ZUMTOBEL

Psychological effect of lights in an urban environment

Zumtobel Research

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DIE LICHTPLANER

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Summary

This study is based on a psychological approach to light in urban environments in order to be able to improve perceptual and residential quality in inner-cities at night time. Due to the number of confounding variables that arise from field tests in the real world, VR technology was chosen as the study methodology and was implemented by Prof. Greule at HAW Hamburg, the company, Die Lichtplaner and the psychologist, Torsten Braun.

Four central questions were formulated:

1. Does the more expensive creation of VR scenes offer more for the evaluation of light than classic visualisation methods e.g. in comparison to Photoshop or Relux Suite?

2. Is VR technology sufficiently suitable for reliably capturing psychological constructs to force future studies of light to use this methodology?

3. Do different planning approaches (e.g. brightening façades) have an influence on emotional evaluation?

4. What planning recommendations can be derived?

In the first part of the test, 21 test subjects undertook the evaluation of a scene in three different visualisation qualities. The representation had no influence on the emotional evaluation of the scene. However, a clear preference arose from the qualitative statements of the participants for the high visualisation quality in order to better be able to perceive differences in brightness, textures and architectural quality.

In the second part of the study, the main test, the test subjects were presented with a total of 19 different lighting situations via an Oculus Rift headset and their emotional impacts were recorded via semantic differential. At the same time, product based assessments on the design and lighting effect of the Nightsight and SUPERSYSTEM outdoor families were recorded via four items.

The following result, among others, was able to be recorded:
Lighting situations are able to be evaluated in detail with the help of VR simulations. Lighting experts are able to analyse a VR simulation in more detail but an alternative psychological evaluation of the lighting situations could not be ascertained in this series of tests. This means that VR simulations allow for comparisons of different lighting systems.

It is possible to plan the residential quality of a location and thus to predict it. Lighting quality and good lighting technology are immediately perceived by the test subjects. Simple lighting solutions have worse psychological evaluations. The surfaces and objects that are visible and important during the day, should also remain discernible in the darkness in order to preserve the identity of the location.

A hierarchy of perception should be determined with regards to importance and value. In this test, it was:

- Basic brightness of the location
- Brightness of façades
- Brightness of the Bismarck monument and its immediate surroundings
- Brightness of trees
- Brightness of seating cubes

The result of the test and its alternative design possibilities in terms of façade brightness, illumination of trees, seating furniture and monuments, show that the unambiguity and clarity of the creative intent is expedient for an appropriate appearance and its value. The level of detail of individual lighting solutions should not be overstated. In this case, this applied to the Bismarck monument. A highly differentiated illumination of the statue was perceived but not valued.

1. Background

Due to monotonous building practices, cities are becoming less and less attractive to people. The environmental psychologist, Prof. Colin Ellard (University of Waterloo, Ontario, Canada), noticed that people are looking for something interesting and lively in cities so that they can go more slowly and dwell for longer. Detailed remarks are explained in his book, Places of the Heart.

“Our surroundings can powerfully affect our thoughts, emotions, and physical responses“ … (Colin Ellard)

For this reason, this also means that interesting lighting belongs in interesting inner cities, in order to achieve a better sense of life and emotions in them and to increase the standard of living.

In order to test this theory by Prof. Ellard more accurately, an experiment into the psychological effects of lighting in urban environments was started in collaboration with the Zumtobel Group, specialists in lighting simulation, Prof. Roland Greule (Lichtplanungsbüro Greule), psychologist Torsten Braun (Die Lichtplaner), the master degree course in architecture, construction and design at the Darmstadt Technical University (TU Darmstadt) under Prof. Annett-Maude Joppien and the Design, Media and Information faculty (DMI) and Media Technology department at the Hamburg University of Applied Sciences (HAW Hamburg).

New to this experiment was the use of VR technology; more accurately, Oculus Rift, to visualise the inner city i.e. to provide outdoor lighting. Thus, the test subjects were able to “look around” the area, sample the lighting and provide their feedback via surveys. Through the use of virtual reality technology, many lighting variants were able to be presented to the test subjects that could never have been done via real world sampling. The test subjects are able to experience a lighting situation through the VR headset as if they were really there.

1.1 Research study: Ludwigsplatz Darmstadt

After various deliberation and to ensure that the conditions of the experiment were valid and replicable, a research study was started that consisted of two test parts in which the psychological effects of light and selected lighting in urban environments was tested. To do this, a real location was chosen (Ludwigsplatz in Darmstadt).

Ludwigsplatz is one of the prominent locations in Darmstadt yet not one of the most known or visited. The square is home to a fountain with a monument of Bismarck. The Bismarck monument (also known as: The Bismarck fountain) was completed in 1906.In the immediate vicinity of the Bismarck monument are various classic, medium-sized shops (banks, chemists, bakeries etc.) as well as a large Saturn store.

The square was completely recreated with the simulation programme, Relux Suite, and the programme, Unity 3D, and then presented to the 21 test subjects in the main test via VR technology and the Unity 3D game engine with an Oculus Rift headset before being evaluated with the help of an additionally developed psychological questionnaire. This is how the best lighting scenario was able to be extracted.

Fig. 1: View of the selected Ludwigsplatz in Darmstadt (source: Google Earth)

Fig. 2: View of the Bismarck monument in Ludwigsplatz in Darmstadt (source: Kevin Kornprobst)

Fig. 3: Former night time lighting of Ludwigsplatz in Darmstadt (source: Die Lichtplaner)

2. “Test design” of the Research study

The research study carried out was concerned with the perceptual-psychological evaluation of lighting situations in the example of Ludwigsplatz in Darmstadt. The test design consisted of two experimental studies:

- Representations of lighting situations (1st Test)
- Psychological evaluation of different lighting situations with VR glasses (main test)

The theses are as follows: “The more realistic the representation, the more homogeneous the judgements by the test subjects will be and thus the basis for communication will obviously be clearer”.

2.1 Representations of lighting situations (1st Test)

In order to be able to systematically differentiate the assessment of the lighting effects on Ludwigsplatz between the selected forms of representation, multiple forms of representation of a 3D view of the lighting effect on Ludwigsplatz were compared:

- in Photoshop
- in Relux Suite 2016
- in virtual reality (Unity 3D)

There was also a question of which of the forms of representation had the greatest predictive value of the subsequent visual reality following technical implementation.

These 3 different forms of representation were shown to the 21 test subjects on an LCD screen (Panasonic, 56") in the VR room of the lighting laboratory at HAW Hamburg.

2.1.1 Visualisation of the lighting concept in Photoshop

As a first step towards improving the former residential quality of Ludwigplatz and to make this possible with new lighting, students on the master degree course in architecture, construction and design at the Darmstadt Technical University (TU Darmstadt), under Prof. Annett-Maude Joppien, developed various lighting concepts in collaboration with Peter Dehoff (Zumtobel Group), Torsten Braun (Die Lichtplaner) and other lighting specialists and visualised them with their conventional methodology (Photoshop). See ill. 4

Fig. 4: New lighting concept for the former night time lighting of Ludwigsplatz in Darmstadt, prepared by master students of TU Darmstadt (source: TU Darmstadt)

2.1.2 Visualisation of the lighting concept in Relux Suite

On the basis of the lighting concept developed by the master students, the concept was further developed by Torsten Braun (Die Lichtplaner), predominantly using Zumtobel Group lighting. This further developed lighting concept was converted and visualised in the lighting simulation program, Relux Suite (2016 version), with simple building geometry but "real" light intensity distribution curves (LVK).

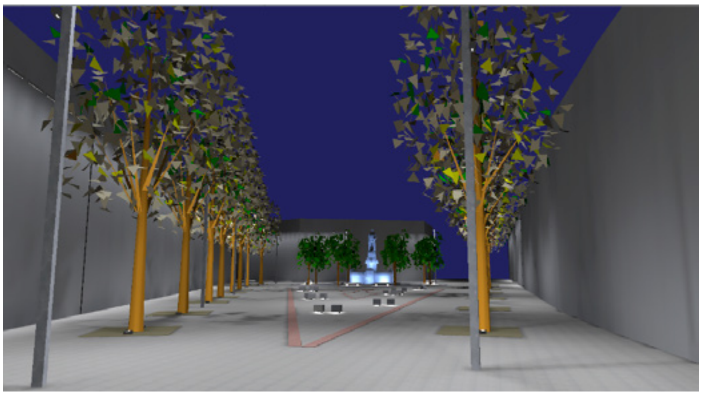

Fig. 5: Lighting concept developed by Torsten Braun, visualised in Relux Suite and created with Zumtobel Group lighting (source: Dennis Flügge)

2.1.3 Visualisation of the lighting concept in Unity 3D

This further developed lighting concept by Torsten Braun was modulated in detail in 3dsMax and implemented in the Unity 3D game engine in order to present the lighting scenarios via VR glasses (Oculus Rift). The Relux programme does not currently support any VR glasses.

Fig. 6: Lighting simulation with the Unity 3D programme (source: Thomas Fischer)

2.2 Lighting systems used

The new SUPERSYSTEM outdoor lighting system was used as on-site lighting. The positions of the pre-existing lights on Ludwigsplatz were kept. SUPERSYSTEM outdoor 30P was used with an output of approx. 4500 lm, warm white as well as Supersystem outdoor 12P (approx. 2000 lm, warm white). The pylon was 10 m high. The 30P system illuminated the market place and the 12P, system the area towards the buildings.


