Security lighting in horse riding halls: Development of a simulation-led testing methodology in VR

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Human eyes as living optical devices can do amazing things such as being able to see to some extent in a moonlit night even though the illuminance is lower than 1 lux most of the times. However, this is mostly true when human eyes are properly adapted to the dark environment, which may take up to 30 minutes. The lack of adaptation time in low light conditions in a building during an emergency such as a fire incident or power outage makes it a difficult affair for the occupants to see properly and safely evacuate the space as soon as possible.

Sweden, being situated very close to the Arctic Circle, experiences early sunsets during a major part of the year. The absence of sunlight makes electric lighting in buildings more important even in regular working hours. Local horse riding facilities in Sweden require 300 lux of average illuminance in the horizontal surface of the building during general lighting condition and 5% or 15 lux illuminance for 20 minutes during emergency. If such a situation occurs during an ongoing sports event after the sunset, the building occupants must rely on the security lighting system to evacuate safely.

The main objective of the project was to develop a methodology to test if such a lighting condition is sufficient or not during an emergency. Although the building occupants include both humans and horses, only human visual perception was taken into consideration for this study. Testing how well humans can see in an emergency lighting condition in the case building in reality is a time consuming and costly affair. On the other hand, computer-based simulations and testing can be done in Virtual Reality (VR) in relatively shorter time and minimal cost. Furthermore, this opens up the possibility to develop several lighting design iterations and test them to achieve a comparative analysis. Therefore, the scope of the project was to adapt a simulation methodology and develop a VR testing methodology to test different lighting conditions of the Malmö Civila Ryttareförening building on human subjects. For the purpose of the study, it was hypothesized that the ability to locate objects in different lighting conditions in VR is proportional to the ability to see in those lighting conditions in reality.

While the requirement for security lighting is set at 5% of the required general lighting according to the handbook by Svenska Ridsportförbundet, some other guidelines suggest it to be 10% for certain critical spaces where there might be risk of injuries and accidents. The intention of this project was to test both requirements as well as the general lighting condition of 300 lux to make a comparative analysis. The existing general and security lighting conditions were simulated, and two optimized design iterations were proposed to match the 5% (15 lux) and 10% (30 lux) requirements. Simulations also suggested that the general lighting condition was in photopic adaptation range while the security lighting conditions were predominantly in the mesopic adaptation range. The general lighting condition along with the two security lighting design iterations were chosen as the final three test conditions. These conditions were then rendered from a fixed viewpoint as equirectangular images in a scientifically validated lighting rendering software. The renderings were used to create the VR environment in a game engine. Invisible game objects were programmed and placed inside the virtual environment that can be coupled with eye gaze tracking technology to determine if the objects were seen by the participants.

The test was intended to be a pilot study for future broader research and was conducted on nine participants for this project. The participants' feedback suggested that they faced difficulty to locate distant objects, objects of specific colours, and objects in darker scenes. Their feedback was in line with the eye gaze tracking and object identification data gathered from the tests. The test data suggests that the participants could identify more objects in 300 lux and 30 lux environments compared to the 15 lux environment. The results of this test indicate that the minimum requirement of 5% security lighting may not be enough for the participants to identify objects in a test environment. More test subjects and further work on the methodology is required to get a definitive answer.

The project can be further developed to conduct broader research for different building types. VR technology has already showed great promise in Architecture, Engineering, and Construction (AEC) industry, and the possibility to incorporate it in lighting design, simulation, and testing process is worth investigating. There are still major technological barriers to overcome, which requires intense research in the upcoming years.

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