Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Eleni Mousteri
Student number	5853524

Studio		
Name / Theme	Building Technology / Façade and Products	
Main mentor	Alessandra Luna Navarro	Façade and Product Design
Second mentor	Eleonora Brembilla	Building Physics and Services
Argumentation of choice of the studio	My academic background with a focus on façade, building physics, climate, and user-centered design fosters a holistic understanding of the built environment and aligns with my interest in sustainable architecture and innovative building envelopes. More specifically the courses that led me to this decision according to the corresponding sectors are the following: • **Facade** – '*Technoledge Façade Design*': focused on façade design • **Building physics and occupant comfort** - '*Technoledge Health and Comfort*': focused on indoor comfort, the associated physiological concepts (one of them being the visual quality) and practical measurements in existing buildings • **Climate design**- '*MEGA' (role of climate designer) & 'Zero-energy design*': focused on the integration of building physics, fire safety, building services, energy efficiency, high level of indoor comfort, and health • **User-centered design** - *User-centered sustainability studio:* focused on societal challenges in combination with well-being, health, and carbon-neutral lifestyles through cooperating, communicating, and designing sustainable interventions	

Graduation project	
Title of the graduation project	'The Effect of Biophilic Glare Control on Occupant Perception: A Laboratory Experiment'
Goal	

Location:	Green Village, Nonohouse building
The posed problem,	**Problem statement:** A novel shading product that controls façade transparency has emerged, which can generate a variety of biophilic patterns and movements, at different speeds and states. However, The impact of this technology on indoor illuminance balance, discomfort glare, and outside view perception remains uncertain. Controlling this technology properly might have a positive impact on occupants' well-being by reducing glare risk, and balancing daylight better, without affecting outdoor views.
research questions and	**Main research question:** Does the integration of biophilic patterns on building facades contribute to greater resilience in occupants' glare tolerance compared to non-natural patterns or clear conditions? **Sub-questions:** **(Background questions)** • What is the evidence of the impact of biophilic design and patterns on occupants? • What are the factors that affect discomfort glare? • What are the challenges of automation systems according to occupant perception? **(Experimental Design)** • How to capture occupant preferences with VideowindoW technology? **(Statistical Analysis)** • What is the occupants' preference for natural patterns over non-natural or clear conditions concerning perceived comfort and aesthetics?

	• Is occupants' glare tolerance affected by the motion of patterns and the presence of natural patterns over a static scenario?
design assignment in which these result.	**Laboratory experiment design and execution:** The final outcome will consist of a controlled experiment to investigate the impact of biophilic glare control on occupants' perception. This involves designing stimuli, selecting participants, and implementing a systematic experiment. Both qualitative measurements and qualitative questionnaires will be collected during the experiment. After the experiment, a statistical analysis will be used to examine the data and provide insights into the effectiveness of biophilic strategies in mitigating glare and enhancing visual comfort.

Process

Method description

Three different methodologies will be used to realize the presented research:

1. **Theoretical part: Literature review**
2. **Practical part: Experimental design and execution**
3. **Interpretation of data: Statistical data analysis**

First, the Literature Review will mainly be focused on the following topics:

- Biophilia, biophilic design, biophilic characterization of the product, and evidence of biophilic patterns on occupants
- Visual comfort, human vision and light perception, glare, lighting design and standards, strategies for mitigating glare, glare indices, factors that affect glare, experimental design on glare
- Automation systems, user-centric control systems, challenges, and considerations based on evidence of occupant perception

(Google Scholar, TU Delft Repository and Science Direct are the main search engines for the literature review)

For the practical part, a laboratory experiment in an office environment will be designed and executed. The experiment will be designed according to literature research. Both quantitative measurements and qualitative questionnaires will be collected. The following information should be included:

- General information: location, orientation, sky conditions, season, time of the day, external scene, equipment, software, indices
- Room set-up: workstation and equipment placement
- Shading settings: the presence and non-presence of the biophilic pattern
- Procedure and duration of the experiment
- Participants recruitment and consent form (ethical considerations)
- Questionnaires: demographics, personal factors, glare assessments
- Evaluation: glare assessments, visual tasks and measurements
- Methods to ensure scientific validity

The third part is an interpretation of the data collected by the experiment and is a statistical analysis of the results to draw accurate conclusions from the data collected.

According to the result of the first experiment on a static image scenario, there is a potential second experiment on a dynamic glazing scenario. A second practical part will be designed and executed in this case, driven to additional conclusions.

