Cycling renaissance: The VR potential in exploring static and moving environment elements

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ABSTRACT

Although cycling attracts increasing attention being an active and healthy way of transport, understanding the determinants of cycling experience is still a challenge. The current study addressed this challenge by exploring how various parameters (i.e. static and moving elements) of the environment influence cycling experience in a simulated Virtual Reality (VR) world. Different scenarios were created mirroring the streetscape of a real Dutch city. The scenarios were designed in such a way that we have a full crossing of the manipulated factors, namely, static (bicycle path presence, crossroad presence) and moving elements (cars, pedestrians, other cyclists intensity). After having a bike ride, participants had to provide their evaluation on the just experienced environment, in terms of safety and enjoyment perception. Naturalness, presence, engagement and liking of the VR environment were also addressed.

The results are clear in showing that safety perception depends on whether bicycle path and crossroads are present. Enjoyment however did not show statistical differences in respect to the above factors. Concerning moving elements, car intensity influenced both, safety and enjoyment perception. Current results are discussed in line with the existing theories on cycling experience. We further focus attention at how well-known VR applications might enhance experience and thus opening avenues to appropriately investigate everyday context scenarios, outside research laboratories and specialist environments.

Keywords: VR environment, static moving elements, cycling

Index Terms: Augmented and virtual realities, information interfaces and presentation, User/Machine Systems-Human Factors

1 INTRODUCTION

Although the potential of Virtual reality (VR) in exploring everyday context like cycling scenarios has been recognized a while ago [3, 4], there is a need for new applications development and user evaluation in order to appropriately address how to enhance cycling. Cycling is an active form of transport, attracting increasing interest among scholars from various disciplines. However, scholars are not univocal on the parameters influencing cycling experience. To address these parameters, and to provide a better understanding on how to possibly encourage cycling, we performed the current study.

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In particular, we employed a VR application offering a bike ride mirroring a real world cycling experience through different streetscapes of an existing Dutch city in province North Brabant. The streetscapes were created by crossing the key parameters assumed to impact experience, namely, static and moving environment elements. A standard bicycle was affixed to an electromagnetic trainer (Elite RealAxiom Wired), and the VR environment was presented via Oculus Rift CV2 headset, see Figure 1. Participants were invited to cycle in and to provide their experience evaluation.

Figure 1: The experimental setting.

User experience we addressed in terms of both, the VR experience evaluation and the cycling experience itself. We assume that along with the increased ease-of-use and flexibility, the system created offers the users a realistic experience, and thus, the evaluation provides a real bike ride reflection. Such realistic experience is especially possible due to the advance of technology, and improvement in real-time synchronization of proprioceptive and visual feedback to user actions [7]. Furthermore, the computer-generated graphics presented can guide cyclists attention to relevant environmental elements (either static or moving) and thus predetermine the behaviour response, mirroring behaviour in the real life scenarios.

In particular, we are interested to know what are the cognitive (e.g., safety perception) and affective (e.g., enjoyment of cycling) responses. Safety has been acknowledged as a major factor in a real-life bike ride [8, 15]. In VR environments, safety also emerged as a crucial parameter [1]. Moreover, the authors argued that factors influencing safety might influence enjoyment of cycling with different magnitude. Whether this is the case, we will explore in the current study, with special focus on the impact of the manipulated factors, i.e. static and moving elements within the VR environment.

In the following, we present consecutively the theory behind the study, the method and results. A discussion is provided on the main findings, from the perspective of existing theories. We further focus attention at how well-known VR applications might enhance experience, and thus, open avenues to appropriately investigate everyday context scenarios, like cycling, driving, transportation.

2 RELATED WORK

2.1 The Virtual Reality Environment

Although the implementation of Virtual reality (VR) in cycling has a long history [3, 4], only recent advance of technology provided evidences that VR is appropriate to enhance outdoor biking [7], as well as to explore cycling experiences reflecting real bike ride [1]. While the interface used in the early age faced technological challenges due to hardware or environmental issues, the contemporary 3D immersive simulation technology seems to address these challenges. Furthermore, virtual elements are created in such a way that can assure (a) correctly perceiving at intended locations in a 3D space, and (b) generating physiological responses in the human visual system consistent with real-world viewing experiences [10].

