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Impact of Public Lighting Intensity on the Feeling of Safety in Virtual Reality

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Over the past decades the urban night landscapes have been associated with over-lighting, which has become the norm. Arguably, lighting systems play a major role in the city life (feeling of safety, development of a night time economy and various night practices). But the urge for reducing energy consumption and protecting biodiversity must be considered while designing public lighting, without compromising the feeling of safety. In this paper, researchers from Urban Planning, Psychology and Computer Science were gathered by the transdisciplinary research program "Noz Breizh". They are proposing an exploratory approach to use Virtual Reality to test different lighting intensities for studying its impact on the feeling of safety of pedestrians. As a first result we observed a logarithmic relation between the feeling of safety and the light intensity.

CCS Concepts: • **Human-centered computing** → **Human computer interaction (HCI)**; **Virtual reality**; • **Applied computing** → **Psychology**; **Urban Planning**;

Additional Key Words and Phrases: Virtual Reality; Public Lighting; Well-being; Urban Planning; Psychology; Safety

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1 INTRODUCTION

This research is a part of a research program named "Noz Breizh" which was created in 2021 and launched with the help of the Foundation of the University of Western Brittany (UBO). This program aims to design transdisciplinary research and it organizes multi-partner scientific projects related to the night and nocturnal activities. Thus public lighting is a crucial part for the nightlife of cities: it encourages recreational and economic activities [Hobbs et al. 2005], and increases social and community interactions [Gaston et al. 2015]. Several studies also proved that public lighting has a significant impact on the reduction of traffic accidents [Jackett and Frith 2013; Wanvik 2009] and to some extent in the crime rates [Welsh and Farrington 2008].

Currently, the management of urban light is seeking to be more environmentally friendly and in line with the objectives of a more sober energy consumption [Saad et al. 2021]. Light pollution has a negative impact on local biodiversity [Pauwels et al. 2019], and it can also disturb the sleeping pattern and the circadian rhythm of people

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who are living nearby [Swaminathan et al. 2017]. However the literature is lacking evidence showing what lighting conditions impact on human well-being [Gaston et al. 2015].

As a first step toward this direction, we propose to analyse the relation between the feeling of safety and the light intensity. In order to build an experiment that can be replicated with the same factors, we decided to setup a simulation in virtual reality (VR) as it allows to generate the scene of a selected street and to change the lighting configuration as other factors remains unchanged (weather, people walking around, sky illumination, etc.).

2 RELATED WORK

2.1 City Lighting

Traditionally, lighting systems have always had a practical objective as they only had to put light in dark places for people to see where they were walking or driving. But the urban light also has an important role in the configuration of a nocturnal sociability (festivities, leisure and night work) [Straw 2015]. The use of photometric units combined with techniques for detecting emotions, facial recognition, behaviours and perception are more commonly used in urban lighting studies [Scorpio et al. 2020].

Boomsma and Steg studied how physical factors such as lighting, entrapment, and individual factors—notably gender, affect the feeling of safety and the acceptability of reduced lighting levels [Boomsma and Steg 2014]. For their tests, they used movie-clip videos on a TV in a dark room. They found that lower lighting and higher entrapment were less desirable and that women felt less safe than men. But like Condon et al. showed in their research about the stated fears of women living in France, the women’s fears do not seem to restrict their nighttime mobility [Condon et al. 2007].

In parallel, some studies show that stray light can have effects on human health and mood [Zissis 2020]. As an example, people report negative sleep disturbances due to the intrusion of light into their homes [Blask et al. 2012]. Artificial lighting may also result in night-time glare, including disability glare, which affects driving and pedestrian safety. Thus, scientific evidence highlighting the negative impacts of artificial lighting on local society and biodiversity [Altermatt and Ebert 2016] contributed to an increase in awareness at a political level in many countries.

In terms of actual safety [Welsh and Farrington 2008], lighting is often seen as an excellent tool for natural surveillance. Still, the intensity of the street light might be reduced or adapted according to the uses of the public space while ensuring the well-being of pedestrian and the road safety.[Struyf et al. 2019].

2.2 Virtual Reality

VR has already been used for the design and development of urban planning [Luigi et al. 2015; Maffei et al. 2016]. By making a simulated environment instead of asking participants to walk in a real street, it opens the doors for more people to give their feedback. As compared to just presenting pictures, videos or 3D models to participants on a simple screen, it is more effective to present lightning environments in VR [Chen et al. 2019] as VR is more immersive and will have more impact on the participant’s feelings.

