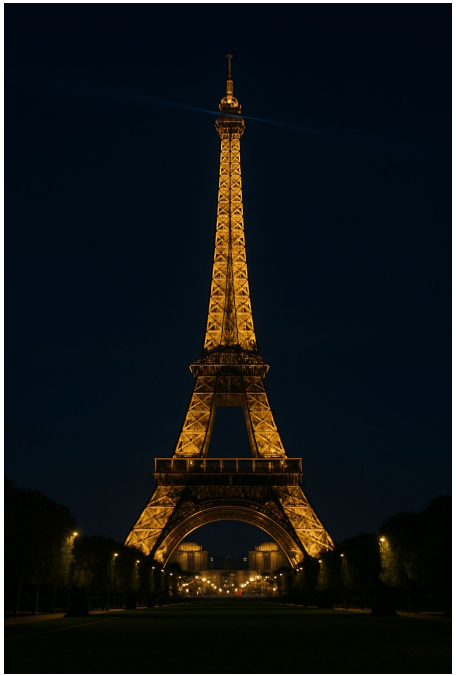
Dark Adaptation

Light Adaptation

How can VR replicate these physiological processes ?

Ambiance Perception

Day Ambiance



Night Ambiance

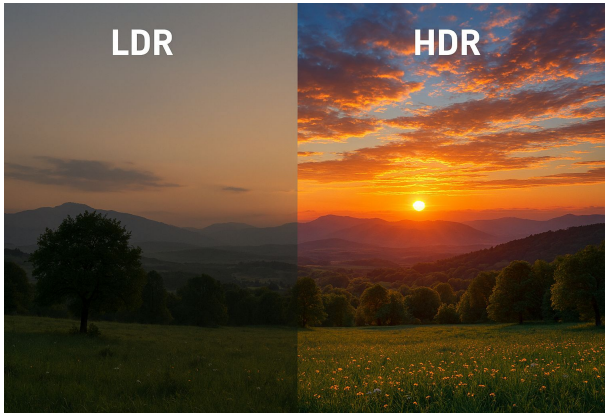
Ambiance Perception

Park as a path

Park as a social place

Representation

Photorealistic

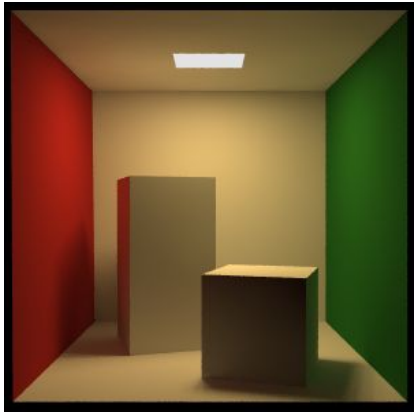


LDR/SDR vs HDR

https://polyhaven.com/a/cobblestone_street_night

HDR Panorama => IBL

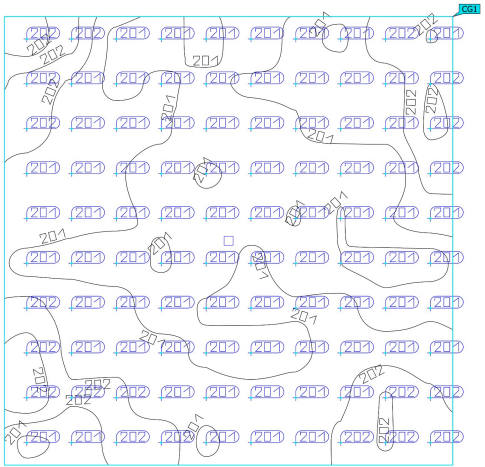
https://fr.wikipedia.org/wiki/Bo%C3%AEte_de_Cornell



Physically Based Rendering (PBR)