Therefore, the naturalness of the VR environment, defined as believability of the depiction of the environment itself and events within the environment [6] has been acknowledged to be crucial in providing experience as in a real outdoor bike ride [1]. The VR experience is evaluated in terms of presence, i.e. the subjective experience of being in one place or environment [16], even when one is physically situated in another place [11]. Perceived presence was assumed to further influence engagement [14], defined as the degree of involvement and immersion [6]. In the context of VR biking, a recent study confirmed that naturalness and presence impact positively engagement, i.e. the better the naturalness and presence were perceived, the higher the engagement was [1]. Researchers further reported a causal relation between engagement and liking of the experience with various VR applications, the higher the engagement was, the more the VR experience was liked [1, 2]. As the present study aims to provide in-depth understanding on the parameters determining cycling experience in VR world reflecting real life scenarios, we closely look at how naturalness, presence, engagement, and liking of the VR environment are perceived.

2.2 The static elements

What is much more interesting in the present context is how various environment elements influence the cycling experience itself. While in real life, to modify streetscapes is a challenging task requiring time, effort, finances, in VR it is possible to simulate various environments, and to combine different elements in relatively effortless way. We embrace the advance of VR technology, and therefore, focus attention at how static elements i.e., infrastructure [5, 8, 15] might enhance cycling experience. Bicycle path is well recognized factor in real life bike ride, in early and recent studies [8, 12]. In VR environment, bicycle path width also showed to be crucial determinant in how safe and enjoyable is perceived to be the cycling experience [1].

Another environment element that might possibly influence cycling experience is the crossroad. Surprisingly, however, literature is scares on the effect of crossroads in real life bike ride. In the VR context, the role of crossroads received good attention concerning the car driving experience [10]. However, for VR biking the role of crossroads invites further investigation. The current study addresses this issue. In particular, we look at cognitive (i.e. safety perception) and affective (i.e. enjoyment of cycling) response. We assume:

H1: Safety is perceived to be higher when cycling in environment where bike path is present (than absent), and crossroad is absent (than present).

Similarly, it is expected:

H2: Cycling will be enjoyed more when bike path is present (than absent), and crossroad is absent.

2.3 The moving objects

Parallel to environment elements that are static (relative to the user's view) there are moving objects that might appear in the cycling environment, namely vehicles, other cyclists, and pedestrians. The intensity of vehicles traffic (e.g., cars, trucks) was pointed out as crucial factor for safe cycling in real life scenarios [8, 15]. In the context of VR biking, high intensity of cars appearance showed to have negative correlation with safety perception [1].

In the same vein, one might argue that other cyclists on road and pedestrians intensity could also influence cycling experience. Previous VR/AR research intensively explored the role of pedestrians in car driving. Furthermore, various (display) technologies have been suggested to improve the pedestrians detection, and empirical evidences have been provided for the relative effectiveness of these displays in driving contexts [10]. Despite the efficiency of technology, pedestrians impact in the context of VR biking calls for further exploration. We address this issue, and hypothesize:

H3: Safety is perceived to be higher in environment with a low (than high) car intensity, and with low (than high) intensity concerning pedestrians/ other cyclists appearance.

Similarly, it is assumed that:

H4: Cycling will be enjoyed more with low car intensity, and less pedestrians/ other cyclists on road.

The above hypotheses are tested in the user study, as described in details in the method section.

3 USER STUDY

A VR environment was created, mirroring the streetscape of a real Dutch city in province North Brabant (see Figure 2). Infrastructure parameters (e.g., bicycle path, crossroad) and moving objects intensity (e.g., cars, cyclists, pedestrians) were manipulated systematically. Participants were invited to cycle in a VR world, and thus being offered a bike ride reflecting real life scenarios. Participants had to evaluate the just experienced environment, concerning the safety, enjoyment, attractiveness. Engagement, naturalness, presence, and liking of the VR environment were also addressed.

Figure 2: A screenshot of the VR environment.

3.1 Participants

54 people (29 male and 25 female; 18 to 70 years old) took part in the study, conducted in The Netherlands. All had normal or corrected to normal vision. 41% reported that they have not experienced VR before. Majority were experienced in cycling, namely, 82% reported to cycle almost every day, and 11% at least once per week.

3.2 Stimuli and Design

The VR environment featured a streetscape of a Dutch city in province North Brabant (see Figure 2, for an example). For the purpose of the study 8 streetscapes (experimental conditions) were designed, after full crossing of the experimental factors, namely Bicycle path (yes, no), Crossroad (yes, no), Car intensity (high, low), Pedestrians/other cyclists intensity (high, low). The speed of vehicles reflected the speed limit for residential streets (selected based on pre-tests). Environment greenness, cleanness, and land typology were dummy factors. Each participant experienced 4 out of 8 conditions, presented in a random order and a counterbalanced manner as described below.