Literature and general practical references

Biophilic design evidence on occupants

- Abboushi, Belal, Ihab Elzeyadi, Richard Taylor, et al. (2019). "Fractals in architecture: The visual interest, preference, and mood response to projected fractal light patterns in interior spaces". In: Journal of Environmental Psychology 61, pp. 57–70. ISSN: 15229610. DOI: 10.1016/j.jenvp.2018.12.005.

- Abboushi, Belal, Ihab Elzeyadi, Kevin Van Den Wymelenberg, et al. (2021). "Assessing the Visual Comfort, Visual Interest of Sunlight Patterns, and View Quality under Different Window Conditions in an Open Plan Office". In: LEUKOS - Journal of Illuminating Engineering Society of North America 17 (4), pp. 321–337. ISSN: 15502716. DOI: 10.1080/15502724.2020.1785309.

- Chamilothori, K., G. Chinazzo, et al. (2019). "Subjective and physiological responses to façade and sunlight pattern geometry in virtual reality". In: Building and Environment 150, pp. 144–155. ISSN: 03601323. DOI:10.1016/j.buildenv.2019.01.009.

- Chamilothori, K., J. Wienold, et al. (2022). "Subjective and physiological responses towards daylit spaces with contemporary façade patterns in virtual reality: Influence of sky type, space function, and latitude". In: Journal of Environmental Psychology 82. ISSN: 15229610. DOI: 10.1016/j.jenvp.2022.101839.

- Haans, Antal (2014). "The natural preference in people's appraisal of light". In: Journal of Environmental Psychology 39, pp. 51–61. ISSN: 15229610. DOI: 10.1016/j.jenvp.2014.04.001.

- Joye, Yannick (2007). "Architectural Lessons From Environmental Psychology: The Case of Biophilic Architecture". In: Review of General Psychology 11 (4), pp. 305–328. ISSN: 10892680. DOI: 10 . 1037 / 1089 - 2680.11.4.305.

- Tuaycharoen, N. and P. R. Tregenza (2005). "Discomfort glare from interesting images". In: Lighting Research and Technology 37 (4), pp. 329–341. ISSN: 14771535. DOI: 10.1191/1365782805li147oa.

- Tuaycharoen, N. and P. R. Tregenza (2007). "View and discomfort glare from windows". In: Lighting Research and Technology 39 (2), pp. 185–198. ISSN: 14771535. DOI: 10.1177/1365782807077193.

Visual comfort and Glare assessments

- Bian, Y., Dai, Q., Ma, Y., & Liu, L. (2020). Variable set points of glare control strategy for side-lit spaces: Daylight glare tolerance by time of day. Solar Energy, 201, 268–278. https://doi.org/10.1016/j.solener.2020.03.016

- Carlucci, S., Causone, F., de Rosa, F., & Pagliano, L. (2015). A review of indices for assessing visual comfort with a view to their use in optimization processes to support building integrated design. In *Renewable and Sustainable Energy Reviews* (Vol. 47, pp. 1016–1033). Elsevier Ltd. https://doi.org/10.1016/j.rser.2015.03.062

- de Kort, Y. A. W. (2019). Tutorial: Theoretical Considerations When Planning Research on Human Factors in Lighting. LEUKOS - Journal of Illuminating Engineering Society of North America, 15(2–3), 85–96. https://doi.org/10.1080/15502724.2018.1558065

- Karlsen, L., Heiselberg, P., & Bryn, I. (2015). Occupant satisfaction with two blind control strategies: Slats closed and slats in cut-off position. Solar Energy, 115, 166–179. https://doi.org/10.1016/j.solener.2015.02.031

- Kent, M. G., Altomonte, S., Wilson, R., & Tregenza, P. R. (2017). Temporal effects on glare response from daylight. Building and Environment, 113, 49–64. https://doi.org/10.1016/j.buildenv.2016.09.002

- Jain, S., Wienold, J., Lagier, M., Schueler, A., & Andersen, M. (2023). Perceived glare from the sun behind tinted glazing: Comparing blue vs. color-neutral tints. Building and Environment, 234, 110146. https://doi.org/10.1016/J.BUILDENV.2023.110146

- Pierson, C., Wienold, J., & Bodart, M. (2018). Review of Factors Influencing Discomfort Glare Perception from Daylight. In LEUKOS - Journal of Illuminating Engineering Society of North America (Vol. 14, Issue 3, pp. 111–148). Taylor and Francis Inc. https://doi.org/10.1080/15502724.2018.1428617

- Pierson, C., Piderit, B., Iwata, T., Bodart, M., & Wienold, J. (2022). Is there a difference in how people from different socio-environmental contexts perceive discomfort due to glare from daylight? Lighting Research and Technology, 54(1), 5–32. https://doi.org/10.1177/1477153520983530

