THE ACT OF (FUTURE) CYCLING: TESTING URBAN DESIGNS AND CONDUCTING RESEARCH IN VIRTUAL REALITY

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1. CITIES IN TRANSITION AND CYCLING IN VIRTUAL REALITY

Cities currently shift their focus to alternative modes of transportation like walking and cycling for utilitarian as well as recreational displacements through the city. In cities' ambition to develop sustainable, attractive and liveable cities they encounter comprehensive urban design challenges in facilitating these alternative modes of transportation within the limited space available and a society often designed around collective car-use. Stimulating cycling plays a key role in promoting healthy urban living, improving accessibility and creating attractive urban environments with less danger, smell and noise pollution caused by motorized traffic. These ambitions can be reached by downplaying the dominant position of the car as main mode of transportation within cities at short and medium distances. How to achieve such a complex transition is a question frequently asked by researchers and policy makers. Although many changes in urban design are being made to stimulate cycling, there is a structural lack in evaluating the outcomes of these changes. Has the situation improved for cyclists and is there an increase in liveability noticeable for the direct surroundings after the transition of a place to bicycle oriented? Some urban designs proof to be successful for both. However, too often the new situations proves not to be the optimal solution still causing stress to cyclists, exposing them to unsafe situations or creating a boring or unpleasant (bicycle) environment. Having to change realized urban designs afterwards is difficult and unwanted. Ex-ante evaluation of urban designs using Virtual Reality (VR) has the potentiality to change our approach of designing cities.

This paper describes the changing situation on bicycle paths in relation to infrastructural design and how VR can be used to explore this relation. On the one hand questions can be raised if current design guidelines of our bicycle infrastructure are sufficient towards the future. On the other hand possible alternatives can be explored using VR. NHTV Breda University of Applied Sciences developed a Virtual Reality cycling simulator called 'Cycle SPACES' (Cycle Spatial Awareness Context Experience Simulator). The primary aim of Cycle SPACES is to gain new insights and increase further understanding in how to improve urban designs by studying *roadside – bicycle side – user side* interactions in VR.

The combination of expertise needed to develop the prototype of Cycle SPACES can be found in NHTV study programs as Built Environment (BE), Game Architecture and Design (IGAD) and a to NHTV related game development studio (Atlantis Games Breda). The prototyping of Cycle SPACES is partially funded by a network of regional and local partners stimulating innovation in cycle intelligence enabling NHTV to build and test the set-up on functionality and potentiality in a pilot study.

This paper first describes different scientific approaches to study the act of cycling and states the potentiality of VR in connecting these approaches in one experimental design. This paper continues describing the prototype Cycle SPACES and discusses the considerations made when constructing the first set-up for the purpose of testing urban design. This paper ends with a pilot study in which Cycle SPACES is used to design the future super cycle highway (SCH) for the city of Breda exploring the first results of cycling in VR and its potentiality in urban design trajectories.

2. CYCLING IN THE CITY AND RESEARCHING THE ACT OF CYLING

The situation on bicycle paths in urban and rural environments is gradually changing. The popularity of cycling is renewed by new types of bicycles, like e-bikes and cargo bikes for example and the increasing popularity of living a healthy lifestyles. More people start cycling over longer distances and continue cycling till an higher age. The heterogeneity on bicycle paths increases and is characterized by differences in levels of skill, attitude, intentions with which different cyclists embark their displacement through the city and the type of bicycle they ride. The increase in heterogeneity on bicycle paths increases accident risks. The effects of the rapid increase in the number of E-bikes (25 km/h) and the development of high-speed E-bikes (>45 km/h) are yet unclear and hardly studied. Standardized design guidelines for cycle infrastructure within the Netherlands often prescribe the five leading principles: coherence, directness, comfort, safety en attractiveness and a new principle of forgiveness (CROW; 2006; 2011; 2014). Taking these changing conditions on the bicycle path into account we can raise the question: Are the bicycle paths being developed by the standards of today ready for the cyclists and bicycles of tomorrow?

The situation on bicycle paths differ all over the world considering things like the position and priority of cyclists in urban design, the awareness of other road users towards cyclists and differences in (local) bicycle usage caused by geographical and climatological factors for example. The ‘act of cycling’ is not universal and heavily reliant on the local situation. NHTV University of Applied Sciences is therefore focusing its research on the complex interplay between urban design, mobility and people, in the case of Cycle SPACES called *roadside – bicycle side - user side* interactions. Many research on cycling focuses on the question why do people cycle, which socioeconomic factors underlie the decision to cycle or what personal factors drives them? Peoples’

personal intentions and motivations to cycle or the long term benefits of cycling for the urban accessibility or the environment for example are well known and broadly examined (e.g. Heinen et. al, 2010). The act of cycling itself, a body on the move on a bicycle in a certain contextual setting is under researched when looking at the body of literature available. This section describes current research methods used to study the act of cycling and states the potential advantage of using Virtual Reality in research to cycling.

