universität wien

MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master‘s Thesis

„Infrastructural Determinants of Cycling Pleasure: How Physical Separation from Motorized Traffic and Impedance impact Enjoyment when Cycling in Urban Areas“

verfasst von / submitted by

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angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien, 2024 / Vienna 2024

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	UA 066 840
Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet:	Masterstudium Psychologie UG2002
Betreut von / Supervisor:	Univ. Prof. Dipl.-Psych. Sabine Pahl, MSc PhD

Abstract

Increasing the share of active transport modes such as cycling while decreasing the trips taken with cars has substantial benefits for the environment, physical health, and well-being. For such a shift, it is crucial to have adequate infrastructure that incentivizes utilitarian cycling. Research regarding the connection between infrastructural characteristics and the subjective cycling experience mainly focuses on negative emotions such as stress. However, it can be argued that enjoyment is an important motivator for utilitarian cycling as it is for physical activity generally. Thus, this study examined how the infrastructural characteristics, Physical Separation from motorized traffic and Impedance, affect enjoyment during cycling. Stress, perception of safety, and intention to cycle were also measured. The experiment was conducted with an online survey. All participants were shown four videos from the point of view of a cyclist driving in Vienna in a randomized order. The videos varied along the independent variables Physical Separation (Yes/No) and Impedance (Low/High). Each iteration of one variable was combined with each iteration of the other variable, making this a 2x2 within-subject experimental design. After every video, the participants were instructed to answer items to measure the dependent variables. A Repeated Measures ANOVA revealed significant main effects of Physical Separation on Enjoyment, Stress, Perception of Safety, and Intention to Cycle as well as significant main effects of Impedance on Enjoyment, Stress, and Intention to Cycle. However, significant interactions between Physical Separation and Impedance on all four dependent variables complicate the picture. Sometimes good conditions in both independent variables were necessary for favorable results, whereas in some cases good conditions in one were sufficient. Nevertheless, practical implications can still be drawn: Build cycling infrastructure that is separated from motorized traffic and that lets cyclists drive at their preferred speed for a better cycling experience in urban areas.

Introduction

Benefits for the environment as well as societal health and well-being warrant a shift from the current car-centric transport systems towards more cycling-friendly infrastructure. Climate change caused by greenhouse gas emissions already has a detrimental impact on human lives today (Ipcc, 2022). Roughly eleven percent of those emissions are caused by road transport, making private motorized transport a crucial driver of climate change (Lamb et al., 2021). More locally, a reduction in car trips can make cities more livable. Cars are a major source of air and noise pollution and thereby increase the risks for a vast array of diseases especially within cities (Singh et al., 2018; Suades-González et al., 2015). Furthermore, cars are an extremely space-ineffective mode of transport; a moving car takes up to 28 times more space than a moving cyclist and even 70 times more space than a moving pedestrian (Nello-Deakin, 2019). Given the evidence for the potential restorative effects of urban areas (Weber & Trojan, 2018), having such a space-ineffective predominant mode of transport likely reduces city planners´ abilities to take advantage of such potentials. Additionally, the pavement needed to accommodate cars in cities critically contributes to increased temperatures in urban areas compared to rural areas (Wong et al., 2011) resulting in increased mortality due to heat deaths for urban populations (Sera et al., 2019). Moreover, cars directly cause fatalities. Globally, around 1.3 million people per year die in traffic crashes making it the leading cause of death for people between the ages of five and 29 years (World Health Organization, 2018).