3.3 Experimental procedure

Participants were first introduced to the experiment, and then completed a consent form, agreeing to take part in the study. After that they were asked to comfortably sit on the bike (trainer adapted for the purpose of the experiment) and to wear the Oculus Rift headset (see Figure 1).

The experiment started with a short practice session (a 300 meters long cycling segment) to familiarize with the environment and the task. Then 4 experimental blocks were presented (each about 2min long). In each block, one of the 8 experimental conditions was presented. The order of blocks was randomized in advance, so that the experimental conditions are counterbalanced across participants, and completing a full conjoint trial.

At the end of each block, participants rated how safe, enjoyable and attractive was the just experienced environment. Rating was conducted within the virtual environment by moving the head and staring at the desired answer, on a 7 point Likert scale (1=”strongly disagree”, 7= “strongly agree”).

After having cycled, participants had to complete a survey, addressing the current VR experience evaluation (naturalness, presence, engagement, liking), and sociodemographics (e.g., age, gender, education, previous VR experience, cycling experience, etc.). In addition, participants ranked the cycling segments (seeing a screenshot) in order from the most attractive to the least attractive. At the end, participants were debriefed and thanked for the participation. Vouchers (20 euros each) were raffled among the participants, as incentive for their participation.

3.4 Apparatus

The VR environment was created with C# and Unity3D game-engine environments by a third party, a professional VR developer studio. The VR application was run via PC on Oculus Rift CV2 headset. A standard bicycle was affixed to an electromagnetic trainer, Elite RealAxiom Wired. The trainer and the Oculus Rift were connected to the same PC, to transmit and record data concerning the virtual cycling movement parameters (see Figure 1, for the experimental setting).

3.5 Instrument

During the VR cycling, participants rated how safe, enjoyable and attractive was the just experienced environment (on a 7-point Likert scale, 1=”strongly disagree”, 7= “strongly agree”).

Perceived Naturalness, Presence, Engagement, and Liking were measured in a survey, based on scales adapted from previous studies. The construct Naturalness encompassed 4 items (e.g., “The displayed environment seemed natural”). The construct Presence encompassed 4 items (e.g., “I felt I was visiting the places in the displayed environment”). Engagement was a single item (“I felt involved in”). Liking was also a single item (“I would have liked the experience to continue”). Engagement, Naturalness and Presence were designed based on questions adapted from [9]. Liking was included based on previous studies exploring liking of VR applications [1, 2]. All items were measured on a 5-point Likert scale (1 = “strongly disagree”, 5 = “strongly agree”).

Few questions captured sociodemographic characteristics (e.g., age, gender, education). We asked about previous experience with VR (yes, no), and frequency of cycling (almost every day, at least once a week, few times a month, less than once a month, I never cycle).

3.6 Analytical procedure

We first performed a reliability check. The scales used demonstrated to be reliable (Cronbach’s α’s > .65).

Concerning the VR experience evaluation, T-test was run to investigate whether there are significant differences, respectively in Engagement, Naturalness, Presence, Liking of the VR experience determined by previous VR experience (no, yes). T-test probed for any significant differences in the above parameters determined by gender (male vs. female). ANOVAs tested whether and how Engagement, Naturalness, Presence, Liking are influenced by cycling experience.

Regression modelling was conducted to check for any causal relations between Naturalness, Presence, Engagement and Liking of the VR experience.

Concerning the cycling experience, separate ANOVAs were conducted to explore whether there was a significant difference in Safety and Enjoyment evaluation, with respect to Gender (male vs. female) and the manipulated factors, respectively, Bicycle path (yes, no), Crossroad (yes, no), Car intensity (high, low), Pedestrians/other cyclists intensity (high, low). Table 1 presents a summary of the statistics (significant effects only reported).

4 RESULTS

The VR experience: Participants evaluated the naturalness of the VR environment well (M = 3.85), and irrespective of factor gender (p > .29). Neither pervious VR experience nor cycling experience influenced the naturalness perception. Similar was the result for engagement (M = 3.35), and liking (M = 3.65). These parameters did not differ with respect to gender, previous VR experience, cycling experience, all p’s > .26. Concerning presence (M = 3.65), neither gender, nor previous VR experience had an impact, all p’s > .19. Cycling experience however was just at the margin (p = 0.051), showing that people who cycle every day felt best present at the VR environment. We have to point out here that the study was conducted in the Netherlands, known as a bicycle-friendly country, with high rate active cycling [13]. Current study also demonstrated that majority of our respondents reported that they cycle regularly, on daily or weekly base (93 %).