The first research method explores the physics behind the 'act of cycling'. This physics approach explains how the body interact with the bicycle to be able to cycle, so to keep balance, steer, stop and accelerate without falling off (Schwab & Meijaard, 2013). These insights in the physics behind cycling explain the effect of speed, the subtle corrections and physical exertions of a body needed and the influence of the technical design of a bicycle to be able to cycle and how this act is performed. The second interesting scientific method mentioned focuses on the status awareness of vulnerable groups while cycling, like children and elderly, and their natural behaviour displayed in different situations (e.g. Twisk, 2005; de Waard, 2013). These studies are related to behavioural studies like a study to the 'negotiation in motion', explained as navigating through traffic while using body language and signage to prevent miscommunication and accidents with other road users while cycling (e.g. Jensen, 2010). The third scientific approach mentioned is characterized by a more ethnographic approaches using focus groups, performing bike-alongs, video analysis and in-depth interviews to gain a better understanding of what interactions happen between the cyclists on a bicycle in certain environments (e.g. Jones, 2005; Spinney, 2007; Jones & Burwood 2011; Jones, 2012; Duppen & Spierings,2013). These outcomes of qualitative research approaches offer other perspectives on cycling to designers and policy makers than knowledge about personal intentions and motivations, or long term benefits of collective bicycle use to both people as well as cities. These studies provide a better understanding about cyclists navigating the city, their natural behaviour while performing this act on a daily basis, the choices they make while cycling, their embodied experiences and how urban design and contextual factors affect this.

Researching the act of cycling is relatively time consuming for both researcher as well as the respondents, committing themselves to a time consuming research period while performing longitudinal or in-depth research. An etnographic approach like cycle-along research is furthermore limited to the specific geographical location and a small number of respondents (van Duppen & Spierings, 2013). Furthermore research methods like cycle-along research are not without any risk for both researcher and respondent navigating the city's streets while participating in research. An ideal situation for conducting research to the act of cycling would be a controlled environment where respondents can be monitored and be exposed to multiple contextual settings and

urban designs without risk for those involved. An experimental design not bound to a certain geographical position and an experimental design in which large numbers of respondents can participate and be questioned within a short time period would potentially change the ability to study the act of cycling. Combining different research methods to study cycling and possibly add other fields of research to the experimental design can lead to new research opportunities using VR.

3. CONSIDERATIONS MADE IN SIMULATING CYCLING IN VIRTUAL REALITY

Simulating the act of cycling is different than simulating driving a car, train or airplane. The experience of riding a bicycle is not determined by a cockpit experience and a private or cocooned feeling that can be relatively easy reproduced by using a real cockpit combined with monitors. Whenever a cyclist looks around while cycling he or she is not hindered by a blocked view of a rooftop or the bottom of the vehicle. A cyclist is not protected by a vehicle but experiences natural elements directly to the body and experiences a certain level of vulnerability through mass and speed differences and the lack of a protective cover surrounding the cyclist. Working with monitors for a cycling simulator would make a set-up complex and the level of immersion would be questionable. Virtual Reality Glasses as the ‘Oculus Rift Dk2’ offered opportunities in developing a set-up capable of simulating the act of cycling that would have the potential to approach reality through the ability of free vision and a proper level of immersion in the VR world. The NHTV Breda University of Applied Sciences explored the available technology and tested the ‘Oculus Rift DK2’ for the purpose of a Virtual Reality cycling simulator successfully. Making Cycle SPACES suitable for testing urban designs and studying the act of cycling presented certain technical challenges when constructing the set-up and choices on software and programming. One important question raised was how to prevent respondents getting dizzy while using the Oculus Rift DK2 while using Cycle SPACES for example. Or how to match real sensations of speed, proximity of other road users and elements in Virtual Reality and match real cycling motions. Also certain considerations were made in the choice which design software to use, what level of reality should be strived for to achieve a proper level of immersion in the experience and what options should Cycle SPACES contain to be able to manipulate the contextual setting in Virtual Reality? A period of prototyping and testing offered valuable insights in answering these kind of questions.