Fig. 7: Shown here the SUPERSYSTEM outdoor 12P and 30P lighting systems (sources: Zumtobel Lighting)

As an alternative system, Nightsight was used for comparative purposes (approx. 2000 lm, warm white).


Fig. 8: Nightsight 4/8 and 2/8 lighting systems (source: Zumtobel Lighting)

To illuminate the façades of the surrounding buildings, the ELEVO line warm white lighting system was used at eaves height 1m away with potential output of 950 – 2850 lm.

Fig. 9: Shows the ELEVO line lighting system (source: Zumtobel Lighting)

To illuminate the trees, the EFACT R2 (Thorn) was used as an uplight in order to illuminate the relative high number of trees on Ludwigsplatz. Output: 186 lm, warm white. The staging of the seating cubes was able to be handled by the Viso system in order to obtain additional lighting points on the market place. Output: 750 lm, warm white.

The Wibre lighting system was used for the fountain. Output: 660 lm, colour temperature 4500 K.

2.3 Test subjects

21 test subjects (12 men, 9 women) took part in the test (aged 21 – 53). As the control variable, the prior level of knowledge was requested before the test started.

There were 10 laymen, 6 lighting experts and 5 VR experts. At the end of the test, a questionnaire about virtual reality and motion sickness was handed out.

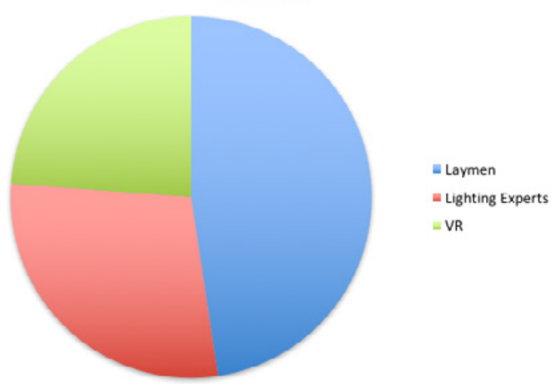

Fig. 10: Shows the prior level of knowledge of the test subjects (source: Thomas Fischer)

2.4 Semantic differential – adjective pairs

In addition to perception by the so-called visual pathway, there is also the aspect of the creation/impact of emotions and sentiment. This means: In the case of statistical and, above all, dynamic lighting scenarios, the psychological aspect must be considered since people do not just evaluate the surrounding lighting situation based on perceptive processes but are also at the mercy of emotional influence.

In order to be able to test emotions scientifically, so-called adjective pairs are used that consist of pairs of opposites. The psychologist Torsten Braun used ten different adjective pairs for this experiment in order to evaluate the effect of light. See Fig. 11. The test process was randomised i.e. the presentation of the lighting scenarios was randomly switched between Photoshop, Relux and Unity.

☐	relaxing	☐	rather relaxing	☐	neutral	☐	rather stimulating	☐	stimulating
☐	friendly	☐	rather friendly	☐	neutral	☐	rather unfriendly	☐	unfriendly
☐	ugly	☐	rather ugly	☐	neutral	☐	rather beautiful	☐	beautiful
☐	light	☐	rather light	☐	neutral	☐	rather dark	☐	dark
☐	positive	☐	rather positive	☐	neutral	☐	rather negative	☐	negative
☐	new	☐	rather new	☐	neutral	☐	rather ordinary	☐	ordinary
☐	comfortable	☐	rather comfortable	☐	neutral	☐	rather uncomfortable	☐	uncomfortable
☐	radiant	☐	rather radiant	☐	neutral	☐	rather dull	☐	dull
☐	well-illuminated	☐	rather well-illuminated	☐	neutral	☐	rather badly illuminated	☐	badly illuminated
☐	featured	☐	rather featured	☐	neutral	☐	rather shapeless	☐	shapeless

Fig. 11: List of the adjective pairs used throughout the test (source: Torsten Braun)

2.4.1 Additional questions

In addition to the questioning on the 10 adjective pairs for each lighting scenario, the examiners asked the test subjects additional questions:

What do you find particularly positive?

1.)

2.)

What do you find particularly negative?

1.)

2.)

In addition to the questioning on the lighting scenarios, additional questions about the lighting system and pylon height etc. were also asked at the end.

How do you evaluate the design of the used lighting systems in general?									
☐	positive	☐	rather positive	☐	neutral	☐	rather negative	☐	negative
How do you evaluate the chosen arrangement of the luminaires in general?									
☐	positive	☐	rather positive	☐	neutral	☐	rather negative	☐	negative
How do you evaluate the visible brightenings of the floor areas and the facades?									
☐	positive	☐	rather positive	☐	neutral	☐	rather negative	☐	negative
How do you evaluate the pylon heights of the local square lighting?									
☐	positive	☐	rather positive	☐	neutral	☐	rather negative	☐	negative

Fig. 12: Questioning on the appearance of the lighting systems used with adjective pairs (source: Torsten Braun)

3. Results of the 1st series of tests

The following results arose from the first series of tests. In the case of the adjective pair (relaxing – stimulating), for example, the representation of the lighting scene in Photoshop and Unity 3D was assessed as relaxing. The representation with Relux is rather stimulating. This result has the same assertion when the evaluation is differentiated and the test subjects are separated into lighting experts and laymen, see Fig. 13. For the adjective pair (friendly – unfriendly), the representation of the lighting scene is assessed as particularly friendly, see Fig. 14, the same applies for the adjective pair (ugly – beautiful). Here, the representation in Unity 3D is identified as particularly beautiful by all test subjects compared to the representation of the effect of light in Photoshop being assessed as neutral.

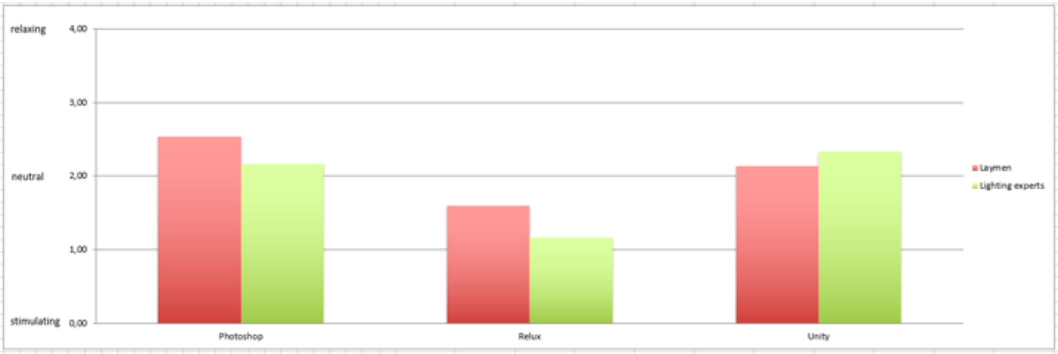

Fig. 13: Results of the adjective pair (relaxing – stimulating), differ among light experts and laymen

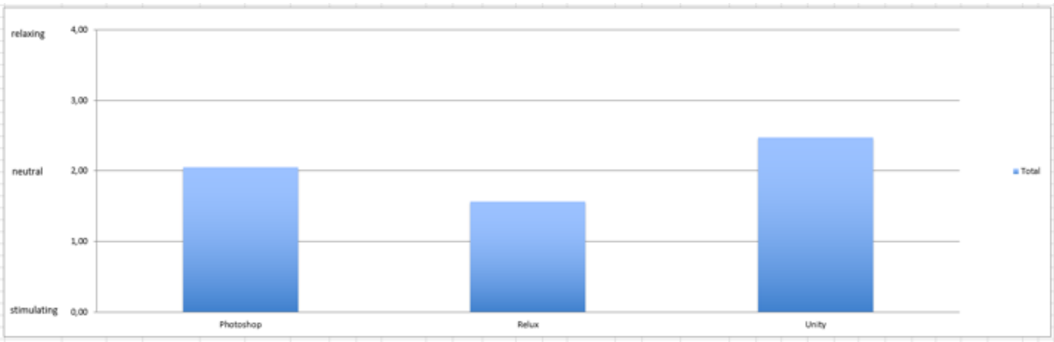

Fig. 14: Results of the adjective pair (friendly – unfriendly)

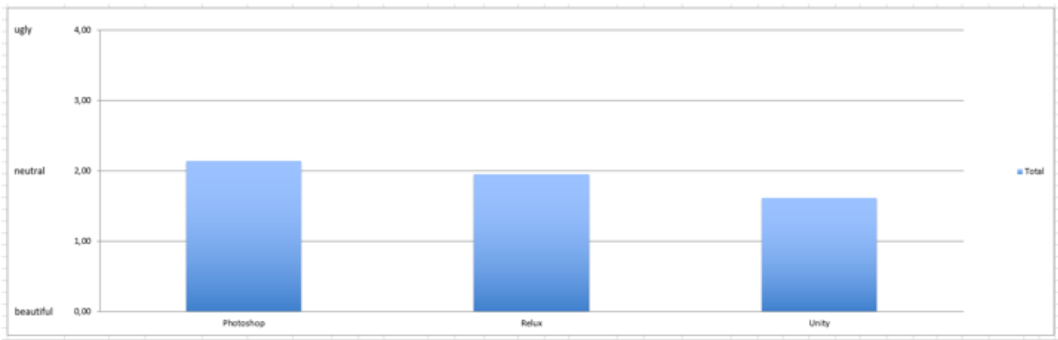

Fig. 15: Results of the adjective pair (ugly – beautiful)

3.1 Overall assessment of all adjective pairs

The overall assessment of all adjective pairs is represented in Fig. 16. As you can see, Relux and Unity have relatively comparable results. However, the visualisation of the lighting scenarios in Photoshop are not so highly assessed.