But individual transport choices do not only affect others, they also impact the people who are moving themselves. In contrast to driving, cycling comes with numerous health benefits such as increased cardiovascular fitness, improved aerobic power, and lower risk of all-cause and cardiovascular disease mortality (Oja et al., 2011). Furthermore, commuting not only affects physical health, it also impacts mental well-being. Generally commuting is seen as unpleasant (Kahneman & Krueger, 2006). However, research indicates that cycling as a mode of commuting has more positive effects on well-being compared to driving a car or taking public transportation (Chatterjee et al., 2020). Cyclists appear to be happier with their commutes than their motorized counterparts (Smith, 2017). Furthermore, the results of Schneider and Willman (2019) indicate that changing one´s mode of commuting to cycling increases commute satisfaction. Overall these findings suggest that cycling is an enjoyable mode of transport. This characteristic can be utilized by public officials to increase the share of utilitarian cycling since positive affect during physical activity is associated with a higher likelihood of future physical activity (Rhodes & Kates, 2015). Generally, there is a growing consensus in sports science literature that enjoyment is an important motivator for physical activity (Chen et al., 2021; Yli-Piipari et al., 2013). Hence, creating cycling infrastructure that enhances the enjoyability of bike rides would likely facilitate an uptake in cycling trips. However, when researchers look into the relationship between the affective experience during cycling and infrastructural features their main focus tends to be on negative emotions, especially stress (Lim et al., 2022). To complement the existing research I examined how certain infrastructural characteristics in urban areas affect enjoyment when cycling.

The first characteristic of interest is the existence or lack of a Physical Separation between cyclists and motorized traffic. Survey data suggests that having bike lanes with a physical separation from motorized traffic is a key motivator for cycling (Winters et al., 2011) and a lack of such separation is associated with a higher risk of injury (Lusk et al., 2011) and stress (Teixeira et al., 2020).

The second characteristic of interest is Impedance. Impedance is caused by any external factors that hinder a commuter´s movement toward their destination (Schaeffer et al., 1988) and can be operationalized with travel time and distance (e.g., Novaco et al., 1979). According to various studies, that focused on car commuters, high impedance is associated with increased stress (Chatterjee et al., 2020). For cyclists, the connection between impedance and stress or other affective states is not established; impedance is often defined differently

(Vale et al., 2015). However, anecdotal evidence suggests that part of the appeal of cycling is the playful attempt to maintain “continuous movement” or “flow” (Spinney, 2011). High impedance conditions would likely disrupt this feeling of flow and therefore joy.

Next to enjoyment, I also examined the effect of those characteristics on stress when cycling. Evidence for the association between no physical separation and increased stress already exists (Teixeira et al., 2020). This study tried to replicate these findings with a different methodology. The link between impedance and stress has only been demonstrated in car drivers (Chatterjee et al., 2020). The present study examined whether this link extends to cyclists. Furthermore, I investigated how physical separation and impedance affect the perception of safety as it is an important and commonly used measure for the evaluation of street designs (e.g., Huemer et al., 2022). At last, the intention to cycle was also measured to bridge the gap between subjective experience and volitional mechanisms.

Thus, I hypothesized that Physical Separation in comparison with No Physical Separation will lead to increased enjoyment (H1a), less stress (H1b), a higher perception of safety (H1c), and a heightened intention to cycle (H1d). Furthermore, I posited that Low Impedance in contrast to High Impedance would be associated with increased enjoyment (H2a), lower stress (H2b), and a heightened intention to cycle (H2d). Additionally, I examined the interaction between the effects of Physical Separation and Impedance on enjoyment, stress, perception of safety, and intention to cycle on an explorative basis.

Methods

To examine the effect of Physical Separation from motorized traffic and Impedance on Enjoyment, Stress, Perception of Safety, and Intention a pilot study and a main study were conducted. Both studies had the form of an online survey that showed the participants the same four videos. The only difference was that, in the pilot study, the participants had to answer some additional questions that were not presented in the main study. The purpose of those additional questions was to validate the independent variables Physical Separation as well as Impedance and to control for the potential confounding variables greenery, weather, and traffic. Furthermore, the data from the pilot study was used to calculate the correlation between repeated measures for the power analysis of the main study. Unless explicitly mentioned, the following descriptions apply to both studies.

Participants

For both studies, all people that are at least 18 years old were eligible to participate. In the pilot study, ten individuals, eight males and two females, participated. Their age was between 22 and 28 years old with a mean age of 25.6. However, three participants did not provide age information.