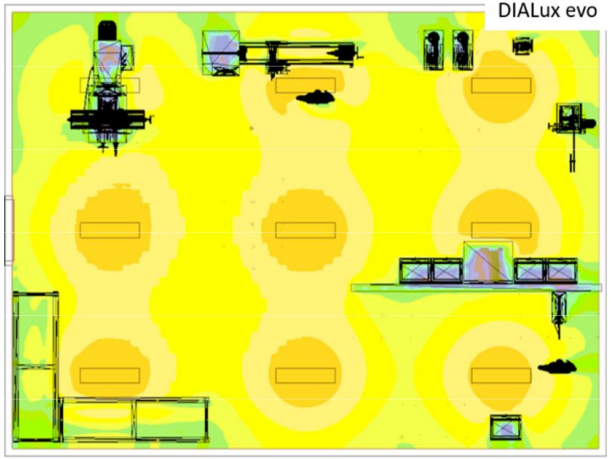
Representation

Data-driven



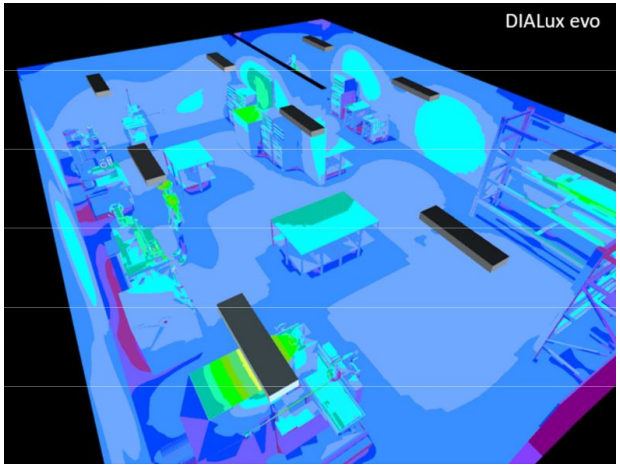
Value chart & Isolines

(Fernandez-Prieto & Hagen, 2017)



2D false color map

(Fernandez-Prieto & Hagen, 2017)

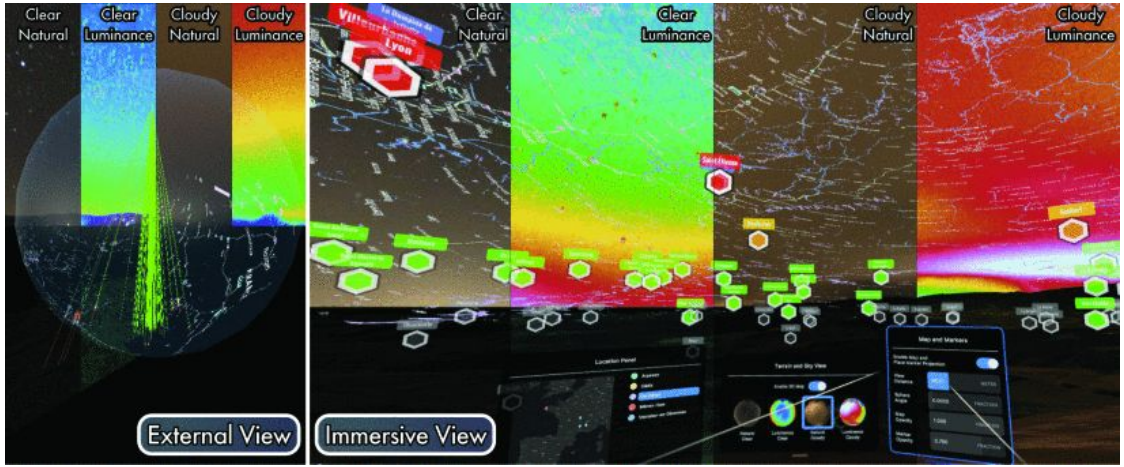


3D false color maps

Representation

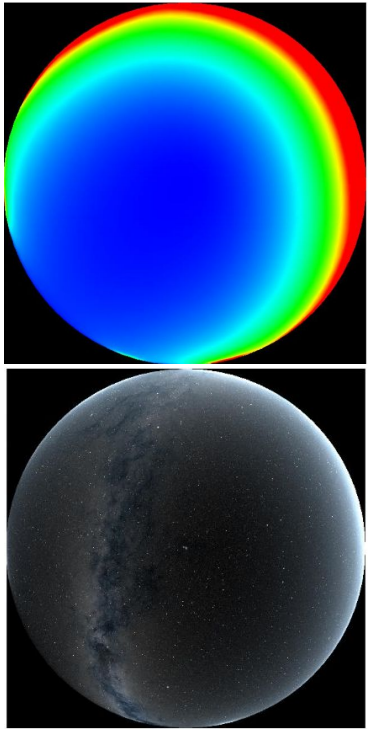
Combination

(Spur et al., 2025)



Night Sky Explorer VR

(Dobashi et al., 2023)



Realistic vs False Color

=> Enough for non-experts to grasp the impact of light pollution?