4. CYCLE SPACES – PROTOTYPNG, TESTING AND POSSIBLE APPLICATIONS

Virtual Reality has the potential to conduct research to previous mentioned *roadside – bicycle side – user side* interactions while being on the move. While moving through VR on a bicycle the respondent can be exposed to varying contextual scenarios, urban designs and traffic situations riding different speeds and being monitored while doing so. The following triangle forms the basis of the concept Cycle SPACES:

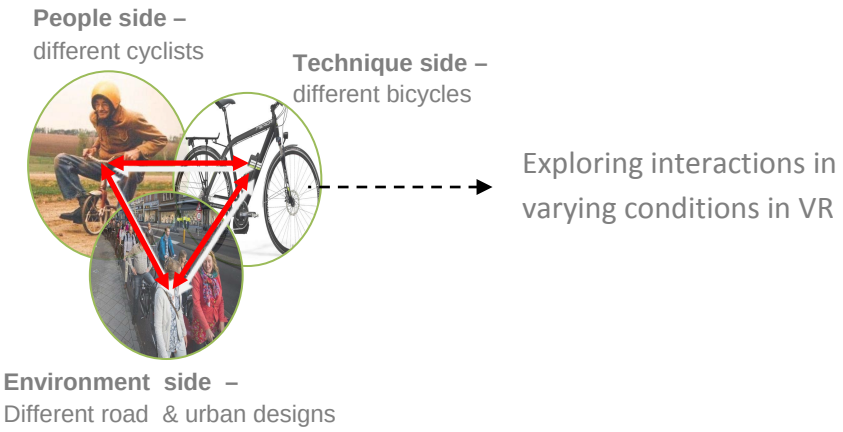

Fig. 1: Triangle *roadside – bicycle side – user side*, exploring interactions while cycling in Virtual Reality (source: NTHV Breda)

Figure 2 shows the concept behind the prototype set-up of Cycle SPACES and a conceptual outline of the technical specifications. The first experiences with Virtual Reality are discussed below this figure.

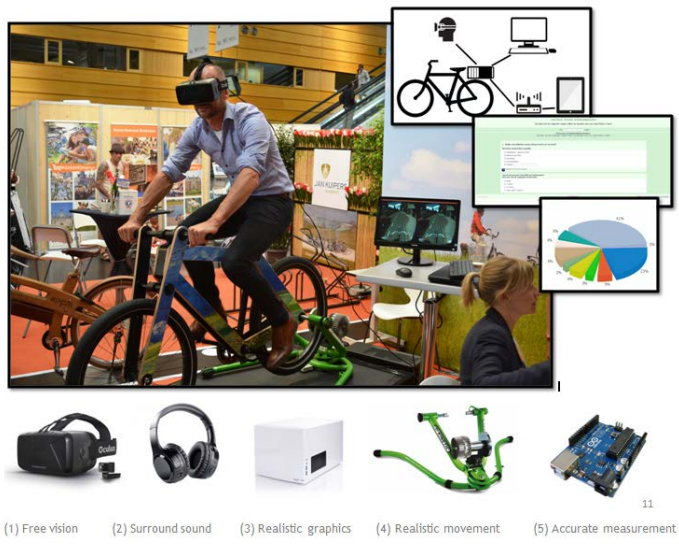

Fig. 2: The first prototype set-up of Cycle SPACES displayed at Velocity Nantes 2015, visit our Google+ page to view back our activities (source: NHTV Breda)

Prototyping and testing Cycle SPACES on functionality and potentiality showed that cycling in Virtual Reality is possible. The technical connection between riding a bicycle and creating a forward and stopping motion in-game proved possible in a relatively easy way combining existing techniques mostly. Wearing the Oculus Rift DK2 while cycling was possible for most users not having personal issues with dizziness, balance problems or poor sight. Young people, especially children adapted to wearing the Oculus within a remarkable short habituation time. Adults however needed approximately 10 to 20 minutes habituation time before feeling comfortable in Virtual Reality. This also had to do with the “new-factor” of VR-glasses as well as the nonrealistic feeling of being in control of the bicycle within the prototype. Being in Virtual Reality for the first time creates a “wow-factor” and tricks the mind overruling other experiences and can be experienced as quite intense when the controls do not match reality fully. After using the Oculus more often this effect quickly disappeared and the glasses became a practical extension to the body offering an experience of being immersed in Virtual Reality. Testing the prototype of Cycle SPACES within a network of professionals, students and people with all kinds of expertise and backgrounds resulted in a first list of possible applications of Cycle SPACES in test and research trajectories. Figure 3 show six potential applications for Cycle SPACES thus far, some already tested, others yet in development or marked interesting towards the future.