To find an appropriate sample size for the main study a power analysis with G*Power was conducted (Faul et al., 2007). For this analysis, I used the weakest reported effect size (η_p^2 = .060) of the subjective measures (subjective safety, stress, comfort) from study 2 of a paper by Huemer et al. (2022). Here, the study design, statistical analysis, and online format are similar to the present study. With a significance level of 5%, a statistical power of 95%, and a correlation between repeated measures of 0.133, which was calculated with the data from the pilot study, the recommended sample size was 60.

Overall 75 people participated in the study. However, 15 were excluded because they did not complete the survey and/or more than one answer was missing. This resulted in 60 participants whose answers were included in the analysis. Their age range was from 20 to 60 years old, with a mean age of 29.5 years. 24 of the respondents were male, 36 were female.

Procedure

In the pilot as well as the main study, the participants were shown four videos from the point of view of a cyclist, who is driving in the city of Vienna, which vary along the independent Variables Physical Separation (Yes/No) and Impedance (Low/High). These videos were presented to the participants through an online survey that was created with Qualtrics (https://www.qualtrics.com). In the distribution of the survey and the instruction text within the survey, it was emphasized that the participants should use a laptop or personal computer and be in a quiet place to have the ideal experience. Additionally, it was advised to use headphones if possible.

The online survey started with an instruction text. Then the first video was presented. After the video, the items for the dependent variables were displayed. In the pilot study participants also had to answer additional items for the validation of the independent variables and the controlling for potential confounding variables after each video. When a participant completed the items and pressed “continue”, the next video was shown. This process was repeated until the fourth video and its subsequent items. The order of the videos was randomized. In the end, items regarding demographic information and mobility behavior were presented. For my purposes, demographic information included age, gender, occupational status, and current place of residence; mobility behavior here meant the frequency of the participants' usage of cars, public transportation, walking, and cycling per week. After that, the participants were thanked for their time and debriefed on the last page of the survey.

Materials

The videos were filmed with a camera mounted on the researcher´s chest while he was riding on his bike on selected streets in Vienna. The camera used was a GoPro 8 with the brand´s supplied chest strap. To get the right angle, the camera was mounted on this strap upside down. Here, the goal was to simulate the point of view of a cyclist with the road ahead in the center, the surroundings on the sides, and the handlebars at the bottom. In the activity mode, the camera was set to a resolution of 2704 x 1520 pixels (2.7k) in a 16:9 aspect ratio, 60 frames per second, and a wide (16 – 34 mm) field of view. An illustration of the camera setup and a screenshot of a resulting video can be seen in Figure 1. As mentioned above, the videos varied along the independent variables Physical Separation (Yes/No) and Impedance (Low/High). To be more precise, each of the two iterations of one variable were combined with each of the two iterations of the other variable. This resulted in four videos with the

Figure 1

Illustration of the Camera Setup on the left and a Screenshot from a Video on the right

following combinations of variables: Physical Separation + Low Impedance, Physical Separation + High Impedance, No Physical Separation + Low Impedance, and No Physical Separation + High Impedance.

Measures

After each video, the same seven items for the dependent variables and instruction text were portrayed. The first four items aim at the dependent variable Enjoyment. These items are taken from the PACE-S (Chen et al., 2021) and modified for this study. The PACE-S is a shortened version of the Physical Enjoyment Scale and measures how much people enjoy being physically active. For the analysis, the average of those four items was used. Below them, one item for each of the other dependent variables, stress, perception of safety, and intention, was presented. The participants were asked to rate all items from “strongly disagree” to “strongly agree” on a five-point Likert scale.

The pilot study had five additional questions that were shown below the seven items for the independent variables. Of those 5, the first two aimed to validate the independent variables Physical Separation and Impedance. The other three controlled for the potential confounding variables greenery, weather, and traffic. An overview of all items can be seen in Table 1.

