

# VR & Neurofeedback

## Towards an inclusive city



## Introduction

The Olifantenpad Consortium is a collaboration between outdoor designers, lighting designers, VR and neurofeedback experts, and an urban psychologist. What unites and drives us is:

- » A keen interest in a **different role for city residents** in the spatial design process.
- » The **use of technology and psychology** to support the spatial design process.

Together, we are shaping a new, different kind of process and experimenting with this process in various configurations in our projects. We consciously use technology in this process.

The Municipality of Eindhoven asked us to design lighting scenarios for the city center. This was the first time we combined VR and neurofeedback in practice to measure people's conscious and subconscious responses to the various designs.

In the following section, we explain this method and draw conclusions.



**PROPOSITION:** The traditional role and way of working of urban designers is changing. We want to leave behind the era of well-intentioned drawing board plans and unintentional “elephant trails”. We no longer try to offer a comprehensive design solution, but instead want to support city residents in making sound choices for their own environment.

*"....In short, designing the female half of the world out of our public spaces is not a matter of resources. It's a matter of priorities, and, currently, whether unthinkingly or not, we just aren't prioritizing women. This is manifestly unjust, and economically illiterate. Women have an equal right to public resources: we must stop excluding them by design."*

**-INVISIBLE WOMEN, Data bias in a world designed for men - Caroline Criado Perez**



<----- Biking Tunnel Eindhoven

## Inclusivity and Spatial design

We want to design and furnish public spaces so that they are accessible to all users and everybody will feel comfortable and safe there. This isn't easy; a young man of 1.90m might experience space differently than a Turkish grandmother. To design a truly inclusive public space, the designer needs input from as broad a group of future users as possible. This involves encountering several obstacles:

- » A spatial designer, in a sense, has a **professional deformity**. Their own training and experience cause them to experience space differently. Even the least arrogant, most empathetic designer can't completely avoid this phenomenon.
- » **Participatory projects** yield little inclusive input that is useful for designers. It's beyond the scope of this article to delve further into the current practice of participation in spatial design, but we dare say that useful information is rarely generated in this area.
- » **Spatial experience is largely subconscious**. The presence of greenery and the city lighting, for example, are very important aspects when it comes to spatial experience, but when you ask residents about this, it quickly becomes clear that they're not that aware of it. They know whether they feel safe, comfortable, or uncomfortable, but they struggle to explain why they feel that way. This becomes even more difficult when you ask them to imagine this in a design that hasn't yet been built.

**How can we then achieve a truly inclusive design?**

## Technology and psychology

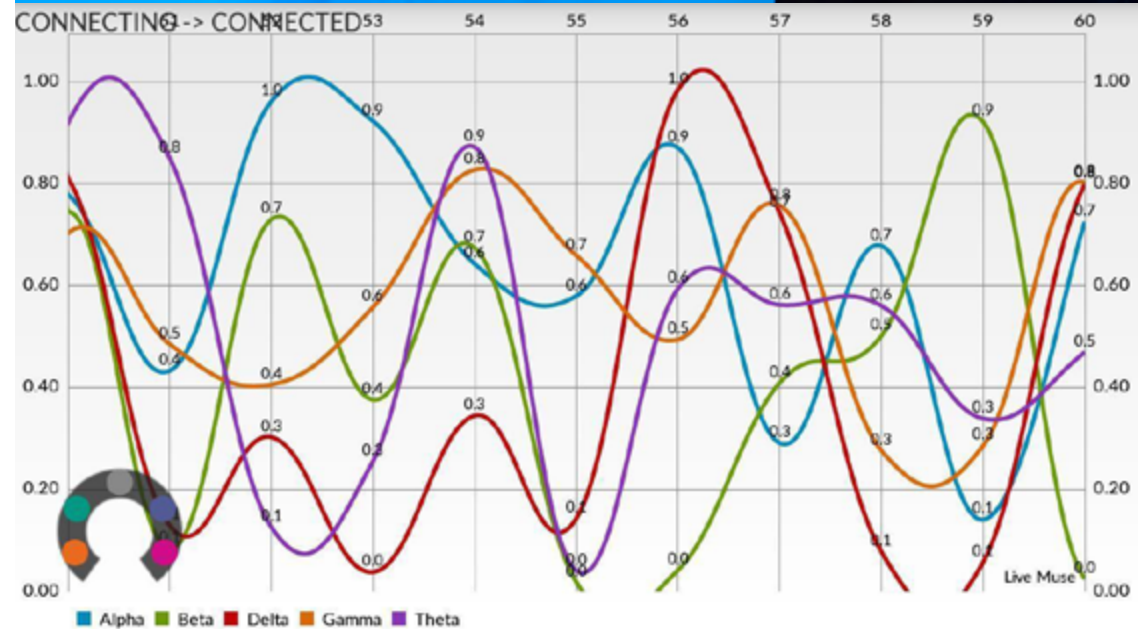
The members of the Olifantenpad Consortium are developing a tool that allows designers to measure both conscious and subconscious responses to spatial designs. This tool utilizes a combination of new technologies (VR, AI, and Neurofeedback) and psychology.