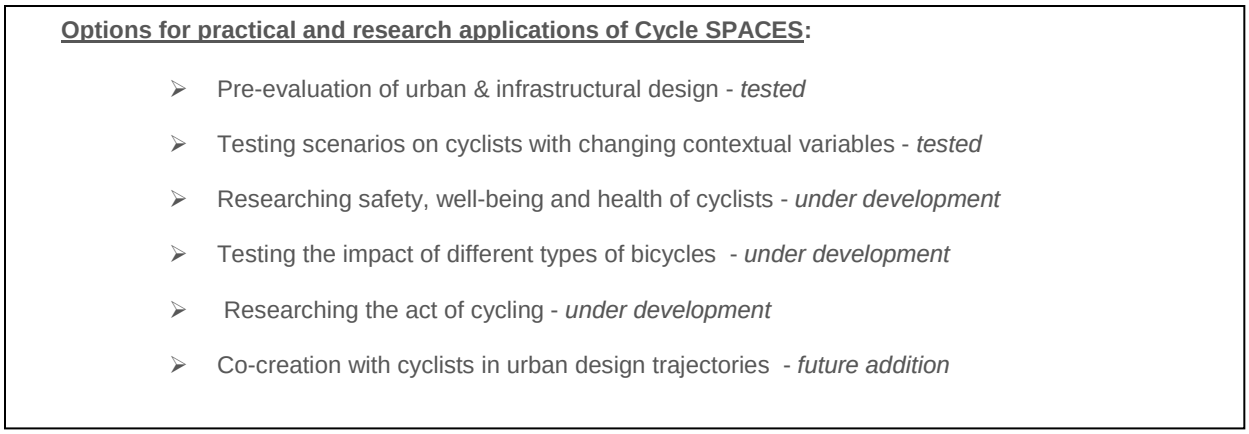

Fig 3: Experimental design Cycle SPACES – possibilities and future additions

Figure 4 shows the current development and priority status of several options of Cycle SPACES making it more suitable for test and research purposes. Some options listed are tested, while others are under (priority) development while writing this paper. Some options are marked as interesting future additions. The next paragraph focuses on the pilot study concerning the design of a super cycle highway in Breda and our first findings regarding the use of Cycle SPACES as a tool for ex-ante evaluation of urban design.

Current development status of the Cycle SPACES set-up:

- **Road side**
  - Develop environments creating a feeling of immersion - *tested*
  - Creating predetermined scenarios - *tested*
  - Changing context with a click of a button - *tested*
  - Changing the intensity of other road users – *priority development*
  - Artificial Intelligence of other road users – *future addition*
  - Simplify building virtual worlds (e.g. from AutoCAD to VR) - *future addition*

- **Bicycle side**
  - Forward and stopping motion - *tested*
  - Direct and precise steering - *priority development*
  - Adaptable speed (e.g. switch to E-bike) – *priority development*
  - Changing level of resistance when climbing and descending - *priority development*
  - Leaning - *future addition*

- **User side**
  - Monitoring attitude & (natural) behaviour related to urban design – *tested*
  - Questioning route choices & on the spot decisions - *tested*
  - Questioning pre-expectations and post-experiences – *tested*
  - Identifying sensations of fear or excitement – *short term development*
  - Measuring direct health effects – *short term development*
  - Monitoring physical exercise – *short term development*
  - Adding eye-tracking in the Oculus (where are cyclists really looking) – *under development*

Fig 4: Experimental design Cycle SPACES – current development status

5. PILOT STUDY – THE CITY OF BREDA

1. Political ambitions

The City of Breda has the local political ambition to maintain the accessibility of the city center. Detangling the bicycle and car through urban design is one of its challenges. Developing super cycle highways (SCH) from the city center outwards in multiple directions is part of the city's strategy. The City of Breda selected five potential trajectories to develop a SCH and marked one trajectory as highest in potential based on an exploratory research of a NHTV graduation student in Built Environment. At this point the City of Breda initiated to use Cycle SPACES for a pilot study to test scenarios for the SCH. This section describes the steps taken within this pilot study and the testing of different applications of Cycle SPACES.

2. Modelling the current situation in Virtual Reality

The first step taken in this pilot study was modelling the current situation of the trajectory in Virtual Reality. Modelling the current situation makes it possible to establish a baseline assessment before letting respondents cycle through the future situation and compare experiences and preferences. The focus on modelling the current situation was on matching the road design as close to reality as possible and creating a recognizable atmosphere of the surroundings. The first local respondents immediately recognized where they were cycling within the city of Breda, figure 5 shows several impressions of the current situation with recognizable traffic situations and several characterizing buildings along the trajectory like the NHTV university building (*right)*.