Table 1

Overview of the Items used in the Pilot and Main Study

Items with instruction that were used in both the main and the pilot study:
Imagine you are riding this section on a bike. Please indicate how much you agree to the following statements:
I would enjoy it (strongly disagree – strongly agree)
I would find it pleasurable (strongly disagree – strongly agree)
It would be very pleasant (strongly disagree – strongly agree)
It would feel good (strongly disagree – strongly agree)
It would be stressful (strongly disagree – strongly agree)
It would be safe (strongly disagree – strongly agree)
I would like to commute on my bike in such a section (strongly disagree – strongly agree)
Items that were only used in the pilot study:
How close are cyclists and motorized traffic on this section? (not close at all – very close)
How fast can a cyclist travel in this section? (not fast at all – very fast)
How much greenery is in this section? (very little – very much)
How is the weather in the video? (very bad – very good)

Experimental Design and Statistical Analysis

The study was conducted with a 2x2 within-subject design; the four videos combined two iterations of two variables and all participants were presented the same videos. This design resulted in a Repeated Measures ANOVA to test the main effects of the independent variables on the dependent variables and their interaction for significance.

Results

Pilot Study

Validating the Independent Variables

To assess whether the videos represent the independent variables adequately, the participants were asked to rate, for each video, the proximity between cyclists and motorized traffic as well as the speed a cyclist could travel. On average, sections with Physical Separation between cyclists and motorized traffic were rated less close (2.30 with High Impedance, 3.40 with High Impedance) than the ones with No Physical Separation (4.50 with High Impedance, 4.40 with Low Impedance). This indicates that the videos correctly represent the Variable (No) Physical Separation.

When asked about the speed at which a cyclist could travel, the conditions featuring Low Impedance were rated 4.30 with Physical Separation and 3.80 with No Physical Separation on average. In contrast, the sections with High Impedance received average ratings of 1.50 with Physical Separation and 3.30 with No Physical Separation. Thus, it seems that the videos correctly represent the categories Low/High Impedance.

Controlling for possible Confounding Variables

The pilot study included three items after each video to control for the potential confounding variables greenery, weather, and amount of traffic. Ideally, all videos should receive similar ratings here. The average ratings for greenery in the section were 2.80 (Physical Separation and Low Impedance), 1.40 (Physical Separation and High Impedance), 1.80 (No Physical Separation and Low Impedance), and 1.30 (No Physical Separation and High Impedance). The average appraisals for weather were 4.40 (Physical Separation and Low Impedance), 4.40 (Physical Separation and High Impedance), 4.50 (No Physical Separation and Low Impedance), and 3.90 (No Physical Separation and High Impedance). For the amount of traffic, those averages were 2.80 (Physical Separation and Low Impedance), 4.60 (Physical Separation and High Impedance), 3.00 (No Physical Separation and Low Impedance), and 3.60 (No Physical Separation and High Impedance).

Hence, the weather conditions seem relatively similar throughout the videos. In regards to greenery and the amount of traffic, there are some differences between the videos. This should be kept in mind when interpreting the results.

Main Study

An overview of all descriptive results can be seen in Table 2.

Enjoyment

After each video, the participants responded to four items as a measure of Enjoyment. The average of those items was then used for the analysis. To test the reliability and internal consistency between these four items, Cronbach´s alpha coefficient was calculated in each condition. For the condition with Physical Separation and Low Impedance, Cronbach´s alpha coefficient is .946, for the condition with Physical Separation and High Impedance it is .949, for the condition with No Physical Separation and Low Impedance it is .938, and for the condition with No Physical Separation and High Impedance it is .940. This suggests a very high consistency between the four items for Enjoyment and that they likely measure the same construct. However, the degree of consistency might also indicate that some of the items were redundant.