### Virtual Reality

We see virtual reality as the ideal test environment for urban interventions or spatial research. A key element of a successful test environment is that the parameters for all test subjects are as identical as possible. Only then can you compare their responses. This is easy (and inexpensive) to achieve with VR. Another major advantage of VR is that, unlike working with drawings, you don't need spatial awareness to understand it. You feel like you're actually there. We know from experience that the immersiveness of this technology is so great that visitors to the virtual environment get a realistic impression of the design.

### Neurofeedback, AI and psychology

Although everyone's brainwaves are unique, neurofeedback allows us to "read" when people feel comfortable, activated, relaxed, or unsafe. Correctly interpreting these responses is essential and has been studied by us during various tests by questioning the test subjects in addition to measuring their brainwaves. To filter out the responses essential for spatial perception, we have developed algorithms that emphasize certain brainwaves based on these tests and conclusions.



^ output neurofeedback



## Lighting scenarios in the city center of Eindhoven

After several experiments, including “The Light Cathedral” during GLOW 2019, where we measured the reactions of hundreds of people using neurofeedback, we were given the opportunity to put our tool to the test in a new project: designing new lighting for Eindhoven’s city center.

We used VR and neurofeedback to test various lighting scenarios with groups of Eindhoven residents, with the goal of selecting the lighting scenarios with which most people felt comfortable. We distinguished between Rechtestraat and Stratumseind. The former is a shopping street that is empty and closed in the evening, while the latter is located in the entertainment district and only comes alive after dark.

The following text discusses this research and its results.

<----- Prototype ILSE on Stratumseind

## Co-designing lighting experiences with VR, neurofeedback and psychological research

Democratization within urban development is about participation, engagement, and decision-making. For lighting design, this requires an innovative approach. For the simple reason that people’s awareness of light in public spaces often doesn’t go beyond the perception of too much or too little light. How can residents and users then meaningfully participate in discussions and decisions about lighting design? To develop new lighting scenarios for Eindhoven’s city center, we developed a combined approach consisting of Virtual Reality (VR), neurofeedback, and psychological survey research and interviews.

### Subconscious experience of light requires a mixed-method research process

Light contributes significantly to a pleasant experience of the environment. Because the experience of light is largely subconscious, lighting designers face a complex challenge. How do you question people about something that is subconscious? And how do you take into account that public spaces belong to everyone and are used by a huge diversity of people? When the experience of light might depend on factors such as age, gender, culture, and so on?

Simply questioning people with a survey, f.e., has limitations. It quickly leads to rationalization of subconscious behavior and socially desirable answers, making it difficult to determine what is “true.” Investigating unconscious experiences, such as the experience of light, requires a mixed-methods approach. We developed such an approach for the Eindhoven’s city center.