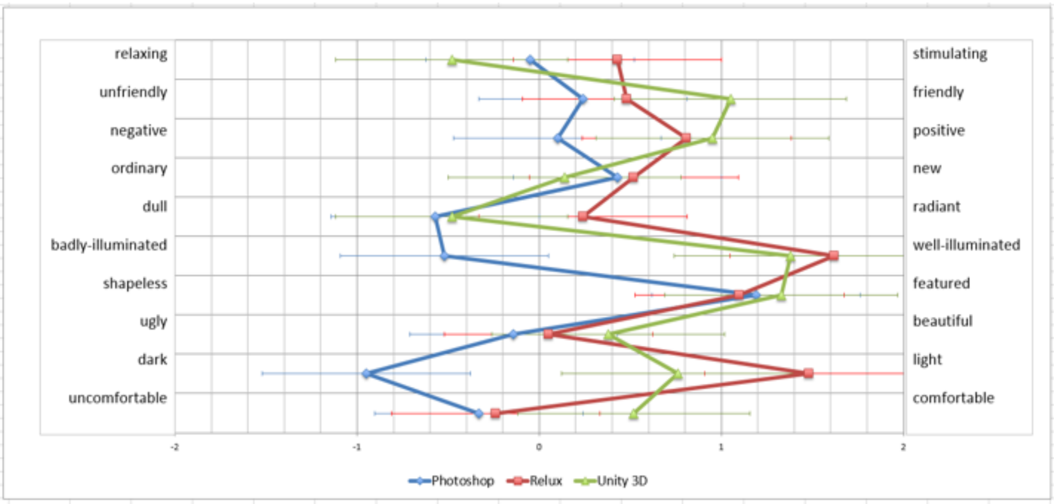

Fig. 16: Overall assessment of all adjective pairs

3.2 Results of the questioning on the lighting systems

Fig. 17 shows all of the results of the questioning on the lighting systems, the arrangement of the lights, the visible brightening of the floor and façades and the pylon height. As you can see, Relux and Unity have comparably positive results. Whereas Photoshop is assessed as neutral.

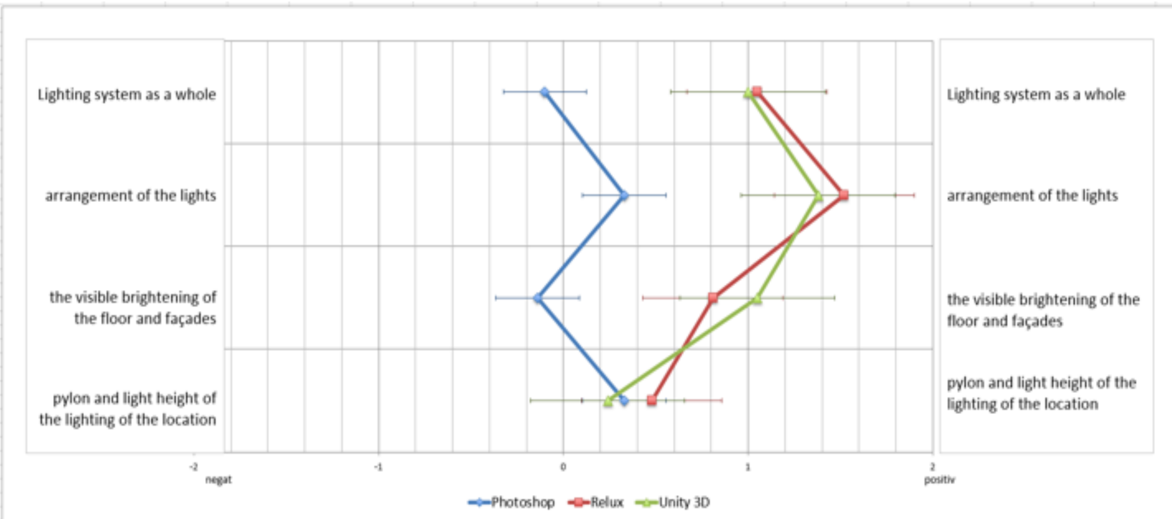

Fig. 17: All of the results of the questioning on the lighting systems, the arrangement of the lights, the visible brightening of the floor and façades and the pylon height

3.3 Test subject comments

The following are test subject comments on Photoshop, Relux and Unity.

Photoshop:
- Picture becomes too dark towards the back
- Statue isn't featured
- Dark spots in the middle
- Church tower too dark (this is seen as part of the square, which isn't true)
- Lamps have beautiful cones of light

Relux:
- Light pylons too high
- Façades too abstract
- Unnatural shadows
- Missing textures
- Buildings too shapeless

Unity:
- Everything clearly visible
- Revegetation
- Pylons fade into the background
- Accents and structures seem positive
- Natural, not so glaring

3.4 Summary of the 1st series of tests

As a summary of the 1st test, you could say that the Photoshop image is not as highly valued as the representation in Relux, Unity or Unity 3D. The representation in Relux appears altogether stimulating and well-illuminated. The representation in Unity 3D appears friendly. This means that you can present immersive visualisation on the computer with Unity 3D lighting simulations for future presentations of lighting effects and that these assessments are more valid than the previous Photoshop presentations. Nobody has yet to research and represent this method of presentation so clearly.

4. Psychological evaluation of different lighting situations with VR glasses (main test)

On the basis of the 1st test , a total of 19 different lighting situations were subsequently prepared for the main test and the psychological evaluation was carried out with a VR headset (Oculus Rift DK2). Thus allowing the test subjects to look around the space. Movement in the space was not planned or implemented at that point.

4.1 Virtual reality

Virtual reality will play a key role in the future: in architecture, aircraft construction and overall planning. In the future, the aim is to perceive complete, constructed buildings, aeroplanes etc. in an interactive, virtual computer model in advance. The advantage of this completely new possibility is being able to consider a location or a building etc. in a complete 360 degree space and to thus be able to "immerse" oneself in the scenario. Previously, the problem was that computer models were too big to be able to consider them in real-time and accurate lighting simulation just wasn't possible since the classical lighting simulation programmes, which rely on fibre optic cables, required too much computation time to be able to visualise the results in real-time. This is now possible with the use of game engines such as Unity 3D or Unreal 3D. Furthermore, VR glasses were extremely expensive until recent years to the extent that almost nobody was able to use them outside of research institutes. With the Oculus Rift headset and the HTC Vive, inexpensive VR glasses have now hit the market.

4.1.1 Oculus Rift headset

Oculus Rift is a head-mounted display (HMD) for virtual visualisation as well as real pictures, videos and films. Oculus Rift has a field of view of 110 degrees horizontally and 90 degrees vertically. Inside the headset there is an OLED display with a resolution of 1980x1080 (HD) and two lenses to accommodate the eyes. The CV1 version that was used in the test also has an additional head-tracking system.

Fig. 18: Oculus Rift headset CV1 (source: Oculus Rift)

4.1.2 Unity 3D game engine

In order to be able to represent and simulate lighting effects in real-time, game engines such as Unity 3D or Unreal 3D are currently necessary. These programmes are the core of games. With them, entire scenes/worlds can be relatively quickly developed, constructed and simulated in real-time. In the mean time, these programmes also work with IES files i.e. accurate photometrically measured light intensity distribution curves (LVK) can be used. The Unity 3D game engine was used in the main test.

4.1.3 Perspective and variants

In order to be able to assess a place like Ludwigsplatz in Darmstadt and its lighting, a total of 19 different variants of lighting situations and perspectives were used. More lighting situations and perspectives could have been used but the test was not to last longer than 60 mins. Fig. 19 shows the different variants. The 1.1 Central variant (central perspective, approx. 40 m from the Bismarck fountain) was the foundation for this and was developed over time. The SUPERSYSTEM outdoor lighting system was set at 100% brightness, the façade illumination at 6.5%, the illumination of the trees at 20%, the illumination of the seating cubes at 40% and the illumination of the fountain at 50%. From this central perspective there were 8 variants with different lighting scenes in which only a single component of the scene was changed for each variant while the other components remained the same. In addition, there was a viewing position in which the test subject was closer to the fountain (e.g. 1.1 Sides), at a distance of approx. 20 m. From this viewing position there were 6 variants with different lighting. And there was a viewing position in which the test subject was close to the fountain (e.g. 1.1 Fountain). From this fountain viewing position there were 5 variants with different lighting.

These 19 variants were presented to the 21 test subjects throughout the course of the test, which lasted roughly 1 hour, and for each variant, questions were asked concerning the 10 adjective pairs on photometric and emotional evaluation as well as the 4 adjective pairs concerning the lighting systems used. Test subjects were simultaneously permitted to share positive or negative remarks with the examiners.