Table 2

Mean Ratings of the Dependent Variables in each Condition with the Standard Deviation in Parentheses

	Enjoyment	Stress	Perception of Safety	Intention to Cycle
Physical Separation Low Impedance	3.63 (0.94)	1.82 (0.97)	4.22 (0.96)	4.07 (1.10)
Physical Separation High Impedance	2.56 (0.95)	3.18 (1.27)	3.50 (1.00)	2.77 (1.23)
No Physical Separation Low Impedance	1.94 (0.82)	3.67 (1.10)	2.17 (0.96)	2.05 (1.00)
No Physical Separation High Impedance	2.36 (0.90)	3.53 (1.14)	2.62 (0.96)	2.27 (1.02)

In accordance with H1a, the main effect of Physical Separation on Enjoyment was significant (F (1,56) = 63.148, p < .001, η_p^2 = .530) – Physical Separation is associated with more Enjoyment in comparison to No Physical Separation. Similarly, the main effect of Impedance on Enjoyment (H2a) was also significant as previously assumed (F (1,56) = 13.062, p < .001, η_p^2 = .189). However, the Interaction between Physical Separation and Impedance was significant as well (F (1,56) = 66.926, p < .001, η_p^2 = .544).

Post-hoc paired samples t-tests showed that the difference between the conditions with Physical Separation and with No Physical Separation was significant in the conditions with Low Impedance (t (58) = 9.162, p < .001) but not with High Impedance (t (57) = 1.828, p = .073). The differences between the conditions with Low Impedance and High Impedance were both significant in the conditions with Physical Separation (t (58) = 7.368, p < .001) as well as with No Physical Separation (t (57) = -4.286, p < .001). However, these significant differences go in opposite directions: When there is Physical Separation, Low Impedance in comparison to High Impedance leads to higher enjoyment, whereas when there is No Physical Separation Low Impedance is associated with lower enjoyment compared to High Impedance. The former conforms with the hypothesis, the latter contradicts it. A visualization of the interaction between the effects of Physical Separation and Impedance can be seen in Figure 2.

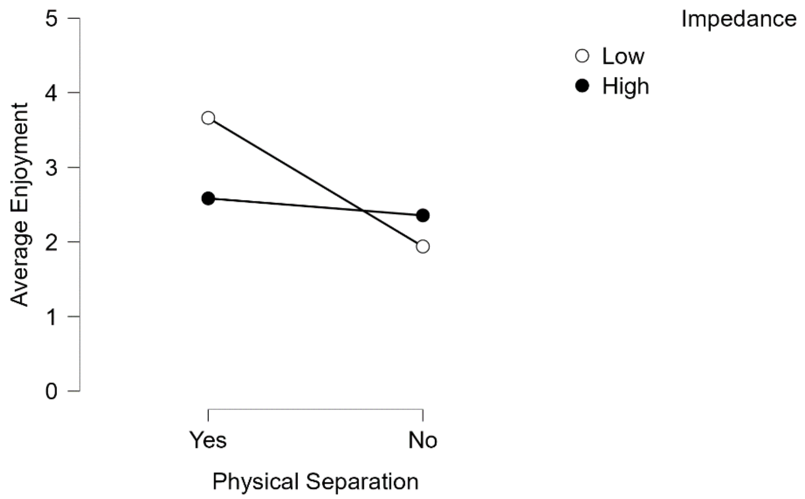
Stress

As hypothesized, both the main effects of Physical Separation (H1b) (F (1,59) = 46.609, p < .001, η_p^2 = .441) and Impedance (H2b) on Stress were significant (F (1,59) = 24.618, p < .001, η_p^2 = .294) – Physical Separation and Low Impedance were associated with lower Stress. Furthermore, the interaction between Physical Separation and Impedance was significant (F (1,59) = 37.749, p < .001, η_p^2 = .390).