<----- Stratumseind

For the municipality of Eindhoven, we investigated lighting scenarios for the new Intelligent Lighting System (ILSE) in the city center. We combined four research methods into a single research process and invited professionals and residents to participate. Participants were first given VR glasses and a headband to measure brainwaves (Muse Headband) upon arrival. In the VR environment, participants were presented with seven lighting scenarios on two different streets. Neurofeedback data was collected while participants looked around. After the VR experience, participants completed a questionnaire in which they rated the same lighting scenarios again on the extent to which they evoked relaxation, alertness, or anxiety. In an interview with an environmental psychologist, the participants discussed and interpreted their assessments. Attention was paid to influences and assumptions from personal, social, and cultural contexts.

This research process ensured that all participants experienced the exact same experience. This allowed for better comparison and interpretation of the test results. The lighting designer plays a key role in this process. At the front end, when determining the lighting scenarios to be investigated, and at the back end by translating the research results into definitive lighting scenarios.

### **Lighting the street in five zones**

The research conducted in Eindhoven's city center with residents and professionals offers several useful insights into lighting design. The main conclusion was that illuminating specific sections of the street is crucial. Lighting scenarios where the facades were illuminated were considered the most relaxing. When the facade lighting was switched off, participants consistently felt alert and anxious. The areas in front of the facades and the pedestrian and bicycle paths also required their own lighting.



#### <----- Scenarios Rechtestraat

Based on the results, the street can be divided into five zones (facade, sidewalk, street, sidewalk, and facade). Illuminating the facade proved essential for a pleasant street experience. Participants in the study felt safer because it reduced or eliminated dark areas on the street and allowed them to see faces more clearly. This was surprising, as public lighting generally doesn't focus on the facade. Participants often opted for lighting scenarios with warmer light, believing this created a more atmospheric atmosphere.

### **Difference between women and men in perception**

For women, public spaces are often more unpleasant in the dark. In the Eindhoven study, we clearly saw this difference between women's and men's experiences. Both experienced scenarios in which facade lighting is turned off, the least pleasant, but women find this more unpleasant than men. The main reason could be that we have more difficulty seeing others in the dark and reading their faces in that situation. We can deduce from this that women feel they have to be much more alert in the dark and in situations with poor lighting (read: dark places) are more likely to experience anxiety. For the men in the study, the mere presence of others was enough to induce relaxation.

We also tested a scenario with red light, the new nature-inclusive lighting. Women, in particular, felt significantly less relaxed in this scenario than men. In the interviews, women mentioned having unpleasant associations with red lights (associating them with a red-light district that's hostile to women), which made them more alert.

In summary: the research findings show that there are differences between how women and men experience lighting. An attractive public space at night where women feel comfortable requires good and varied lighting. Current public lighting almost always falls short in this regard.



## Residents experience light differently than spatial professionals

To say that a professional experiences light differently than a resident is a strange observation. After all, a professional is also a resident when they're at home. And yet, this study led to this (tentative) conclusion. The professionals involved in Eindhoven's city center experienced the lighting scenarios in the study differently than people who participated as residents.

Professionals made different considerations than those not involved. It was striking that professionals experienced alertness sooner than residents. A process of cognitive dissonance seemed to be taking place, with professionals rationalizing their perceptions and paying more attention to the potential "dangers" associated with the lighting scenarios. Professional involvement in an area plays a role in the assessment of the lighting scenarios. We draw a cautious conclusion here because the group of professionals in this study was small. Further research is needed to gain more insight into the differences and their significance for the design of public lighting.

Context is important in this regard, both the context of the location itself, and the point of view of the people in that location. For police and firefighters for example, a lot of light is essential to assess the situation. However, this type of light is highly unpleasant for residents (or visitors to a location). Research into lighting scenarios requires location-specific elements because these naturally interact with perception. The width of a street, a prominent landmark, events, and the color of the street and buildings influence perception, associations, and thus behavior.