Fig. 20 depicts the situation during the test. In the main test, the screen served only to allow the examiner to be able to see what the test subject was seeing with the Oculus Rift headset at that moment.

Varia.-Nr	System	Facade	Trees	Cubes	Well
1.1-Centr.	Supers. Outd.	6,5%	20%	40%	50%
1.1-Site.	Supers. Outd.	6,5%	20%	40%	50%
1.1-Well.	Supers. Outd.	6,5%	20%	40%	50%
1.2-Centr.	Supers. Outd.	30%	20%	40%	50%
1.2-Site.	Supers. Outd.	30%	20%	40%	50%
1.2-Well.	Supers. Outd.	30%	20%	40%	50%
2.1-Centr.	Supers. Outd.	6,5%	0%	40%	50%
2.2-Centr.	Supers. Outd.	6,5%	Seitlich 20%	40%	50%
3.1-Centr.	Supers. Outd.	6,5%	20%	0%	50%
4.1-Centr.	Supers. Outd.	6,5%	20%	40%	0%
4.1-Site.	Supers. Outd.	6,5%	20%	40%	0%
4.2-Centr.	Supers. Outd.	6,5%	20%	40%	Only Bismarck
4.2-Site.	Supers. Outd.	6,5%	20%	40%	Only Bismarck
4.2-Well.	Supers. Outd.	6,5%	20%	40%	Only Bismarck
4.3-Well.	Supers. Outd.	6,5%	20%	40%	Beautiful Face
5.1-Centr.	Nights.-längs	6,5%	20%	40%	50%
5.1-Site.	Nights.-längs	6,5%	20%	40%	50%
5.2-Site.	Nights.-kompl	6,5%	20%	40%	50%
5.2-Well.	Nights.-kompl.	6,5%	20%	40%	50%

Fig. 19: List of the lighting variants

4.1.4 Instruction

At the start of the test, the test subjects were shown how the Oculus Rift headset worked, how to put it on and how to move with it. After that came the next instruction: “It is 20:00. You are on your own and on your way to a restaurant and must pass through this square: What are your overall impressions of this square?”

Other instructions during the test included: “The intensity of the lighting for an object or object group has been changed. Can you tell which object or object group?” The test subjects could answer with yes/no and were then told what had been changed in the new variant.

Fig. 20: Test conditions of the test subjects with the Oculus Rift headset CV1 (source: Kevin Konrprobst)

4.1.5 Variants

The 19 variants of the different lighting and perspective situations are shown below.

Fig. 21: Basic variant 1.1 Central with SUPERSYSTEM outdoor 100%, façades 6.5%, trees 20%, seating cubes 40%, fountain 50%

Fig. 22: Variant 1.2 Central with SUPERSYSTEM outdoor 100%, façades 30%, trees 20%, seating cubes 40%, fountain 50%

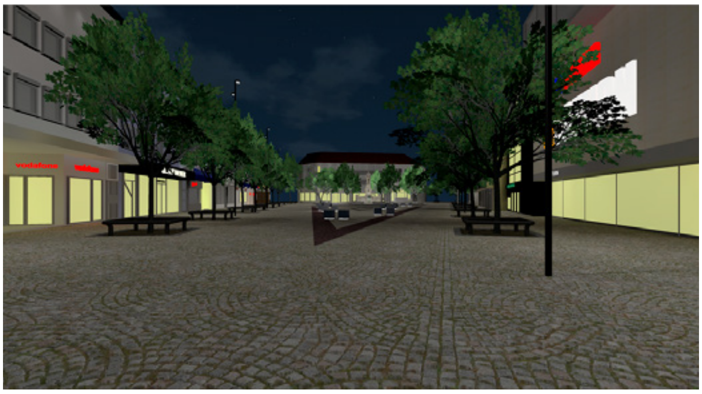

Fig. 23: Variant 2.1 Central with SUPERSYSTEM outdoor 100%, façades 6.5%, trees 0%, seating cubes 40%, fountain 50%

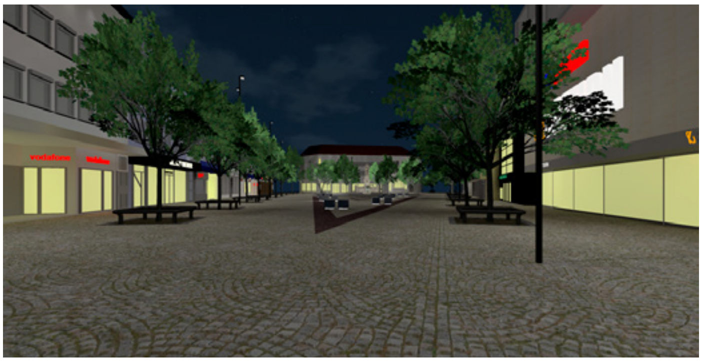

Fig. 24: Variant 2.2 Central with SUPERSYSTEM outdoor 100%, façades 6.5%, trees at the side 20%, seating cubes 40%, fountain 50%

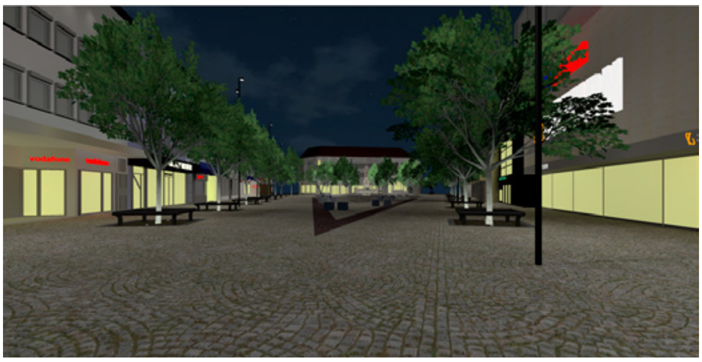

Fig. 25: Variant 3.1 Central with SUPERSYSTEM outdoor 100%, façades 6.5%, trees 20%, seating cubes 0%, fountain 50%

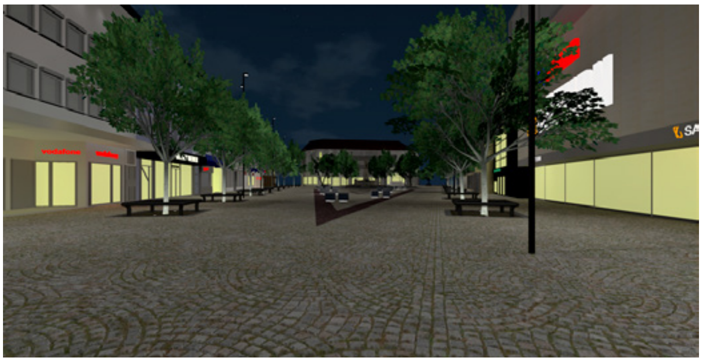

Fig. 26: Variant 4.1 Central with SUPERSYSTEM outdoor 100%, façades 6.5%, trees 20%, seating cubes 40%, fountain 0%

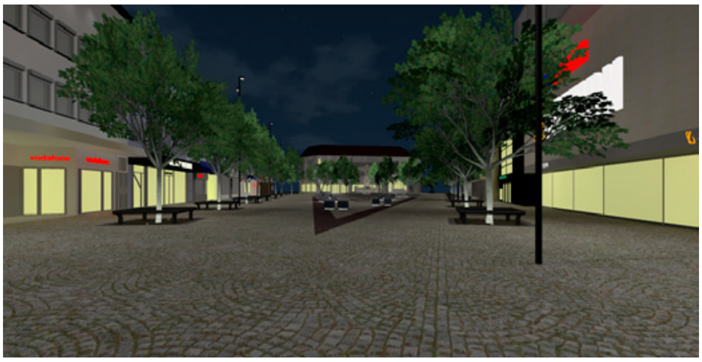

Fig. 27: Variant 4.2 Central with SUPERSYSTEM outdoor 100%, façades 6.5%, trees 20%, seating cubes 40%, only Bismarck

Fig. 28: Variant 5.1 Central with Nightsight lengthways, façades 6.5%, trees 20%, seating cubes 20%, fountain 50%)

Fig. 29: Variant 1.1 Side with SUPERSYSTEM outdoor 100%, façades 6.5%, trees 20%, seating cubes 40%, fountain 50%

Fig. 30: Variant 1.2 Side with SUPERSYSTEM outdoor 100%, façades 30%, trees 20%, seating cubes 40%, fountain 50%

Fig. 31: Variant 4.1 Side with SUPERSYSTEM outdoor 100%, façades 30%, trees 20%, seating cubes 40%, fountain 0%

Fig. 32: Variant 4.2 Side with SUPERSYSTEM outdoor 100%, façades 30%, trees 20%, seating cubes 40%, only Bismarck

Fig. 33: Variant 5.1 Side with Nightsight lengthways, façades 6.5%, trees 20%, seating cubes 40%, fountain 50%

Fig. 34: Variant 5.2 Side with complete Nightsight , façades 6.5%, trees 20%, seating cubes 40%, fountain 50%

Fig. 35: Variant 1.1 Fountain with SUPERSYSTEM outdoor, façades 6.5%, trees 20%, seating cubes 40%, fountain 50%

Fig. 36: Variant 1.2 Fountain with SUPERSYSTEM outdoor, façades 30%, trees 20%, seating cubes 40%, fountain 50%

Fig. 37: Variant 4.1 Fountain with SUPERSYSTEM outdoor, façades 6.5%, trees 20%, seating cubes 40%, only Bismarck

Fig. 38: Variant 4.3 Fountain with SUPERSYSTEM outdoor, façades 6.5%, trees 20%, seating cubes 40%, face of Bismarck beautifully staged

Fig. 39: Variant 5.2 Fountain with complete Nightsight, façades 6.5%, trees 20%, seating cubes 40%, fountain 50%

4.2. Results of main test

4.2.1 Test series 2: adjective pair relaxing – stimulating

For the adjective pair relaxing – stimulating, variant 1.2 Central appeared particularly stimulating, see Fig. 40. For the variant, the illumination of façades was set at 30% rather than the usual 6.5%. Variant 4.2 (only the statue of Bismarck is illuminated in the situation) appeared particularly relaxing. If you consider the differentiated results of the lighting experts in comparison to the laymen, similar statements arise.