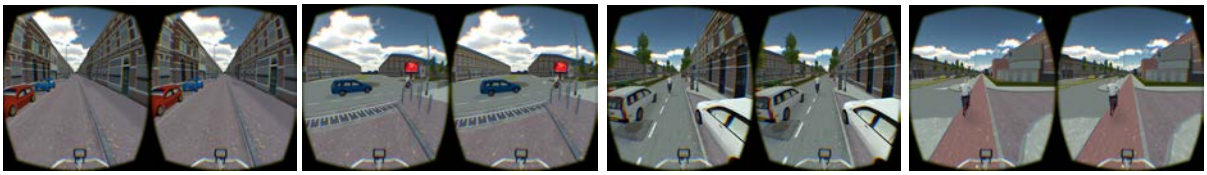

Fig 5: impressions of the current situation on the trajectory in Cycle SPACES (source: NHTV & Atlantis games Breda)

3. Scenarios for the urban design of the SCH

Continuing Breda's search to a future design for the SCH a third year NHTV student Built Environment drew three possible urban designs for the SCH. The varying urban designs covered different solutions for certain bottlenecks in the current situation of the trajectory. The three designs on paper were discussed with local mobility experts, fellow mobility students as well as local cyclists. All kinds of scenarios were discussed focussing on priority levels for the cyclists on the trajectory, design solutions for intersections and the positioning of the cycle path in the actual road design. This discussion resulted in a final urban design for the SCH.

4. Modelling the SCH in Virtual Reality

The design of the SCH was implemented by Atlantis Games Breda in the virtual world under supervision of the third year Built Environment student. The game development studio changed the road design within the current situation to the new road design creating a scenario of the future situation. Translating an urban design drawn with software as *AutoCAD* to a gaming environment using software as *Unity* proved to be challenging. There is no easy to use conversion software known to NHTV yet to translate these extensions to one another. Other interesting findings within the cooperation between urban and game designers were done. First, urban designers measure their designs as precise as possible where game developers are more used to designing fictional environments in which they proportionate size based on estimations

or standardized ratios. Second, small details in urban designs can be crucial for its overall functioning. A game designer might not know the importance of such (relatively) small details making compromises to the design by its own while translating it into Virtual Reality. The challenge in this process was to let experts with different backgrounds and expertise talk the same language during this pioneering phase. Figure 6 shows several impressions of the design of the super cycle highway in VR.

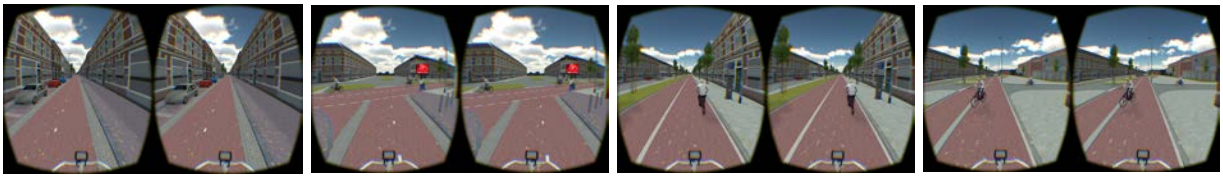

Fig 6: impressions of the future situation on the trajectory in Cycle SPACES (source: NHTV & Atlantis games Breda)

5. Changing context with a click of a button while cycling in Virtual Reality

The modelling of the SCH in Cycle SPACES offered the possibility to cycle through both the current and future situation in VR. To make the set-up of Cycle SPACES more flexible and efficient in use, a control panel was developed adding the option of switching between scenarios and changing contextual factors with a click of a button without having to restart the game. Changing the context comprises changes in the environment while someone is cycling, like the colour of the asphalt or switching between day and night. For the first time during this pilot study respondents could experience different scenarios (current/future) and be exposed to changes in the contextual setting while cycling (colour bicycle path/ day-night). This created the possibility to measure responses related to the urban designs.

6. Responses – switching between scenarios

When cycling through the current situation in VR followed by cycling the future situation, different responses were noticeable by the respondents. Within the current situation respondents reacted to bottlenecks in the urban design experiencing feelings like the proximity of contextual elements, discomfort by differences in speed, stress and even panic at moments something unexpected happened. The respondents hardly looked around and were focused on the traffic situation. When switching the scenario to the future situation the respondents were more comfortable and started noticing more details in the surroundings. Figure 7 give an impression of the urban designs related to these reactions when making a turn in the current and future situation.