<----- Setup during test days

### The participatory value of mixed-method research in lighting design

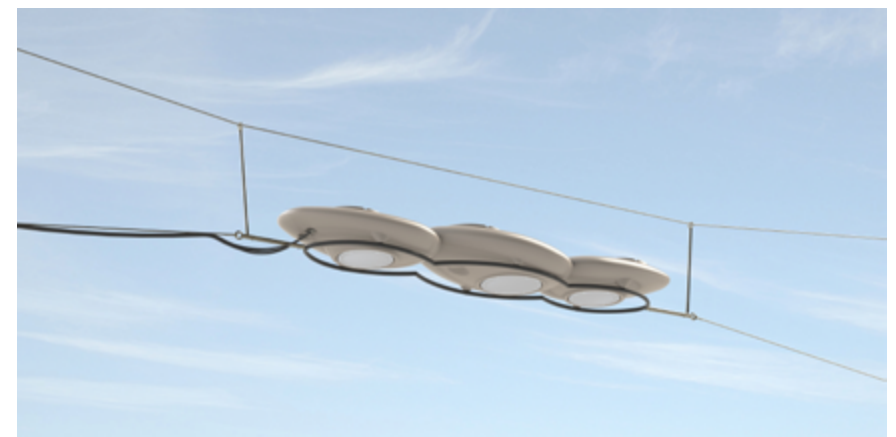
The combination of VR, neurofeedback, survey research, and psychological interviews yields a vast amount of data. Data that can be used to truly understand the experience of public lighting and provide lighting designers with the information they need to develop appropriate lighting scenarios. It appears that the experience of light occurs largely unconsciously. We can therefore cautiously conclude that asking people (e.g., via surveys) about their assessment of light in public spaces is not, in itself, sufficiently reliable to arrive at a sound design for public lighting.

The research approach we followed also has a positive side effect: people value being involved in the development of their city and their streets in this way. This approach can be used in the development and improvement of public spaces, allowing citizens to participate and participate in decision-making (both consciously and unconsciously). We are now taking the next step, enabling people to design their future living environment themselves in a VR environment.

Alert/Beta		26	Mannen 9	Vrouwen 6	Resultaten Interview Alert Algemeen	Resultaten Interview Alert Mannen	Resultaten Interview Alert Vrouwen
User		Gemiddeld	Gemiddeld	Gemiddeld			
Rechtsonder	1. Smalle lichtbundel	3,44	2,87	4,17	3,15	3,07	3,23
	2. Brede lichtbundel	4,11	3,33	5,08	3,22	3,29	3,15
	3. Warm licht	4,56	3,67	5,67	2,81	2,71	2,92
	4. Koud licht	3,74	4,13	3,25	2,78	3,21	2,31
	5. Gevel aan	3,59	3,93	3,17	2,56	2,79	2,31
	6. Gevel uit	3,33	3,40	3,25	3,22	3,07	3,38
	7. Road	3,53	3,56	3,50	2,8	2,89	2,67
Bijzondere	1. Smalle lichtbundel	3,96	3,73	4,25	2,59	2,36	2,85
	2. Brede lichtbundel	3,26	2,73	3,92	2,52	2,43	2,62
	3. Warm licht	3,52	3,40	3,67	2,74	2,79	2,69
	4. Koud licht	3,85	3,47	4,33	2,56	2,79	2,31
	5. Gevel aan	3,52	3,38	3,92	2,78	2,86	2,69
	6. Gevel uit	3,81	3,87	3,75	3,15	3,5	2,77
	7. Road	4,2	5,00	3,00	3,33	3,22	3,5

Neurofeedback  
■ Meest Alert  
■ Minst Alert

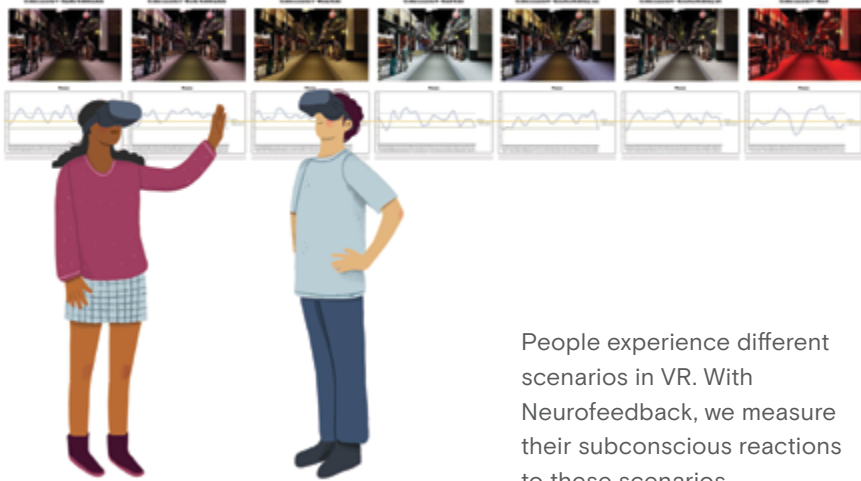
Interview  
■ Meest Alert  
■ Minst Alert