Concerning the regression modelling, results are clear in showing that both, naturalness and presence enhanced engagement, explaining 45 % of the variance in the model, R^2 = .45, $F(2, 51) = 32.55$, $p < 0.0001$. The higher the naturalness and the presence were, the higher the engagement was.

The cycling experience: Both, cognitive (safety perception) and affective (enjoyment) responses were addressed as a function of the manipulated factors: Bicycle path (yes, no), Crossroad (yes, no), Car intensity (high, low), Pedestrians/other cyclists intensity

(high, low). Gender was a between participants factor we also took into account in the ANOVAs performed.

The results are clear in showing that Bicycle path presence is a crucial determinant in how safe is perceived to be the cycling experience, $F(1, 52) = 11.30$, $p < 0.001$. This effect appeared irrespective of factor gender, $p > .30$. Although the tendency for more enjoyable experience when bicycle path is present (than absent), this effect was not substantiated statistically, $p > .12$ (for details, see Table 1 and Figure 3).

Table 1. Summary of the statistics for cycling experience

	Safety	Enjoyment
Static elements		
Path	$F(1,52) = 11.30$, $p < 0.001$	$p > .12$
Yes	$M = 5.19$	$M = 4.85$
No	$M = 4.52$	$M = 4.52$
Crossroad	$F(1,52) = 9.91$, $p < 0.005$	$p > .10$
Yes	$M = 4.54$	$M = 4.55$
No	$M = 5.13$	$M = 4.85$
Moving objects		
Cars	$F(1,52) = 10.59$, $p < 0.005$	$F(1,52) = 4.53$, $p = 0.038$
High	$M = 4.51$	$M = 4.47$
Low	$M = 5.19$	$M = 4.93$
Pedestrians	$p > .62$	$p > .68$
High	$M = 4.71$	$M = 4.53$
Low	$M = 4.81$	$M = 4.62$

Concerning the crossroad, it was safer to cycle in (VR) environment, if there was no crossroad, $F(1, 52) = 9.91$, $p < 0.005$. This effect was pronounced irrespectively of factor gender, $p > .36$. There was also a tendency for a more enjoyable cycling when no crossroad was present (see Table 1). However, this effect was not significant, $p > .10$.

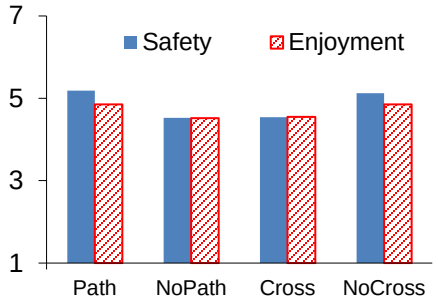

Figure 3: Static elements influence on (VR) cycling experience

The moving elements, in particular vehicles played a role as a function of the intensity with which appeared. It was safer to cycle when the cars intensity was low (than high), $F(1, 52) = 10.59$, $p < 0.005$. Enjoyment was also better pronounced when the cars intensity was low, $F(1, 52) = 4.53$, $p < 0.05$ (see Figure 4). Both effects appeared irrespective of factor gender, all p's $> .21$.

Concerning the pedestrians, other cyclists on road, there was a tendency for a better safety and enjoyment evaluation with less people on road (see Table 1). However, neither the main effects (p's $>.62$), nor the interactions with factor gender were significant, (all p's $>.32$).

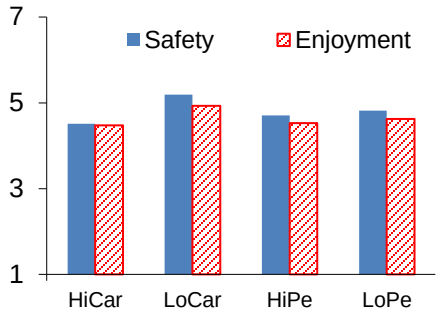

Figure 4: Moving objects influence on (VR) cycling experience

5 Discussion

Understanding the determinants of cycling experience is a challenging task. Despite increasing interest and efforts in encouraging cycling as an active form of transport, specialists struggle in defining the determinants of safe and enjoyable cycling. The current study addressed this challenge by exploring how various parameters (i.e. static and moving elements) of the environment influence cycling experience in a simulated Virtual Reality (VR) world. The influence of the manipulated factors was measured in terms of cognitive (i.e. safety perception) and affective (i.e. enjoyment of cycling) responses. Naturalness, presence, engagement, and liking, as key parameters determining the VR experience, were also addressed. The results demonstrated that safety perception is modulated by both static and moving environment elements. Enjoyment, however, was modulated only by moving vehicles. Current outcomes provide clear evidences that VR bike applications could be well used in dynamically simulating environments, combining various parameters real-time, and thus, finding appropriate settings of static/moving elements that could best enhance cycling.