Felnhofer et al. used VR to investigate the effects of weather conditions on people’s emotions and moods. They created virtual models of five parks, each designed to induce different moods (joy, anger, boredom, anxiety and sadness). The virtual environments were displayed to the participant using a smartphone as an input device. For example, to induce sadness the scenario represented a gray and rainy day and one with different park lighting conditions was used to cause the sense of anxiety [Felnhofer et al. 2015].



Fig. 1. A 3D environment simulated in virtual reality representing an existing large pedestrian street at night. Multiple parameters of the public lighting can be tested to analyse its impact on the feeling of safety.

More specifically, Maciejewski studied the influence of light temperature on the feeling of safety [Maciejewski 2018]. The researcher presented a 3D scene based on pictures to 10 participants. The scene is virtually separated in two parts (South and North), where each part was lit with a specific value of temperature (expressed in Kelvin) among three: 3000K, 5000K or 6500K. Each participant saw all combinations (six pairs) in a random order. The participants were asked to indicate each time if they felt more comfortable having to walk into the north or the south part. On average, the majority of participants preferred higher color temperature light.

3 METHODOLOGY

Our research goal is to find the relationship between lighting intensity and the feeling of safety at night. We are interested to see how reducing the light intensity is impacting the feeling of safety.

The VR simulation was presented by using the HTC Vive device. We set a “room scale” playing area which allows the user to stand up and to explore the scene by looking around. The simulation used for the experiment is a 3D scene of a popular street named “Siam” located in the city center of Brest (France, Brittany). It is particularly known for bars, restaurants and nightlife.

Once the environment is set up and configured, an experiment was carried out with participants to analyze their perception of safety in that environment. Twelve people participated in the experience: 5 men (41,7%) and seven women (58,3%). The age of the participants was between 19 and 24 years-old with an average of 21,3 years. All participants were familiar with the environment that was presented to them as it is quite a popular street. In addition, all participants were unfamiliar with VR technology and have never used it before the experiment.

3.1 Simulation

The original 3D environment was created by the city of Brest. The data is open and available online¹. We used an improved version of this 3D model which was made by Anne-Gwenn Bosser and some students that she supervised. Then we added the lights and changed the parameters related to natural ambiance light at night, to have a resemblance with reality². The way light is perceived in VR is quite different from what we can see in Fig.1. The light setup was achieved with two different types of lamppost, according to the real disposition. The light intensity was set to be the same in all lampposts. One important parameter in the configuration of street lights is the temperature. In studies

¹<https://geo.pays-de-brest.fr/zapp/Pages/Donnees3D.aspx>

²The simulation was created with Unreal Engine 4.23

mentioned before, typical scenarios for light testing are green areas and urban areas. In our case, we considered the test scenario to be more of like a green area, even though there are not many trees, but because it is a large pedestrian area with no cars in this section of the street. The chosen temperature was 4200K according to these studies [Maciejewski 2018; Scorpio et al. 2020].

3.2 Procedure

The participants were asked to fill a consent form explaining the purpose of the experiment. They were free to stop at any time. Then the participants were equipped with the VR headset to start the experiment. The experience consisted of multiple periods of 15 seconds in which we lit the scene with a random light intensity selected from an array of preset values. When the time has elapsed, we switch to a completely dark scene and show an image with a question asking the participant "How safe do you feel?" with a Likert scale going from 1 to 10. From 1 to 5 the indication "not safe" was written on the image, from 6 to 10 the indication "safe" was written. The experimenter wrote the answer and proceeded with the experiment.

As we want to reduce light intensity, we chose rather low values in order to find the specific area in which we observe a shift in the perceived safety. With that in mind, we made an array of six intensities expressed in Lumens: [100, 400, 800, 1500, 3000, 5000]. These values were carefully selected based on the literature and on pretest. We knew that it is not necessary to test with higher values of intensity as it will be too strong. Each intensity was shown in a randomised order and four different times to prevent any influence of any particular sequence. So each participant saw a total of 24 scenes. At the end of the experiment, the participants were asked to fill a questionnaire on the technical quality of the simulation, and a short interview was done.