In the post-hoc paired samples t-test, the difference between the conditions with Physical Separation and No Physical Separation was significant in the Low Impedance

Figure 2

The Interaction between the effects of Physical Separation and Impedance on Enjoyment



condition (t (59) = -2.532, p = .014) but not in the High Impedance Condition (t (59) = -1.888, p = .064). In a similar pattern as with the dependent variable Enjoyment, the differences between Low Impedance and High Impedance were both significant in the condition with Physical Separation (t (59) = -6.641, p < .001) and with No Physical Separation (t (59) = 0.984, p = .329) but in a different direction. Low Impedance was associated with lower Stress compared to High Impedance in the condition with Physical Separation; in the condition with No Physical Separation, it was vice versa. As before, the former is in accordance with the hypothesis, but the latter is not.

Perception of Safety

In keeping with H1c, the main effect of Physical Separation on the Perception of Safety was significant (F (1,59) = 126.006, p < .001, η_p^2 = .681) – sections with Physical Separation were perceived as safer than sections with No Physical Separation. There were no previous assumptions about the association between Impedance and Perception of Safety. Accordingly, the main effect of Impedance on the Perception of Safety was not significant (F (1,59) = 1.385, p = .244, η_p^2 = .023).

However, the interaction between the effects of Physical Separation and Impedance was significant ($F (1,59) = 23.581$, $p < .001$, $\eta_p^2 = .286$) leading to post-hoc paired samples t-tests for the effect of Physical Separation. Here, the differences between Physical Separation and No Physical Separation were significant in the Low Impedance condition ($t (59) = 10.503$, $p < .001$) as well as in the High Impedance condition ($t (59) = 5.597$, $p < .001$).

Intention to Cycle

Corresponding to H1d and H2d, both the main effects of Physical Separation ($F (1,59) = 106.269$, $p < .001$, $\eta_p^2 = .643$) and Impedance ($F (1,59) = 21.573$, $p < .001$, $\eta_p^2 = .268$) on the Intention to Cycle were significant. Furthermore, the interaction between these effects was also significant ($F (1,59) = 47.074$, $p < .001$, $\eta_p^2 = .444$).

In the subsequent post-hoc paired samples t-tests, the difference between Physical Separation and No Physical Separation was significant in the Low Impedance condition ($t (59) = 10.328$, $p < .001$) as well as in the High Impedance Condition ($t (59) = 3.940$, $p < .001$). However, the difference between Low Impedance and High Impedance was only significant in the condition with Physical Separation ($t (59) = 6.618$, $p < .001$) and not with No Physical Separation ($t (59) = -1.897$, $p = .063$).

Discussion

The present study aimed to examine the effects of Physical Separation and Impedance on the subjective cycling experience in urban areas. It was hypothesized that the existence of a Physical Separation would lead to higher enjoyment, lower stress, a higher perception of safety, and a higher intention to cycle. Similar effects were expected for Low Impedance (in contrast to High Impedance) with an exception for perception of safety; no assumptions were made here.

With a Repeated Measures ANOVA, significant main effects of both Physical Separation and Impedance on Enjoyment were found. However, the interaction between the two effects was significant as well. The subsequent post-hoc paired samples t-test showed that

Physical Separation only had a positive significant effect on Enjoyment in the condition with Low Impedance but not with High Impedance. The differences between Low and High Impedance were significant in both conditions with and without Physical Separation, but these differences went in a different direction; with Physical Separation, Low Impedance was associated with higher Enjoyment, with No Physical Separation it led to lower Enjoyment.

The main effects of Physical Separation and Impedance on Stress as well as their interaction were significant. In the following post-hoc paired samples t-test, the differences between Physical Separation and No Physical Separation turned out significant only with Low Impedance but not with High Impedance. The contrast between Low and High Impedance was significant with Physical Separation but not with No Physical Separation.

Physical Separation had a significant main effect on the Perception of Safety, whereas Impedance did not. However, the interaction between the two was significant again. According to the post-hoc paired samples t-test, Physical Separation had a significant positive effect on Perception of Safety both with Low and High Impedance.

The main effects of Physical Separation and Impedance on the Intention to Cycle as well as their interaction were significant. In the subsequent post-hoc paired samples t-tests, Physical Separation is associated with a higher Intention to Cycle both with Low and High Impedance. However, Low Impedance only led to a higher Intention to Cycle with a Physical Separation and not with No Physical Separation.