5.1 The VR environment

Naturalness, presence, engagement and liking of the VR environment were well pronounced. These parameters emerged irrespective of factor gender, and irrespective of previous VR experience. Naturalness and presence further influenced engagement, i.e. the better the naturalness and presence were perceived, the higher the engagement was. These findings support prior studies that engagement is enhanced by perceived presence and naturalness [6, 14], and thus enhancing VR experiences and liking [1, 2].

We have to note hereby that previous cycling experience did not modulate the current VR experience evaluation (in terms of naturalness, presence, engagement, liking). These results nicely cohere with the outcomes of a recent study in the VR bike context [1]. A plausible explanation the authors provided was that the study was conducted in The Netherlands, a bike-friendly country with active cycling rate [13]. Our study was also conducted in The Netherlands, and 82% of the participants reported to cycle almost every day, and 11% at least once per week. Therefore, we assume that they have a realistic cycling representations, and thus, the current VR experience reflects the real-life bike ride.

5.2 The static elements

It was safer to cycle in VR environments where bike path was present (than absent), and where there was no crossroad (see Figure 3). These results support **H1**, and cohere with real-life bike

ride literature that bicycle path is a crucial determinant in safe cycling [8, 12, 15]. Concerning the crossroad, its absence was a significant predictor for safe cycling. While in VR car driving experience [10], various cross points scenarios were addressed, hereby, results are clear in showing that actually the absence of crossroad is the safest, in precluding collisions. This has to be taken into account by planers, designers when creating cycling infrastructure, namely to avoid/reduce crossroads.

As part of the design, we also addressed enjoyment. Although the tendencies for more enjoyable cycling when bicycle path is present (than absent), and when crossroad was absent (than present), these effects have not been substantiated statistically, see Table 1. Current outcomes support a recent VR bike study, claiming that the environment factors might influence cognitive and affective response with different magnitude [1]. Hereby, it might be the case that static environment elements do not influence the enjoyment component at all, and thus, rejecting **H2**. But it would also be the case that the enjoyment correlates with other temporal parameters, in order to be pronounced. To provide a plausible answer, a follow-up study should address these issues, when manipulating the cycling speed, and/or the time spent at crossroads (e.g., traffic light delay).

5.3 The moving objects

Concerning moving objects, the results are clear in showing that the more intensive the car traffic was, the less safe the cycling was. These results cohere with a recent VR bike study that high intensity of cars appearance had a negative correlation with safety perception [1]. In this respect, VR studies completely support literature on real-life bike ride, demonstrating that the intensity of vehicles (e.g., cars, trucks) is crucial for safe cycling [8, 15].

Pedestrians and other cyclists, however, did not modulate safety perception, and thus **H3** is only supported concerning the car intensity. Note that previous VR/AR research investigating the role of pedestrians in car driving also reported some differences with respect to pedestrians detection, and the relative effectiveness of the existing displays in driving contexts [10]. In the current environment, the naturalness of represented objects was evaluated to be very high, and thus assuring (a) correctly perceiving at intended locations in a 3D space, and (b) generating physiological responses in the human visual system consistent with real-world viewing experiences. However, we have to point out here that pedestrians appeared on a separate side walk, and thus, might not be perceived as potential obstacle, or even attention attractor/distracter.

The above explanation could also hold concerning enjoyment perception, as pedestrians did not influence enjoyment of cycling. Cars intensity, however, influenced enjoyment, i.e. cycling was enjoyed more with low car intensity, in line with **H4**. Another explanation for the strong effect of car intensity (and no effect of pedestrians) could be the size of the vehicles (vs size of pedestrians/cyclists on road), and the speed with which moving objects appeared. Hereby the speed of vehicles reflected the speed limit for residential streets. Whether and how speed, size, and positioning of moving objects within 3D environment, and in (non-)residential scenarios play a role for cycling experience could be addressed in a follow-up study.