Fig 7: comparing feelings of stress and safety in making a turn to an integrated cycle lane (*left)* and to a solitary cycle path *(right)* (source: NHTV & Atlantis games Breda)

The same kind of responses were noticeable by the respondents in the situation as displayed in figure 8 when in the current situation the respondents had to cycle over an integrated cycle lane in the current situation and then switched to a solitary cycle path. The cyclist in the current situation experiences stress levels and feelings of proximity in VR as if it is real. Respondents displayed behaviour like retracting their knee to prevent them hitting the wrongly parked car or experienced discomfort when suddenly a car or scooter rushed by in close proximity. In the future situations the cyclist only has to worry about passing another cyclist and were able to look around freely. Respondents start making fun here displaying behaviour like 'tapping that bold guy on the head' when passing other cyclists.

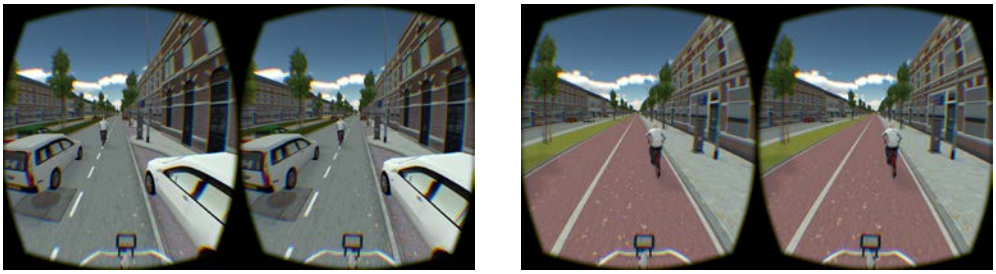

Fig 8: comparing feelings of stress and proximity on an integrated cycle lane (*left)* and a solitary cycle path (*right*) (source: NHTV & Atlantis games Breda)

8. Testing urban designs – switching between scenarios

This pilot study furthermore provided valuable insights in the potential of Cycle SPACES as tool for evaluating urban designs ex-ante. Figure 9 shows a standardized design in the current situation (cyclist positioned far right in road design) in comparison to the future situation (cyclists positioned central in the road design). The current situation leaves space for double lane motorized traffic and the new design only for single lane. Cycling in the future situation was experienced as more attractive and comfortable by the respondents. The urban design offered a better overview on the whole situation reducing the reactions of respondents to cyclists coming from the right. Furthermore the design leaves room for adding urban greenery and other contextual elements like

benches. Furthermore, the new design reduces the amount of parking lots and passing cars resulting in less smells, noises and potential danger.

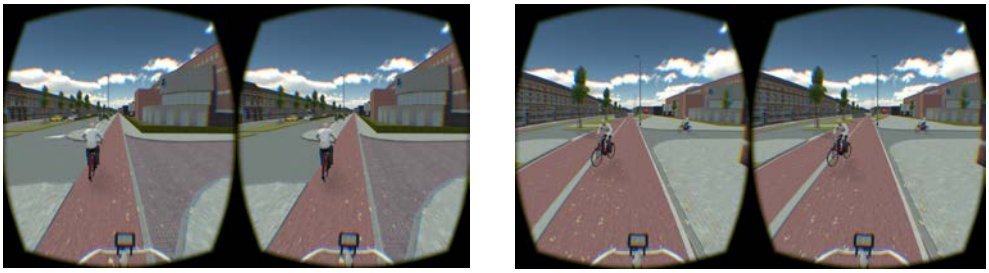

Fig 9: questioning standard design solutions. Cycle path positioned right in the road design (*left)* or cycle path central in road design (*right)* (source: NHTV & Atlantis games Breda)

The second example shown in figure 10 displays an innovative design solution to a bottleneck in the current situation in which both cyclists and cars have to wait a long time at the traffic light. An underpass for motorized traffic or cyclists can be an ideal design solution to improve the situation for both modalities as well as their (negative) effects on the surrounding. Such a solution is usually considered as too expensive or complex. Within this pilot study an non-standard urban design is integrated with which a participatory trajectory with cyclists, local residents and experts will be started to evaluate the urban design ex-ante. These results are not yet available.