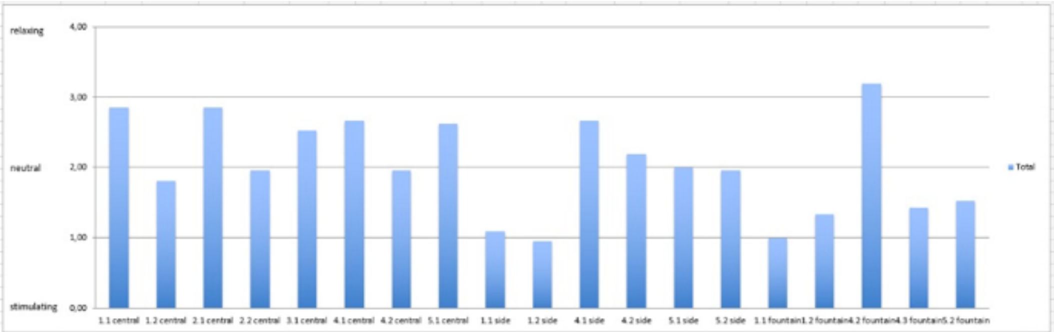

Fig. 40: Result for adjective pair relaxing – stimulating across all 19 variants

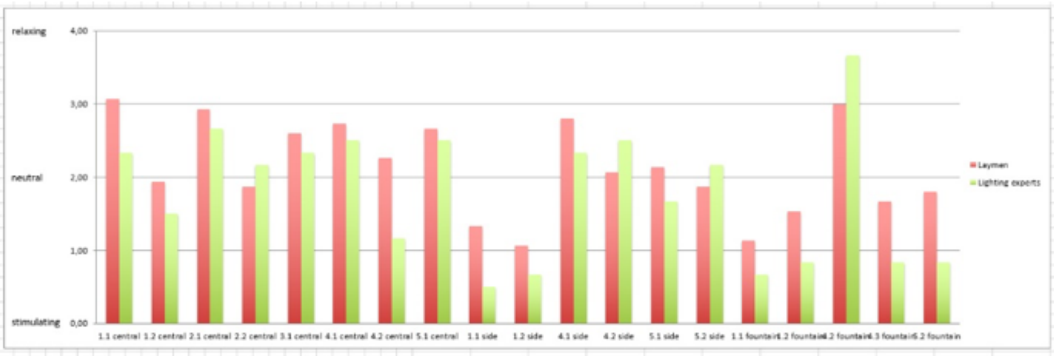

Fig. 41: Result for adjective pair relaxing – stimulating listed according to laymen and lighting experts

4.2.2 Test series 2: adjective pair friendly – unfriendly

For the adjective pair friendly – unfriendly, variant 4.1 Side (of the fountain) appeared particularly unfriendly. All of the test subjects found the unlit fountain to be unfriendly.

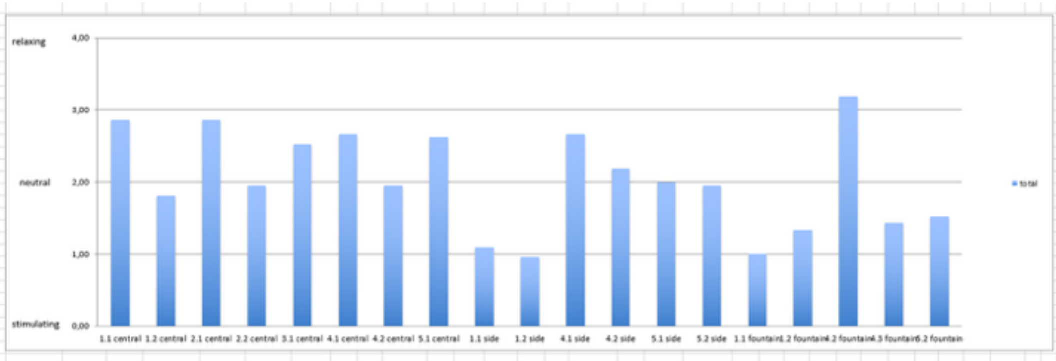

Fig. 42: Result for adjective pair friendly – unfriendly across all 19 variants

4.2.3 Test series 2: adjective pair light – dark

For the adjective pair light – dark, variant 4.1 Side (of the fountain) appeared particularly dark. From this result, you can clearly see that the unlit fountain was assessed as being too dark by all test subjects.

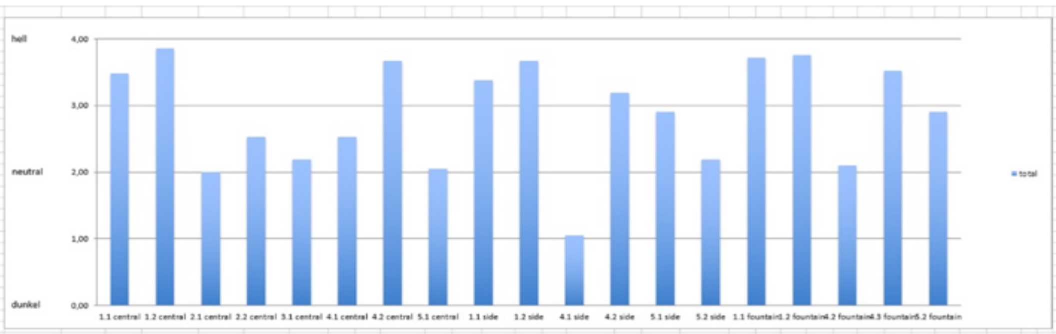

Fig. 43: Result for adjective pair light – dark across all 19 variants

4.2.4 Comparison of all adjective pairs across all central perspectives

The results of all eight central perspectives are shown in Fig. 44. You can see that the test subjects evaluate the individual lighting situations very differently. The individual evaluations are listed below in more detail.

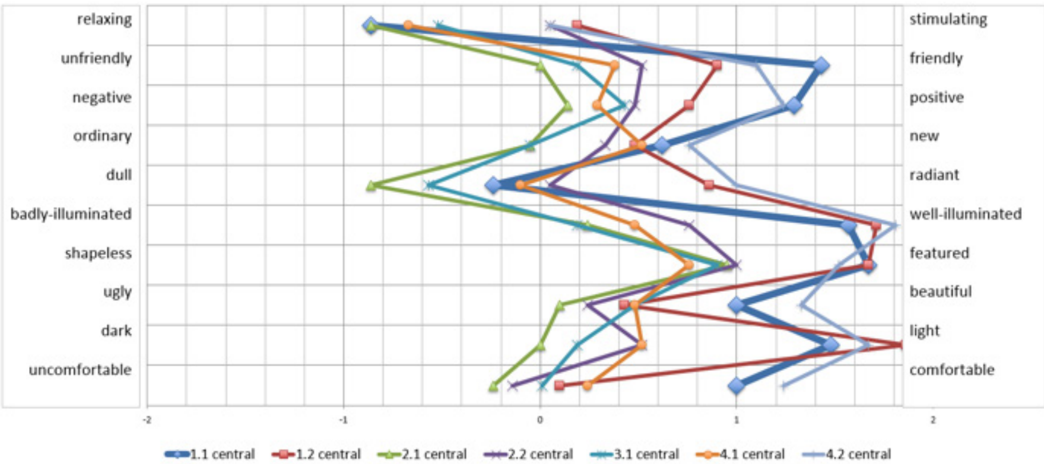

Fig. 44: Results for all adjective pairs of variant 1.1 Central vs. 1.2 / 2.1 / 2.2 / 3.1 / 4.1 / 4.2 Central

4.2.5 Variant 1.1 Central (SUPERSYSTEM outdoor) vs. 5.1 Central (Nightsight lengthways)

Fig. 44 shows the result of variant 1.1 Central (SUPERSYSTEM outdoor) vs. 5.1 Central (Nightsight lengthways). As you can see, there is no major difference between the SUPERSYSTEM outdoor lighting system and Nightsight except for one marked difference. The Nightsight system is considered considerably darker. Fig. 46 shows the results with standard deviation. Here you can see a clear significance in the case of the adjective pair (light – dark).