6 Conclusion

Current study employed VR bike applications to dynamically simulate environments where both static (i.e. bike path, crossroad) and moving (i.e. cars, cyclists, pedestrians) objects appeared. The results are clear in demonstrating that bike path, crossroad, and cars intensity significantly modulate how safe the cycling is perceived to be. Enjoyment of cycling, however, has been only modulated by cars intensity.

Present results should be taken into account when developing highly precision VR systems simulating real time, a real-life bike ride. Furthermore, the suggested users studies in respect to moving objects are of great importance, opening new avenues to appropriately address everyday context scenarios, like cycling, driving, transportation.

References

[1] S. Bialkova, D. Ettema, and M. Dijst (2018). Urban future: Unlocking Cycling with VR Applications. In *proceedings of the 4th Workshop on Virtual reality for Good, IEEE VR2018,* (Reutlingen, Germany, March 18-22, 2018).

[2] S. Bialkova, and M. S. van Gisbergen (2017). When sound modulates vision: VR applications for art and entertainment. In *Proceedings of the 3rd Workshop of Everyday Virtual Reality, IEEE VR2017*, (Los Angeles, US, March 18-22, 2017).

[3] C. D. Brogan, R. A. Metoyer, and J.K. Hodgins (1998). Dynamically simulated characters in virtual environments. *IEEE Computer Graphics and Applications, 18*(5), 58-69.

[4] G. U. Carraro, M. Cortes, J.T. Edmark, and J.R. Ensor (1998). The peloton bicycling simulator. *In Proceedings of the third symposium on Virtual reality modeling language,* ACM p63-70.

[5] E. Fishman, S. Washington, and N. Haworth (2012). Barriers and facilitators to public bicycle scheme use: A qualitative approach, *Transportation Research Part F: Traffic Psychology and Behaviour 15*, 686-698.

[6] J. Freeman, and J. Lessiter (2001). Here, there and everywhere: The effect of multichannel audio on presence. In *Proceedings of ICAD 2001*, (Espoo, Finland, July 29-August 1, 2001).

[7] F. Grani, and J. R. Bruun-Pedersen (2017). Giro: Better Biking in Virtual Realit. In *Proceedings of the 3rd Workshop of Everyday Virtual Reality, IEEE VR2017*, (Los Angeles, US, March 18-22, 2017).

[8] E. Heinen, B. van Wee, and K. Maat (2010). Commuting by bicycle: An overview of the literature, *Transport Reviews, 30*, 59-96.

[9] J. Lessiter, J. Freeman, E. Keogh, and J. Davidoff (2001). A cross-media presence questionnaire: The ITC-Sense of Presence Inventory. *Presence, 10*(3), 282-29.

[10] H. Kim, J. L. Gabbard; A. M. Anon, and T. Misu.(2018). Driver Behavior and Performance with Augmented Reality Pedestrian Collision Warning: An Outdoor User Study. *TVCG, 24*(4), 1515 – 1524.

[11] A. McMahan (2003). Immersion, engagement and presence. A method for analyzing 3D video game theory reader, In The Video Game, Theory Reader, Mark J.P. Wolf and Bernard Perron, eds. NY, US: Routledge, Taylor & Francis Group, p67- 86.

[12] L. Mertens, D. Van Dyck, A. Ghekiere, I. De Bourdeaudhuij, B. Deforche, N. Van de Weghe, and J.Van Cauwenberg (2016). Which environmental factors most strongly influence a street's appeal for bicycle transport among adults? A conjoint study using manipulated photographs, *International Journal of Health Geography, 15*, 31-45.

[13] A. T. M. Oakila, D. Ettema, T. Arentze, and H. Timmermans (2016). Bicycle commuting in the Netherlands: An analysis of modal shift and its dependence on life cycle and mobility events. *International Journal of Sustainable Transportation, 10*(4), 376–384.

[14] J. Steuer (1992). Defining virtual reality: Dimensions determining telepresence. *Journal of Communication*, *42*(4), 73-93.

[15] M. Winters, G. Davidson, D. Kao, and K., Teschke (2011). Motivators and deterrents of bicycling: Comparing influences on decisions to ride. *Transportation, 38*, 153-168.

[16] G. Witmer, and M. J. Singer (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and Virtual Environments*, *7*(3), 225-240.

ACKNOWLEDGMENT

This research is part of the DEPICT project, funded by NWO Grant N 485-14-005. We thank the municipally of Utrecht for hosting the experimental work in the city hall. We thank Evelien Damhuis and Ellen Ootes for the assistance with the data collection.