- Shafavi, N. S., Zomorodian, Z. S., Tahsildoost, M., & Javadi, M. (2020). Occupants visual comfort assessments: A review of field studies and lab experiments. In Solar Energy (Vol. 208, pp. 249–274). Elsevier Ltd. https://doi.org/10.1016/j.solener.2020.07.058

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- van den Wymelenberg, K., Inanici, M., & Johnson, P. (2007). The Effect of Luminance Distribution Patterns on Occupant Preference in a. In *Daylit Office Environment. Leukos* (Vol. 7, Issue 2). http://www.ies.org/leukos/download_G.cfm?art_id=207

- Yamín Garretón, J. A., Rodriguez, R. G., & Pattini, A. E. (2016). Glare indicators: An analysis of ocular behaviour in an office equipped with venetian blinds. Indoor and Built Environment, 25(1), 69–80. https://doi.org/10.1177/1420326X14538082

Automation and occupant perception

- Bakker, L. G., Hoes-van Oeffelen, E. C. M., Loonen, R. C. G. M., & Hensen, J. L. M. (2014). User satisfaction and interaction with automated dynamic facades: A pilot study. *Building and Environment*, *78*, 44–52. https://doi.org/10.1016/j.buildenv.2014.04.007

- de la Barra, P., Luna-Navarro, A., Prieto, A., Vásquez, C., & Knaack, U. (2022). Influence of Automated Façades on Occupants: A Review. *Journal of Facade Design and Engineering*, *10*(2), 19–38. https://doi.org/10.47982/jfde.2022.powerskin.2

- Luna-Navarro, A., Loonen, R., Juaristi, M., Monge-Barrio, A., Attia, S., & Overend, M. (2020). Occupant-Facade interaction: a review and classification scheme. *Building and Environment*, *177*. https://doi.org/10.1016/j.buildenv.2020.106880

- Sadeghi, S. A., Karava, P., Konstantzos, I., & Tzempelikos, A. (2016). Occupant interactions with shading and lighting systems using different control interfaces: A pilot field study. *Building and Environment*, *97*, 177–195. https://doi.org/10.1016/j.buildenv.2015.12.008

- Voss, K. (2003). *Article in Lighting Research and Technology*. https://doi.org/10.1191/1365782803li064oa

Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?

   Graduation topic: My graduation project aims to identify occupants' preferences for biophilic patterns in facades to improve glare tolerance and acceptance of dynamic glazing shading systems and demonstrate their impact against conventional shading systems. This will be combined with a laboratory experiment with human participants, capturing their subjective perceptions according to different patterns within a dynamic glazing in a façade and environmental sensors registering indoor environmental information.

   Relevance with Façade and Product Studio: The project involves exploring innovative solutions for façade products to balance natural light, mitigate glare, and design for occupant well-being and comfort. More specifically, a new façade product has emerged on the market and will be tested on occupants.

   Relevance with the Building Technology master track: The project combines two basic sectors of this track, Façade Design and Climate Design (based on building physics and occupant comfort). It aligns with the focus on

advancing technical knowledge related to building design and performance. This includes biophilic principles integrated into the façade design, aiming to improve occupants' visual comfort and provide feedback for automation and control strategies.

Relevance with the MSc Architecture Urbanism and the Built Environment: The investigation of biophilic glare control is related to the building sciences, considering the technical, environmental, and human aspects of architecture.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

Relevance in the Social Framework: Biophilic design, incorporated into the façade to provide visual comfort directly impacts occupant well-being and creates a healthier and more enjoyable living and working space. Biophilia is also linked with psychological benefits in terms of mental health and productivity, so its presence can have an enhancing role in the built environment. It is also addressed to diverse needs and is accessible to a wide range of occupants.

Relevance in the Professional Framework: The project explores innovative solutions in facades that are linked with an architectural design based on sustainability, well-being, and user-centred design. Furthermore, the research is connected with building industry standards that are related to façade design and daylighting and to biophilic strategies that have been incorporated into guidelines in recent years. Through collaboration with the company and the testing of a façade product that is on the market, the project findings can contribute to the development of the marketplace and façade product with both aesthetic and technical principles.

Relevance in the Scientific Framework: Since the project includes an experiment with empirical data, it contributes to the wider branch of knowledge around architectural theory and practice. Biophilic glare control brings up considerations related to psychology, building physics, and design, uniting the corresponding fields for a better understanding of the built environment. Finally, there is a potential for further research, exploring additional aspects and scales of biophilic design, and investigating glare control strategies and effects.