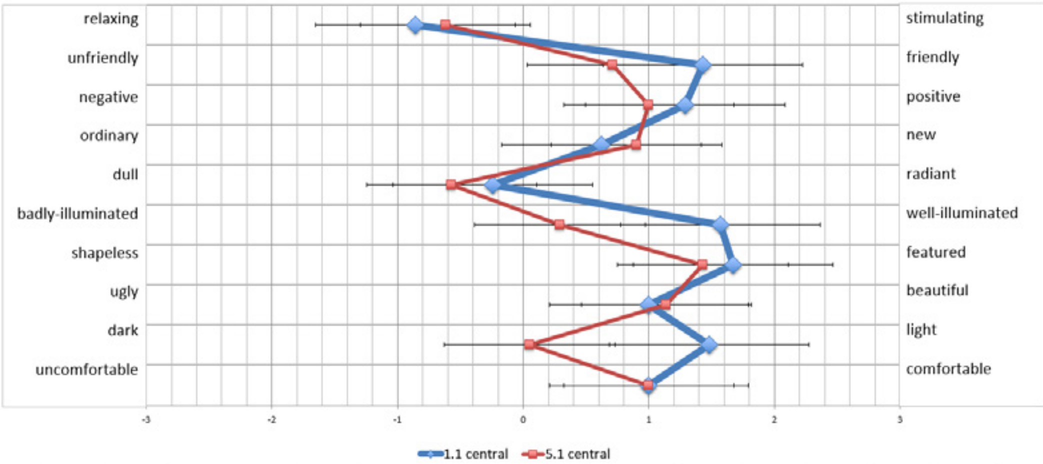

Fig. 45: Result of variant 1.1 Central (SUPERSYSTEM outdoor) vs. 5.1 Central (Nightsight lengthways)

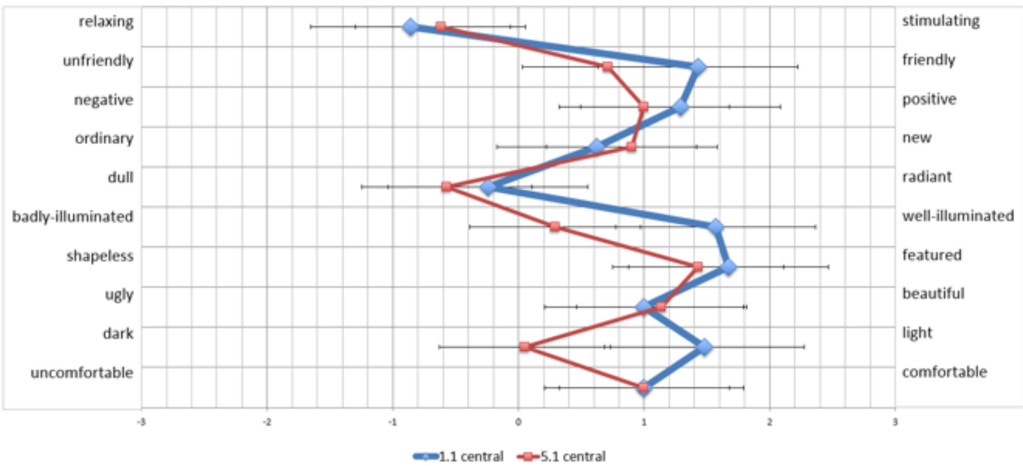

Fig. 46: Result of variant 1.1 Central (SUPERSYSTEM outdoor) vs. 5.1 Central (Nightsight lengthways) with standard deviation

4.2.6 Variant 1.1 Central (6.5% façades) vs. 1.2 Central (30% façades)

Fig. 47 shows the result of a lightly illuminated façade versus a relatively bright façade. Variant 1.1 Central (6.5% façades) vs. 1.2 Central (30% façades). As you can see, the bright façade (1.2 Central) is evaluated as light, yet appears uncomfortable. This means that, on the one hand, the very bright façade illumination is stimulating for the test subjects due to the high vertical lighting but is simultaneously uncomfortable. Thus, the quality of time spent would be very low in this case. People would walk across the square but would certainly not linger.

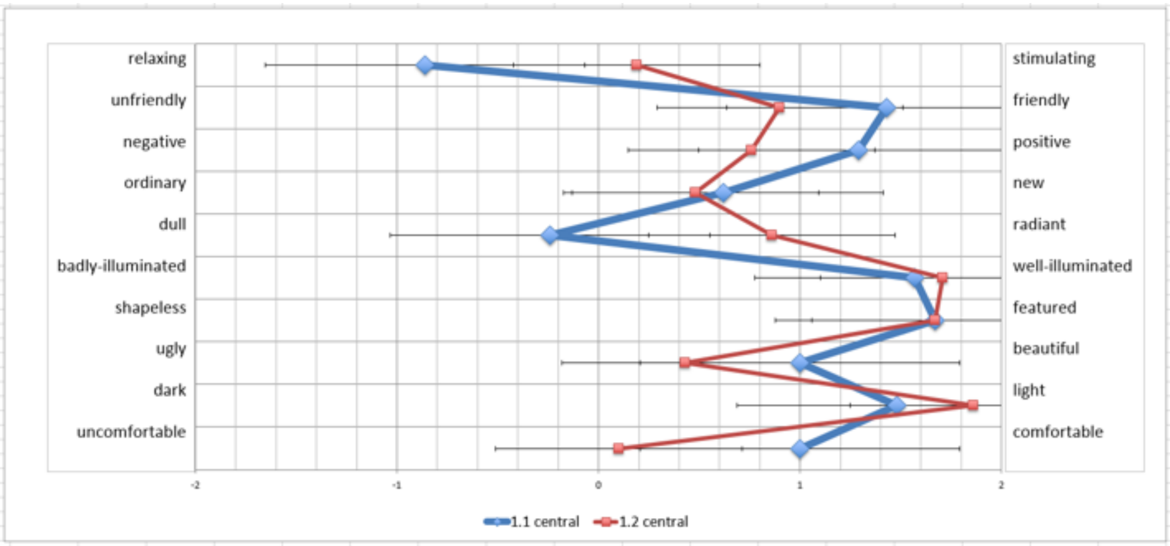

Fig. 47: Variant 1.1 Central (6.5% façades) vs. 1.2 Central (30% façades)

4.2.7 Variant 1.1 Central vs. 2.1 Central (trees 0%) vs. 2.2 Central (trees at the side 20%)

The result of variant 1.1 Central (trees 20%) vs. 2.1 Central (trees 0%) vs. 2.2 Central (trees at the side 20%) is shown in Fig. 48. This compares how strongly the illumination of the trees and tree trunks effects the evaluation. For variant 2.2 Central, the trees were not illuminated from below but from the side. As you can see, 2.1 Central (trees 0%), shown here as the green curve, are evaluated negatively. This means that the majority of test subjects consider the illumination of the trees in the square and, above all, the visibility of the tree trunks, as friendly, positive, featured and bright.

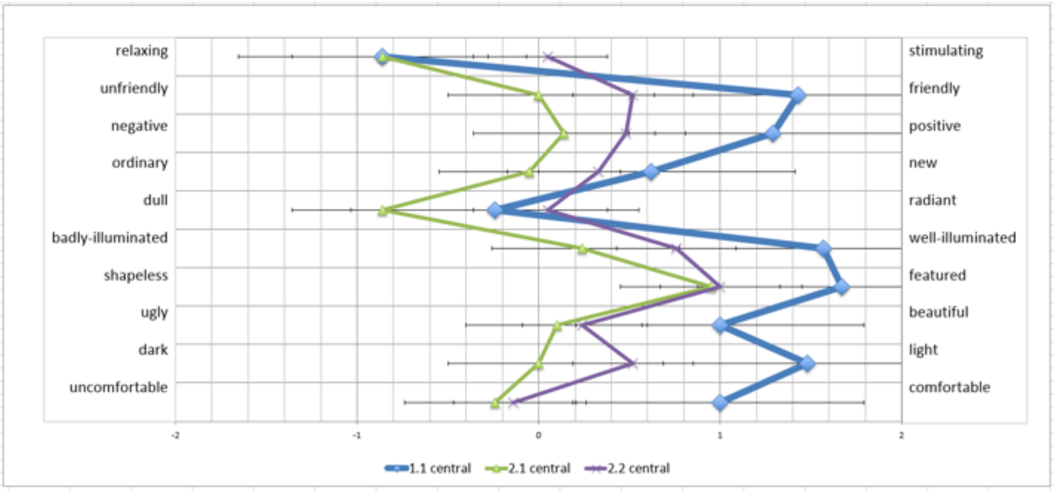

Fig. 48: Variant 1.1 Central vs. 2.1 Central (trees 0%) vs. 2.2 Central (trees at the side 20%)

4.2.8 Variant 1.1 Central vs. 3.1 Central (seating cubes 0%)

Fig. 49 shows the result of variant 1.1 Central (seating cubes 50%) vs. 3.1 Central (seating cubes 0%). As you can see, variant 3.1 Central, in which the seating cubes are not illuminated, is generally considered negatively.