Challenge and Proposed Approach

1 - VR Mesopic Vision

(Luidolt et al., 2020)

VR mesopic effects

- Glare
- Color shift
- Visual Accuity
- temporal adaptation

https://fr.wikipedia.org/wiki/Nuit_am%C3%A9ricaine

Day for night

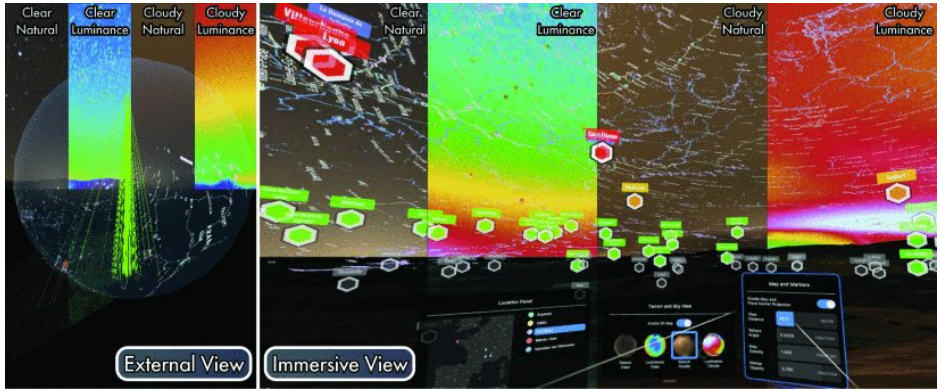
What mesopic vision effect convey night ambiance the most in VR ?

Are physiologically accurate mesopic effects modeling mandatory to convey perceptually accurate VR perception ?

Challenge and Proposed Approach

2 - Skyglow Perception

(Spur et al., 2025)



Light pollution analysis tool

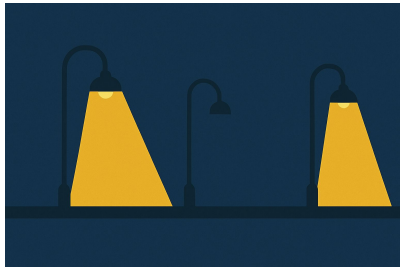
Lack of lighting pollution tools for the design phase
=> Preventive awareness raising

How and to what extent can VR reflect quantitative and qualitative aspects of light pollution for non-experts during the design phase ?

Summary

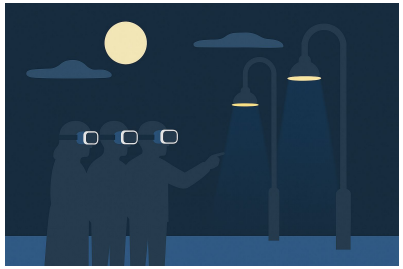
Day to Night Transfer

Consequence

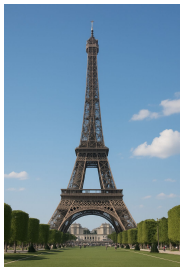


Quantitative

Quantitative & Qualitative

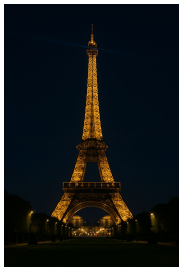


VR as a pedagogical tool

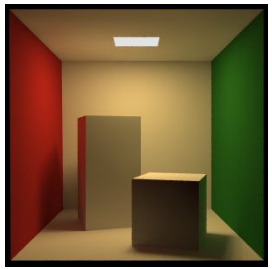


VR study
day / indoor

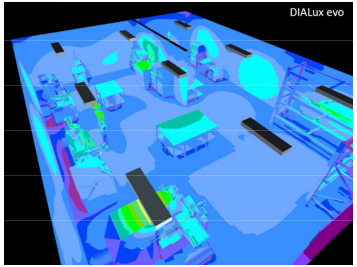
broadly different vision



VR study
Night / Outdoor



Realistic



Data Driven

Light pollution

Bibliography

Fabian, S. T., Sondhi, Y., Allen, P. E., Theobald, J. C., & Lin, H.-T. (2024). Why flying insects gather at artificial light. *Nature Communications*, *15*(1), 689. https://doi.org/10.1038/s41467-024-44785-3

Falchi, F., Cinzano, P., Duriscoe, D., Kyba, C. C. M., Elvidge, C. D., Baugh, K., Portnov, B. A., Rybnikova, N. A., & Furgoni, R. (2016). The new world atlas of artificial night sky brightness. *Science Advances*, *2*(6), e1600377. https://doi.org/10.1126/sciadv.1600377