Watch a video about the project [HERE](#).

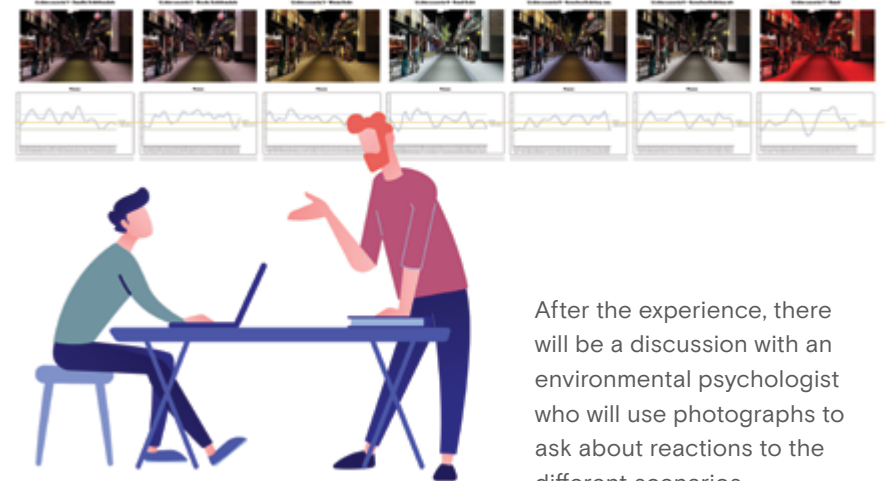
# Hoe werkt het in de praktijk?

## Step 1



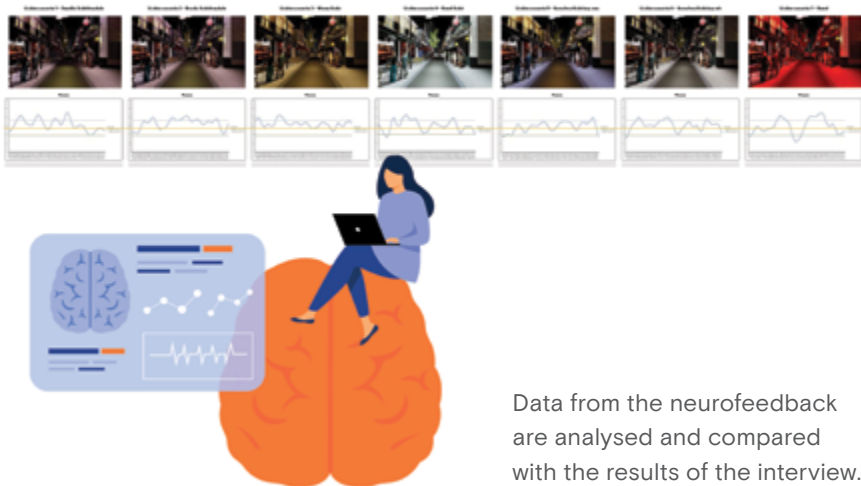
People experience different scenarios in VR. With Neurofeedback, we measure their subconscious reactions to these scenarios.