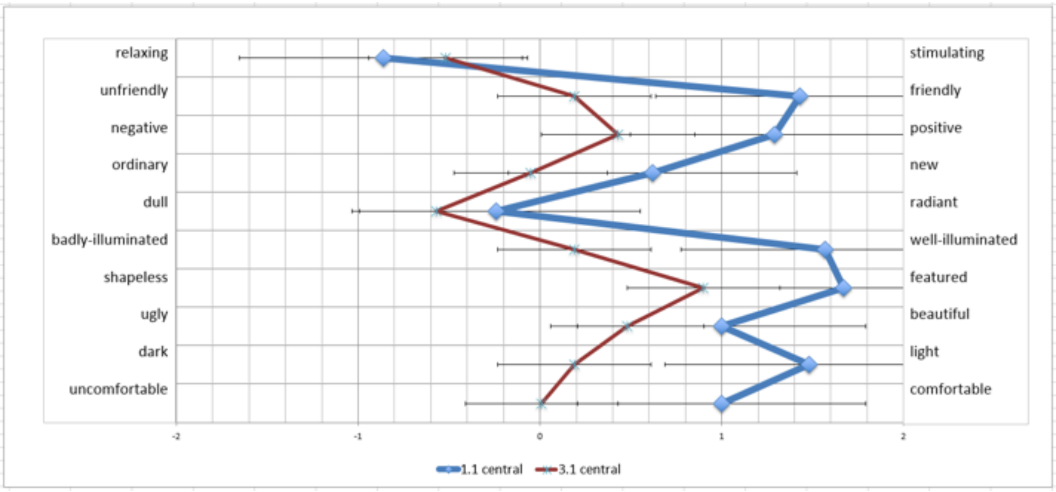

Fig. 49: Variant 1.1 Central vs. 3.1 Central (seating cubes 0%)

4.2.9 Variant 1.1 Side vs. 5.1 Side (Nightsight lengthways) vs. 5.2 Side (complete Nightsight)

Fig. 50 shows the result of variant 1.1 Side (SUPERSYSTEM outdoor) vs. 5.1 Side (Nightsight lengthways) vs. 5.2 Side (complete Nightsight). The results represent the illumination of the square in three different lighting situations. The perspective is directed at the square and the fountain. For variant 1.1, the entire square is illuminated with the SUPERSYSTEM outdoor system. For variant 5.1, illumination along the façades of the houses is provided by the Nightsight lighting system and the SUPERSYSTEM outdoor lighting system was, once again, used to illuminate the area around the fountain. For variant 5.2, all of the light comes from the Nightsight system. As you can see from the evaluations of the test subjects, variant 5.2 Side (complete Nightsight), the green curve, is evaluated negatively. This lighting does not appear well due to the uneven lighting and rather sporadic illumination.

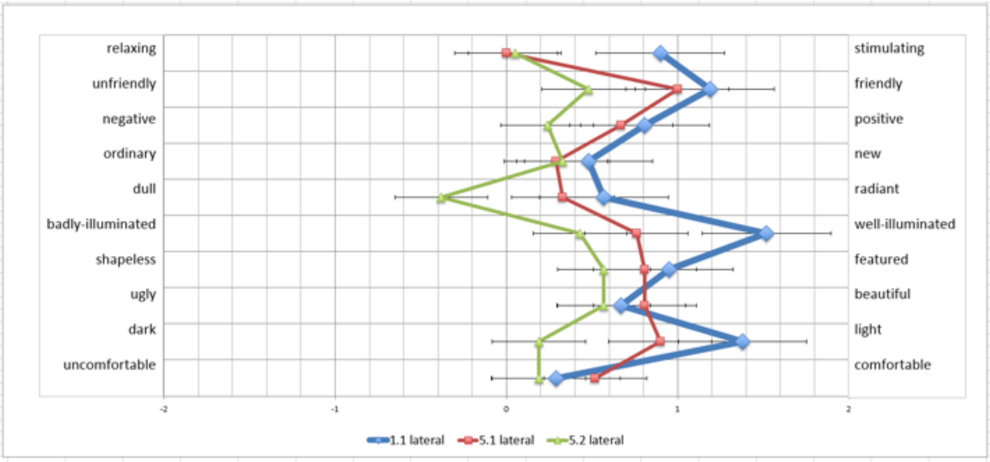

Fig. 50: Variant 1.1 Side vs. 5.1 Side (Nightsight lengthways) vs. 5.2 Side (complete Nightsight)

4.3 Evaluation of lighting systems

Fig. 51 presents the overall result of the questioning on the lighting systems. As you can see, variants 1.1 Central, 1.2 Central (30% façades), 4.2 Central (only Bismarck) and 4.2 Side are evaluated positively. A similar conclusion can be drawn for the arrangement of the lights as well as the visible brightening. Pylon and light height make no major difference, see Fig. 52.

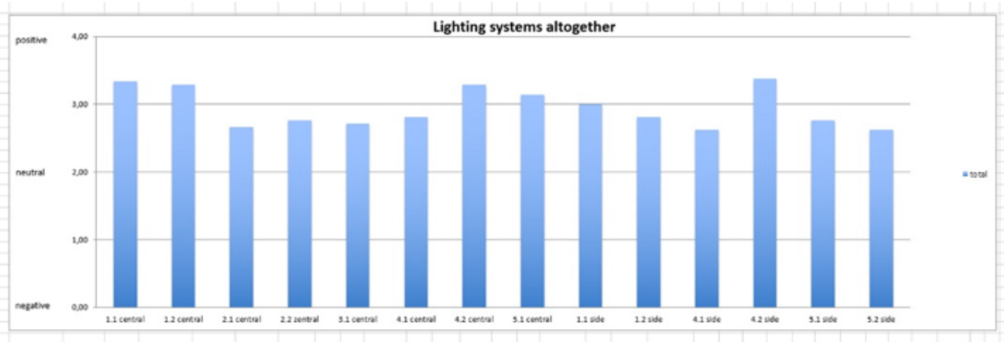

Fig. 51: Overall evaluation of lighting systems

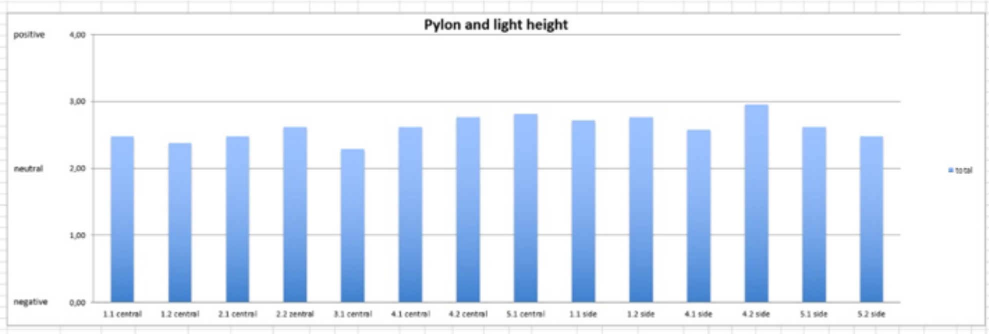

Fig. 52: Evaluation of the pylon and light heights

4.4 Test subject comments

The following are a few comments made by test subjects.

What do you find particularly positive?

- "The lights look good"
- "The fountain is featured beautifully"
- "No neon signs"
- "Everything clearly visible"
- "Trees look beautiful"

What do you find negative?

- "Pools of light too bright"
- "Not enough places to sit" (mentioned multiple times)
- "Illuminated seating cubes" unnecessary (mentioned multiple times)
- When the tree lighting was turned off, multiple verbal complaints were made.

Multiple mentions

- Everything recognisable
- Lights well chosen
- Effect on light on trees and green areas
- Good accents
- Beautiful contrasts
- Psychological evaluations such as "square appears large and sympathetic"
- Multiple positive mentions of the "illumination of the façades"
- Changes in the brightness of the façades was noticed immediately by 19 of the 21 test subjects
- Neon signs were a topic
- Lots of negative opinions without fountain and tree lighting
- Only 7 test subjects realised immediately when only the statue was illuminated in the fountain

4.5 Questions on virtual reality and immersion

At the end of the test, in order to find out how immersive the test subjects experienced the situation with the VR glasses, seven questions were asked on the use of virtual reality. As you can see from the results, the majority of test subjects felt the following: “In the simulation, I thought I was actually there and nowhere else”. And a large proportion stated that: “The simulation was comparable to reality”. This shows that the evaluation of lighting situations is possible with the help of VR glasses and that there is major potential for the selection of lighting situations.

Implementation of virtual reality

		not at all	a bit	moderate	considerable	much
1.	The simulation was comparable to reality.	1	2	8	8	0
2.	I felt like being in reality during the simulation.	0	7	5	4	0
3.	Remembering the simulation is comparable to remembering the real location.	1	4	2	2	2
4.	In the simulation, I thought I was actually there and nowhere else.	2	2	10	2	1
5.	I think, the location in the simulation was comparable to the location in reality.	0	4	5	1	1
6.	During the simulation, most of the time I thought, I was in reality.	2	4	7	1	1
7.	What is beneficial for the impression of being in reality during the simulation and what is not?					

Fig. 53: Responses on virtual reality and immersion

4.6 Questions on motion sickness

However, since VR glasses also cause the problem of motion sickness during use for some people due to the head and movement sensors in the body sending different signals to the brain, fourteen questions were asked at the end of the test concerning symptoms of motion sickness. As you can see from the results, the overwhelming majority of test subjects had no problem with motion sickness and were not bothered during the test while using the Oculus Rift headset.