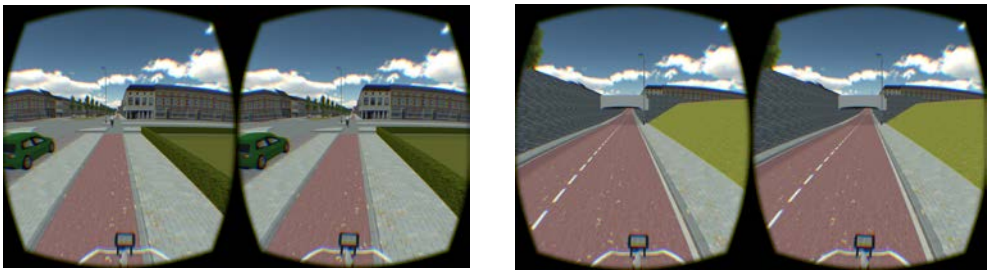

Fig 10: ex-ante evaluation of innovative design solutions, optimize the more costly design (*right*) solutions for future benefits (source: NHTV & Atlantis games Breda)

7. Responses – changing context while cycling in Virtual Reality

The ability of changing the context while respondents are cycling through a certain scenario was the next feature of Cycle SPACES being tested. This feature might contribute in learning the pros and cons of a design in different conditions and creates the opportunity to measure preferences of cyclists to certain contextual settings. Figure 11 and 12 show the ability of Cycle SPACES to change the context like the type and colour of the asphalt and changing the atmosphere completely when switching from day to night with a click of a button. The respondents varied in their preference for the red or

blue asphalt and most of them liked cycling during the night because of the sight of stars and less intense colours displayed by the Oculus Rift DK2. Besides asking personal preferences the fun factor was also an important response by most respondents.

Fig 11: varying scenarios with a click of a button – changing the colour of the cycle path (source: NHTV & Atlantis games Breda)

Fig 12: varying scenarios with a click of a button – changing the colour of the cycle path (source: NHTV & Atlantis games Breda)

6. FIRST FINDINGS

This paper explored the use of Virtual Reality (VR) technology like the Oculus Rift DK2 for the evaluation of urban design ex-ante and the first experiences of applying Cycle SPACES in a pilot study. Cycle SPACES increases further understanding in *roadside – bicycle side – user side* interactions through cycling in VR and displays potential in becoming a valuable tool for improving urban and road designs. The current prototype has its limitations and certain considerations have to be made towards the future for the next development steps. What are valuable additions for its purpose to test urban design and to conduct research? Furthermore the pilot study triggers the mind for applying Cycle SPACES in participatory and research trajectories.

1. Roadside

The roadside concerns the environment displayed by the Oculus to the respondent in VR comprising all contextual factors related to this environment. How this roadside can be experienced as close to reality as possible is a question asked for the further development of Cycle SPACES. Using the Oculus Rift Dk2 learned that the level of immersion in VR determines if realistic embodied reactions occur to respondents when cycling through VR. Which factors are decisive in creating this immersed feeling in VR? Higher graphical quality would be a logical step improving realism. Cycle SPACES displays a rather low graphical quality compared to what is technically possible. Still respondents experience a proper level of immersion in the roadside displayed in Cycle SPACES. Respondents recognized the environment as familiar and scenarios triggered distinctive embodied reaction like retracting their knees or causing feelings of (dis)comfort, speed and proximity. Besides improving the graphical quality of a roadside, creating a more lively roadside can increase the level of immersion even more. Cycle SPACES contains a roadside quite lifeless compared to rush hour. Testing urban design ex-ante requires an adjustable roadside in VR, being able to change intensities of other road users, add traffic light programming, add details like different kind of urban greenery and street furniture. Testing Cycle SPACES learned us that striving for a more lively roadside will have a more significant impact on the level of immersion than improving graphical quality. Creating lively scenarios in Cycle SPACES rather than creating more beautiful but static scenarios will improve the usability of VR for the purpose of testing urban designs. Especially when taking into consideration that improving graphical quality is the most labour intensive part for a game development studio creating a roadside in VR. Looking at the future it is wished for to bridge the gap between urban designers and game developers now using different design software and talking different languages. Making it possible to converse technical designs to VR without the need of both urban design as well as game development experts will mean a major step in the gamification of Urban Design and the use of VR. For example, once a technical design of a road type, building, tree, pedestrian or furniture is transformed to VR, it can be stored in a content library ready to be re-used by urban designers using a Sim City like configurator creating their own VR environments and scenarios.

2. Bicycle side

The Bicycle side concerns the feeling of actually riding a bicycle in VR and being in control of it. The prototype of Cycle SPACES provided a proper indication of what cycling in VR can potentially be. Being up-to-speed in Cycle SPACES is experienced as actually cycling. The respondent sees its own arms, a handlebar and moving legs when looking down. The experience of actually riding a bicycle changes when the need arises to respond to certain situations as a cyclists. The prototype of Cycle SPACES does not offer the ability for respondents to steer in VR or to stop instantly. It does offer a railed

experience through VR at a realistic cycling speed and starts moving when the respondent start pedaling on a real bicycle wearing an Oculus Rift. Adding responsive steering and breaking to Cycle SPACES, but also adaptive resistance when going up or downhill will increase the feeling of respondents being in control of a bicycle and creates the feeling of actually riding a bicycle. These additions are currently under priority development. Cycling in reality, especially steering, also includes a leaning motion of the body. Adding this complex motion to the set-up will be studied on applicability and necessity of creating a tool capable of testing urban designs.