## Step 2



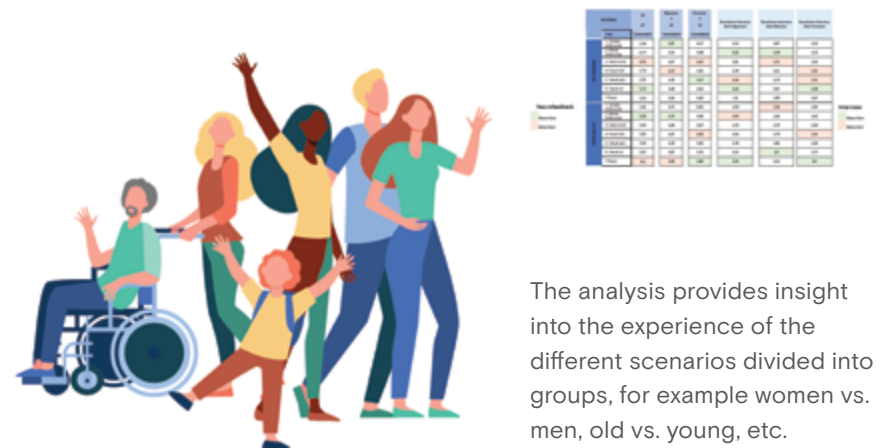
After the experience, there will be a discussion with an environmental psychologist who will use photographs to ask about reactions to the different scenarios.

## Step 3



Data from the neurofeedback are analysed and compared with the results of the interview.

## Step 4



The analysis provides insight into the experience of the different scenarios divided into groups, for example women vs. men, old vs. young, etc.



## Experiences after the Light Project

Based on our experiences, we draw the following conclusions:

- » It's worthwhile to measure the subconscious reactions of different groups of people (in this study, we looked at gender and occupation) to spatial interventions, as there are clear differences in perception.
- » In our view, aspects that are subconsciously experienced, such as lighting and greenery, are better measured using this method than through interviews alone. Our research showed that interview responses sometimes deviated from the measured neurofeedback. We cannot claim that this is due to people giving socially desirable answers, for example, or because they are not as aware of their own feelings. Only the actual reaction is, of course, of interest to spatial designers.
- » It's worthwhile to consider other differences in future research. For example, different cultural backgrounds or age differences could be interesting parameters, depending on the assignment.
- » People find it very interesting to be involved in spatial decisions regarding their own living environment in this way. Therefore, we anticipate no problems finding test subjects for future projects.

## The Future

We believe that measuring people's conscious and subconscious reactions to a spatial design or environment with neurofeedback could become an important tool for spatial designers in the near future. This is particularly interesting because it can lead to a broad understanding of how different groups of people experience the spatial environment. "Smart cities" shouldn't just be about logistics; they should also be about the happiness of city dwellers. We believe the city of the future will be inclusive. Everyone feels safe, comfortable, and engaged.

The technology we propose allows you to directly influence this.

To further develop the method we currently use, into a practical tool that can be easily applied by other spatial designers, more projects need to be conducted, preferably with a broad group of test subjects. This will allow us to fine-tune the algorithms, allowing the method to mature into a useful tool.

For this development, we are looking for partners with projects where inclusivity is a key aspect.



MaMa Producties BV



Het LUXLAB



Thuismakerscollectief



KaiserVR



KRACHTGROEN

## Olifantenpad CS consists of:

### Frederike Manders - VR en Neurofeedback, MaMa Producties BV

A deeply personal, award-winning project ultimately led to a company specialising in Virtual Reality and Neurofeedback. The combination of creativity and technology leads to surprising concepts, driven by the shared desire to make an impact.

[linkedin.com/in/frederikemanders](https://www.linkedin.com/in/frederikemanders)

### Ellen de Vries - Lighting designer, HET LUXLAB

She started as a lighting designer for theater and video productions, but after some experimentation, she moved to Philips Lighting. This led to her developing a personal approach, using light as a design tool to shape spaces and make them more pleasant for people. In 2004, Ellen founded HET LUXLAB, where this approach to lighting takes center stage.

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### Sander van der Ham - Stadspycholoog, Thuismakerscollectief

Sander works as an urban psychologist. His work revolves around the question of how public spaces can contribute to a more pleasant, social, healthy, and happy life. By making subconscious processes visible, he gains insight into the (personal) experience and use of the daily living environment. He works extensively in neighborhoods, where he combines research with participatory processes.