Falchi, F., Cinzano, P., Elvidge, C. D., Keith, D. M., & Haim, A. (2011). Limiting the impact of light pollution on human health, environment and stellar visibility. *Journal of Environmental Management*, *92*(10), 2714–2722. https://doi.org/10.1016/j.jenvman.2011.06.029

Hegazy, M., Ichiriyama, K., Yasufuku, K., & Abe, H. (2021). Comparing daylight brightness perception in real and immersive virtual environments using perceptual light maps. *Automation in Construction*, *131*, 103898. https://doi.org/10.1016/j.autcon.2021.103898

Koslofsky, C. (2011). *Evening's Empire: A History of the Night in Early Modern Europe* (1st edn). Cambridge University Press. https://doi.org/10.1017/CBO9780511977695

Liu, M., Zhang, B., Luo, T., Liu, Y., Portnov, B. A., Trop, T., Jiao, W., Liu, H., Li, Y., & Liu, Q. (2022). Evaluating Street Lighting Quality in Residential Areas by Combining Remote Sensing Tools and a Survey on Pedestrians' Perceptions of Safety and Visual Comfort. *Remote Sensing*, *14*(4), 826. https://doi.org/10.3390/rs14040826

Bibliography

Navarrete-de Galvez, E., Gago-Calderon, A., Garcia-Ceballos, L., Contreras-Lopez, M. A., & Andres-Diaz, J. R. (2021). Adjustment of Lighting Parameters from Photopic to Mesopic Values in Outdoor Lighting Installations Strategy and Associated Evaluation of Variation in Energy Needs. *Sustainability*, *13*(8), 4089. https://doi.org/10.3390/su13084089

Scorpio, M., Carleo, D., Gargiulo, M., Navarro, P. C., Spanodimitriou, Y., Sabet, P., Masullo, M., & Ciampi, G. (2023). A Review of Subjective Assessments in Virtual Reality for Lighting Research. *Sustainability*, *15*(9), 7491. https://doi.org/10.3390/su15097491

Son, D., Im, B., Her, J., Park, W., Kang, S.-J., & Kim, S.-N. (2024). Street lighting environment and fear of crime: A simulated virtual reality experiment. *Virtual Reality*, *29*(1), 8. https://doi.org/10.1007/s10055-024-01080-2

Zele, A. J., & Cao, D. (2015). Vision under mesopic and scotopic illumination. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.01594

Anstis, S. (2002). The Purkinje rod-cone shift as a function of luminance and retinal eccentricity. *Vision Research*, *42*(22), 2485–2491. https://doi.org/10.1016/S0042-6989(02)00267-5

Kalloniatis, M., & Luu, C. (1995). Visual Acuity. In H. Kolb, E. Fernandez, B. Jones, & R. Nelson (Eds), *Webvision: The Organization of the Retina and Visual System*. University of Utah Health Sciences Center. http://www.ncbi.nlm.nih.gov/books/NBK11509/

Bibliography

Kalloniatis, M., & Luu, C. (1995). Light and Dark Adaptation. In H. Kolb, E. Fernandez, B. Jones, & R. Nelson (Eds), *Webvision: The Organization of the Retina and Visual System*. University of Utah Health Sciences Center. http://www.ncbi.nlm.nih.gov/books/NBK11525/

Öner, D. D., & Aktan, E. Ö. A. (2025). Daytime and Nighttime Image of Cities. *Proceedings of the International Conference of Contemporary Affairs in Architecture and Urbanism-ICCAUA*, *8*(1). https://doi.org/10.38027/ICCAUA2025EN0356

Fernandez-Prieto, D., & Hagen, H. (2017). Visualization and Analysis of Lighting Design Alternatives in Simulation Software. *Applied Mechanics and Materials*, *869*, 212–225. https://doi.org/10.4028/www.scientific.net/AMM.869.212

Spur, M., Deverchère, P., Augereau, O., & González, E. H. (2025). Night Sky Explorer VR. *2025 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, 1408–1409. https://doi.org/10.1109/VRW66409.2025.00350

Dobashi, Y., Ishikawa, N., & Iwasaki, K. (2023). Efficient Visualization of Light Pollution for the Night Sky. *ACM Transactions on Graphics*, *42*(6), 1–11. https://doi.org/10.1145/3618337

Dobashi, Y., Ishikawa, N., & Iwasaki, K. (2023). Efficient Visualization of Light Pollution for the Night Sky. *ACM Transactions on Graphics*, *42*(6), 1–11. https://doi.org/10.1145/3618337