4 RESULTS

First, we analyzed the participant's feeling of safety relatively to the light intensity. Each participant gave four answers for each light intensity. We computed the normalized feeling of safety by subtracting to each participant's answer the average answer of this participant (see Fig. 2). The relation between the feeling of safety and the light intensity seems to follow a logarithmic law. However, not all users follow this law, especially participant 6 which tends to have a decreasing feeling of safety when the light intensity increases. The participant 4 seems to follow the logarithmic law but with a stronger growth factor.

During the interviews conducted with the participants, participant 6 explained that she is very familiar with this specific area of the city and that she was not feeling comfortable with the place from her experience, independently from the lighting conditions. In our sense it explained why this participant data did not follow the general trend.

In order to see how the values were spread out among our participants, we plotted a box plot for each lighting condition based on the normalized feeling of safety in Fig. 3. In the box plot the outliers appear as circles. The outliers are found by the interquartile range rule with a 1.5 factor. Most of the outliers come from participants 6 and 4. The fitted log function is $y = a + b * \log(x)$, where the optimal set of parameters was found as $a = -7.6$ and $b = 1.1$.

This logarithmic relation between the light intensity and the feeling of safety shows that if the light is low, changing it will impact much more the feeling of safety than if it is high. With this specific lighting setting, it seems that an intensity of 800 Lumens could be an optimal compromise between the feeling of safety and the light intensity.

In order to see if the simulation was realistic, the participants were also asked on a Likert scale going from 1 to 7 "how much the experience in the virtual environment was similar to the real environment". An average answer of 5.33 were given by the participants. As the participants knew the real scene, we considered that the score was satisfying.

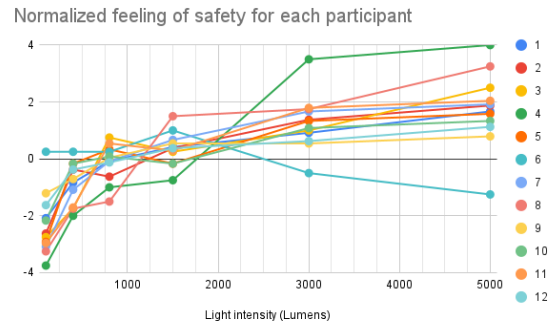


Fig. 2. Each line represents the normalized answer given by the participants. The feeling of safety seems to follow a logarithmic growth as a function of light intensity. We can also see that participant 6’s feeling was not following the general trend.

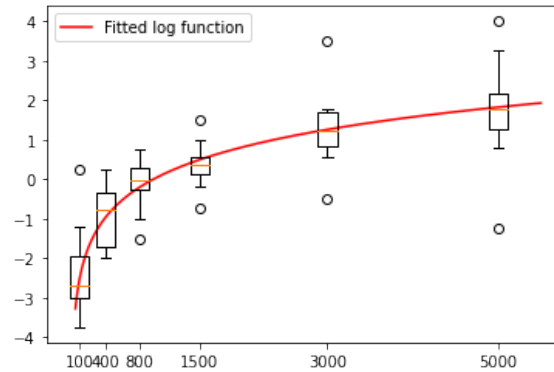


Fig. 3. Box plots with light intensities in x axis (Lumens) based on the normalized feeling of safety of the 12 participants. A logarithmic function $y = a + b * \log(x)$ was fitted to the median values.

5 CONCLUSION AND FUTURE WORK

We presented in this paper an experiment to estimate the relation between the feeling of safety and the light intensity. This is a first experiment gathering the data from only 12 participants but a clear logarithmic trend could be observed.

The fact that the participants were familiar with the area helped to prove that the quality of the experience was high enough. Still, further work will be done to improve the quality of the simulation.

However, the participants’ personal experience influenced their answers. Of course even in a totally unknown area, the personal experience will influence the answers but maybe in a less strong way. Still, to address this problem we are now setting up another experiment with a “handcrafted” street that participants will not be familiar with. The area we tested was rather large, so we will experiment with a narrower street which tends to stimulate the feeling of entrapment.

For now, only questionnaires have been used as a subjective measurement of the participants’ feeling, we will include physiological sensors to capture objective measures such as the electrodermal activity or the heart rate variability which are related to stress [Augereau, Tag, et al. 2018] and cognitive load [Augereau, Brocheton, et al. 2022].

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