[linkedin.com/in/sandervanderham](https://www.linkedin.com/in/sandervanderham)

### Stijn Kaiser - VR en Architectuur, KaiserVR

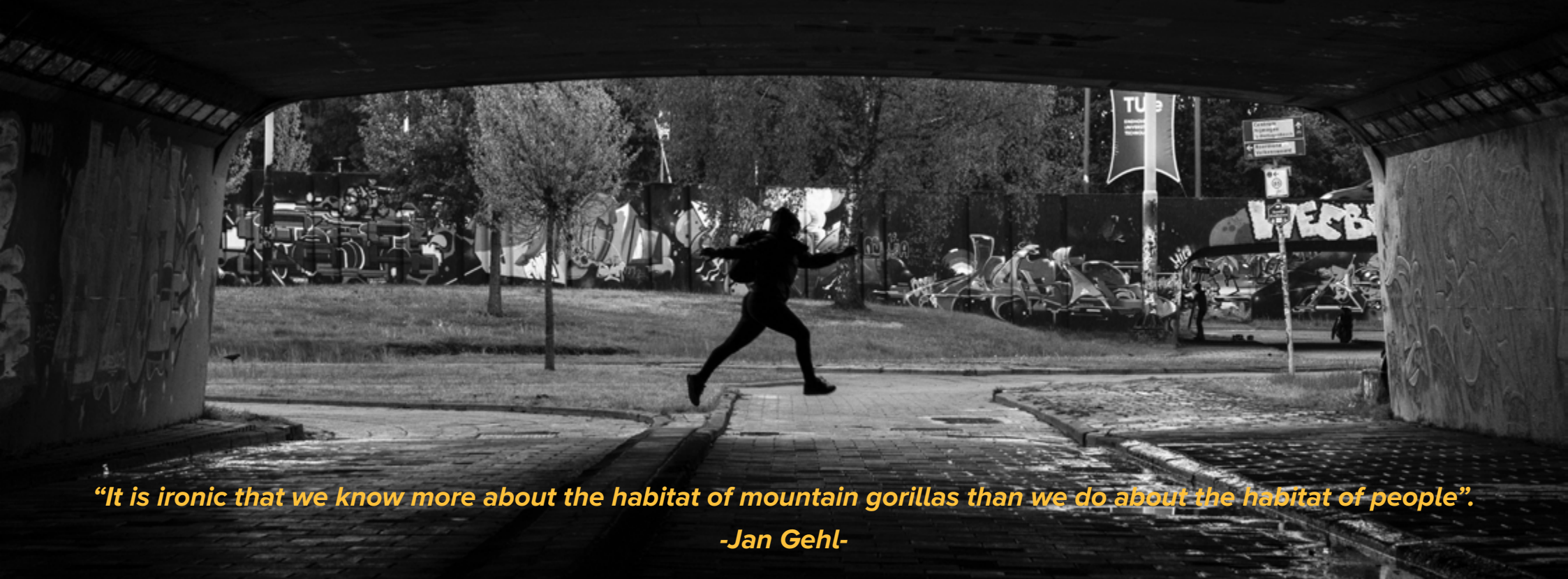
During his Architecture graduation project at Eindhoven University of Technology, Stijn developed a VR tool to help people make design decisions while experiencing the space itself. He has applied this principle to his own company, which focuses on creating interactive visualizations for architecture, urban planning, and the manufacturing industry.

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### Gudule Martens - Architect / Stedenbouwkundige, KRACHTGROEN

After a successful research project on the value of green spaces in cities within the framework of the "Nederland wordt Anders" (The Netherlands will be Different) initiative, she co-founded KRACHTGROEN. Since then, she has conducted numerous projects and studies that develop green initiatives with residents, connect initiatives, and further enrich the city with green spaces.

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*“It is ironic that we know more about the habitat of mountain gorillas than we do about the habitat of people”.*

*-Jan Gehl-*

## Olifantenpad CS

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