3. User side

The user side concerns the respondents using Cycle SPACES and their reactions to wearing the Oculus Rift DK2. The testing and prototyping phase, but also the pilot study learned that people have to get used to wearing Virtual Reality glasses. The habituation time needed to get used to the Oculus Rift differed from person to person. However, the habituation time was remarkably shorter by younger people as by older people. People having personal issues with dizziness or balance problems might better not use Cycle SPACES since a person can fall of a real bicycle getting injured while getting disorientated by wearing the Oculus Rift. Technical improvements to the Oculus Rift improving screen resolution, velocity and portaability will lessen these negative effects. If these problems will fully disappear by technological improvements to the Oculus will be evaluated in the near future. Besides the current limitations of VR technology and Cycle SPACES as set-up, the combination of both mostly triggered enthusiasm and curiosity by the respondents. The fun factor of being in VR cannot be underestimated, especially when having the ability to change the VR environment while respondents are in it. The potentiality of VR technology in a participation trajectory for urban design is present. Testing preferences and embodied reactions of your target group to an urban design in a fun and controlled environment can change the way urban designs are established.

4. Future research

Cycle SPACES has the potential to connect different research methods in one experimental design. Conducting research in a safe and controlled environment enables researchers to expose respondents to different contextual scenarios while monitoring, questioning and analyzing them. Related to urban design several options are being explored within the Cycle SPACES project. First, it is well known that commuting associated to travel-related environments can be stressful which can impairs health and work performance (Novaco and Gonzalez, 2011; Novaco et al., 1990; O' Regan and Buckley, 2003). It is less known what the impact is of cycling and especially e-cycling in physical environments (e.g. colour and wideness of cycle paths, greenness, quietness, lightning, architecture, traffic intensity) on objective stress levels. Cycle SPACES could

contribute in a better understanding of these effects in a ‘virtual’ environment. Second, Cycle SPACES could explore the attributes of (e-) cycling environments contributing the most to a positive (emotional) experience and a stimulation of the use of e-bikes. The use of immersive 3D technology like the Oculus Rift offer new opportunities to explore these relations with an experimental design in a controlled environment.

References

Duppen, van J. & Spierings, B. (2013) Retracing trajectories: the embodied experience of cycling, urban sensescapes and the commute between ‘neighbourhood’ and ‘city’ in Utrecht, NL, In: Journal of Transport Geography, 30, pp. 234-243

Heinen, E., Wee, van G.P. & Maat, K. (2010) Commuting by bicycle: an overview of the literature, In: Transport Reviews A, Transnational Transdiciplinary Journal, 30(1), pp.59-96

Jensen, O.B. (2010) Negotiation in motion: unpacking a geography of mobility, In: Space and Culture, 13, pp. 389-402

Jones, P (2005) Performing the city: a body and a bicycle take on Birmingham, UK, In: Social & Cultural Geography, 6(6), pp.813-830

Jones, P. & Burwood, D. (2011) Cycling and the city: reflections of commuting practices, In: Liminalities, A journal of Performance Studies, 7(4)

Novaco, R.W., Stokols, D., & Milanesi, L. (1990). Objective and subjective dimensions of travel impedance as determinants of commuting stress. American Journal of Community Psychology, 18, 231-257.

Novaco, R.W. & Gonzales, O. (2011) Commuting and Well-being, in: Technology and Well-being, Cambridge University Press

Schwab, A.L. & Meijaard, J.P. (2013) A review on bicycle dynamics and rider control, in: Vehicle System Dynamic 51 (7), pp. 1059 – 1090

Spinney, J. (2007) Cycling in the city: non-place and the sensory construction of meaning in a mobile practice, Published by: Ashgate, Aldershot, England

Waard de, D. (2013) 'Naturalistic cycling research in Groningen en Zwolle', Rijksuniversiteit Groningen, for progress follow: www.vergevingsgezindfietspad.nl

Twisk, D. (2005) 'Het gedrag van de mens van binnenuit, in het kader van door met duurzaam veilig' (PPT), SWOV wetenschappelijk onderzoek verkeersveiligheid

O’Regan, B & Buckley, F (2003) The phychological Effects of Commuting in Dublin, in: Centre for Research in Management Learning and Development Working Paper Series