How severe are the following symptoms at the moment?

		not at all	a bit	moderate	considerable	much
1.	overstrained eyes	4	5	3	3	0
2.	problems with visual acuity	2	10	3	1	0
3.	increased salivation	19	0	0	1	0
4.	sweating	19	4	1	0	0
5.	nausea/vomiting	19	1	0	0	1
6.	difficulty in concentration	1	10	5	0	1
7.	feeling of pressure in the head region	5	8	3	5	0
8.	blurred vision	4	8	1	2	0
9.	dizziness with open eyes	19	6	0	1	0
10.	dizziness with closed eyes	18	3	3	0	0
11.	disturbances of equilibrium	20	1	1	1	0
12.	stomach trouble	20	0	1	0	0
13.	eructation	21	2	0	0	0
14.	headache	8	5	2	1	0

Fig. 54: Responses on motion sickness

5. Summary

5.1 Results – methodology

Lighting situations are able to be evaluated in detail with the help of VR simulations. Lighting experts are able to analyse a VR simulation in more detail but an alternative psychological evaluation of the lighting situations could not be ascertained in this series of tests. This means that VR simulations allow for comparisons of different lighting systems.

5.2 Results – evaluation of lighting systems

It is possible to plan the residential quality of a location and thus to predict it. Lighting quality and good lighting technology are immediately perceived by the test subjects. Simple lighting solutions have worse psychological evaluations. The surfaces and objects that are visible and important during the day, should also remain discernible in the darkness.

This is how we preserve the identity of a place. Environmental psychologists refer to this as a setting. It concerns the objective, physical environment of an acting person and the personal evaluation of their actions in the given context. Ludwigsplatz in Darmstadt is not a prominent location in the city. It is no landmark or monument. The same applies for the Bismarck monument. Standing in Ludwigsplatz, many people mistake the person depicted by the monument for the Grand Duke Ernst Ludwig, the founder of the Jugendstil artist's colony.

There are countless squares like this one in Germany. You take the following approach to lighting design thinking that it could be a prototype for many similar problems. It began with the term papers of over 20 students systematically discussing space and the effect of the night.

The square should have all of the psychological qualities of a room in the evening and at night. This room should be differentiated and this differentiation should be directly communicated to the beholder.
The subjective, psychological evaluation of the place should be bright, visually clear and unambiguous.

The differentiation can take place with light and, consequently, adjustments in brightness. The adjustments in brightness all have a materiality, which doesn't mean that you work graphically with lighting structures, for example, but rather that surfaces and objects are illuminated that are present during the day and that characterise the place. A hierarchy of perception should be determined with regards to importance and value. In this test, it was:

- Basic brightness of the location
- Brightness of façades
- Brightness of the Bismarck monument and its immediate surroundings
- Brightness of trees
- Brightness of seating cubes

Generally speaking, we believe that in places like Bismarckplatz in Darmstadt, the perceptual expectations for artistic lighting are rather classically conservative e.g. tree lighting via classic uplights in the floor.

In order to adjust the amount of light and the distinctiveness of the surfaces and objects, light density models are a relatively simple method of differentiating the effects of brightness. Light density is the product of the impinging amount of light (lux) and the degree of reflection of the surface of the object divided by Pi.

The average degree of reflection of all visible surfaces within the field of view of an observer is approx. 30% and the average light intensity of the illuminated surfaces and objects is approx. 15 lux. Taking into account the brightness of the sky in the field of view (approx. 0.2 cd/m²), there is an adaptive luminance of the visual system of approx. 1 cd/m² for the entire field of view. The light density of individual objects must then be set in relation to the adaptive luminance (L/La).

The standard brightness chosen for the illuminated façades (1 – 3 cd/m²) was lower than that of the square (3 – 5 cd/m²). This is a necessary condition to even make the square seem bright at all.

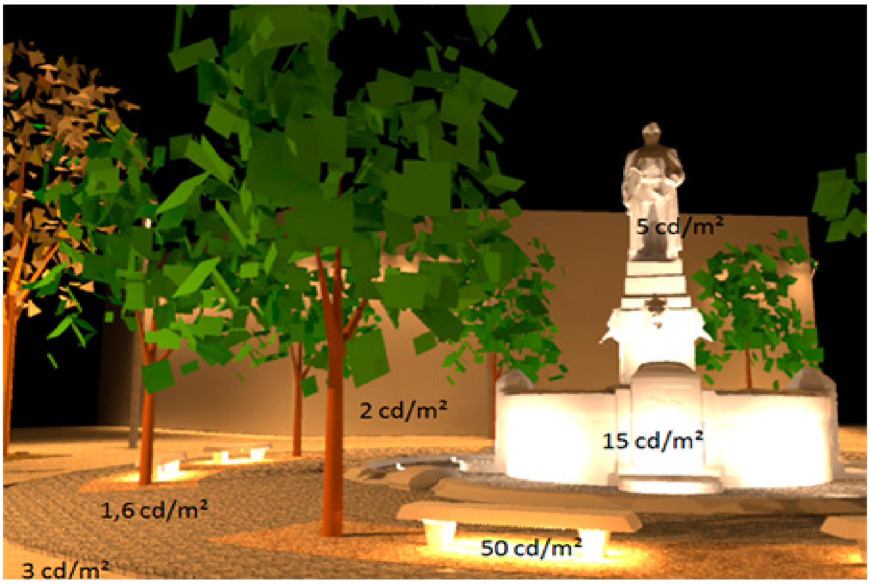

Fig. 55: Light density distribution of the Bismarck fountain and its surroundings (source: Roland Greule)

The Bismarck monument is the brightest object in the square. The copper panels on the outer sides of the fountain are accentuated with accenting beams. The light density of the vertical surfaces lies between 5 and 10 cd/m² and the copper panels are closely zoned at 15 cd/m². These are highlights of the whole scenery. The trees in the basic variant have a light density of 2-4 cd/m². The light zoning is located on the sides of the tree trunks.

The visible surfaces of the seating cubes are illuminated by the pylon lights but their pedestals are accentuated by an indirect beam of light coming from the floor. This is a clearly visible accent with a narrow light density value of up to 50 cd/m². This is also a matter of highlighting.

The following diagram (Fig. 56) shows the abovementioned sequence or hierarchy of brightness allocations. There are no surfaces relevant to psychological perception or any significant objects in areas of darkness or “dark shadows”. All of the surfaces and objects relevant to the brightness recommendation are in the “bright” transitional zone above the adaptive luminance but do not blind. The deliberately set highlights cast light but do not lead to an adaptive blinding. This would be the case if the light density were to be above 100 cd/m².

The light planning and selection of the arrangement of the lighting systems systematically made it impossible to look at the lights directly.

Ludwigsplatz Darmstadt

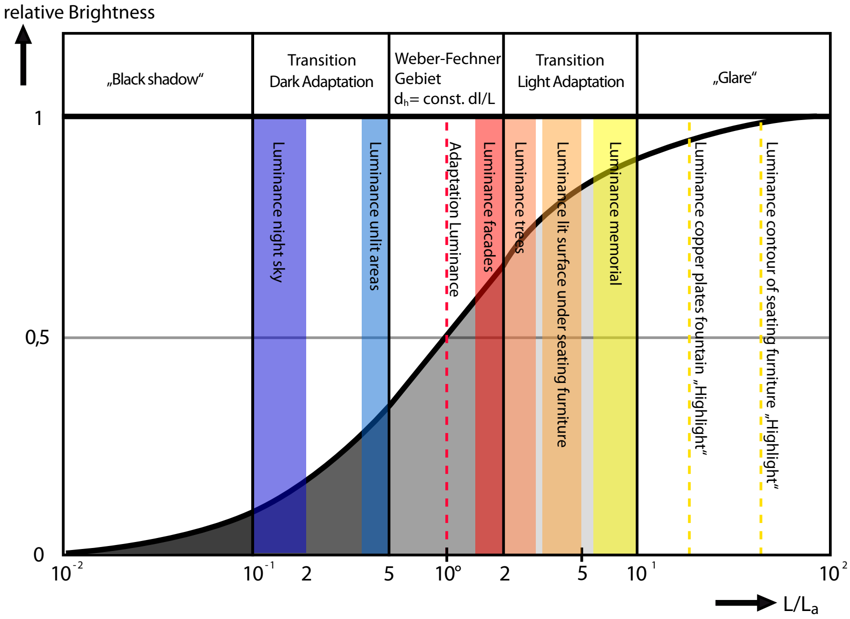

Fig. 56: Effects of brightness on object light densities (L) in relation to adaptive luminance (La) (source: Torsten Braun)

The result of the test and its alternative design possibilities in terms of façade brightness, illumination of trees, seating furniture and monuments, show that the unambiguity and clarity of the creative intent is expedient for an appropriate appearance and its value. The level of detail of individual lighting solutions should not be overstated. In this case, this applied to the Bismarck monument. A highly differentiated illumination of the statue was perceived but not valued.

6. Next steps / tests

6.1. Test set-up: Technical further development

Adjustment of the different lighting situations by the test subjects.
Active exploration of the scenery with recorded eye tracking.

6.2. Lighting research: Photometric-psychological elaboration

Field tests: Validation of the determined selection of lights, arrangement of lights and light densities of the surfaces and objects through 1:1 samplings and surveys.

Henstedt-Ulzburg, Germany 22/01/2017
Limburg an der Lahn, Germany, 22/01/2017

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Graduate psychologist Torsten Braun