When examining the subjective cycling experience in relation to cycling infrastructure, physical separation is a popular feature for researchers. Previous research already links the lack of physical separation between motorized traffic and stress (Teixeira et al., 2020). The present study was able to replicate those findings by providing further evidence that no physical separation is associated with increased stress levels. Furthermore, a physical separation can be an important motivator for cycling (Winters et al., 2011). This is corroborated by the finding that a physical separation is linked with an increased intention to cycle. The lack of a physical separation does lead to a higher injury risk for cyclists (Lusk et al., 2011). It is beyond the scope of the present study to judge the safety implications of a physical separation. However, the results suggest that the participants felt less safe without a physical separation; given the previously mentioned evidence, a correct assessment. The link between a physical separation and enjoyment when cycling has not been in the focus of psychological research yet. Thus, this study was able to present new evidence that a physical separation is important for the enjoyment of cyclists in urban areas.

Research regarding the link between impedance and commuters´ subjective experience focused mainly on car drivers. Here, high impedance is especially associated with increased stress (Chatterjee et al., 2020). Thus, the present findings provide new evidence that high impedance may also lead to increased stress for cyclists. Enjoyment and the intention to drive/cycle has not yet been examined in either car drivers or cyclists. The current results begin to fill that gap and suggest that high impedance lowers cyclist enjoyment and intention to cycle.

The major takeaway of this study is that both Physical Separation and Impedance seem to play an important role in the subjective cycling experience as both affect enjoyment, stress, as well as the intention to cycle and Physical Separation additionally impacts the perception of safety. It is especially noteworthy that the results suggest that good conditions for both Physical Separation and Impedance are necessary for optimal outcomes. The video with Physical Separation and Low Impedance received the best ratings throughout. Furthermore, the post-hoc paired samples t-tests revealed a certain pattern for the dependent variables enjoyment and stress. Here, Physical Separation and Impedance only had a positive significant impact when the other independent variable was in its better condition (Low Impedance and Physical Separation). This was also true for the effect of Impedance on the intention to cycle. However, this pattern was not observable for the effects of Physical Separation on the perception of safety and the intention to cycle. In these cases, Physical

Separation seems to lead to positive outcomes regardless of the degree of Impedance. This suggests that Physical Separation can lead to an improved cycling experience independent of Impedance for those outcomes.

Oddly, the post-hoc paired samples t-test revealed that the section with No Physical Separation and Low Impedance was rated significantly lower for Enjoyment than the section with No Physical Separation and High Impedance. This was unexpected because, in light of a similar degree of physical separation, the better Impedance conditions should in theory lead to higher enjoyment. A possible explanation for this may be the fact that in the video with No Physical Separation and Low Impedance, the cyclist rides in the dooring zone. This means that on the right side of the bike lane are parallel parked cars. When a door of a car gets opened, a cyclist on that bike lane may collide with that door. In such conditions, this is a common type of accident involving cyclists and thus poses a real threat to them (Schimek, 2018). Furthermore, in a study about the heart rate variability of cyclists in relation to their perceived exposure to risk, a car door opening in front of a cyclist was among the incidents with the highest risk ratings (Doorley et al., 2015). Hence, this may plausibly explain why the video with No Physical Separation and Low Impedance received the worst rating for all four dependent variables.

This unexpected result also illustrates a broader limitation of the present study. The videos were filmed on real streets and not created in a laboratory. Thus, it was challenging to clearly designate the independent variables. The two videos with Physical Separation likely do not have the exact same degree of separation; the two videos with High Impedance do not have the exact same level of Impedance. The results of the pilot study indicate that the videos tend to portray the independent variables correctly but this portrayal is not completely precise. Additionally to the dooring zone, the pilot study also revealed potential confounding variables in the amount of traffic and greenery. If you take all of this into account it becomes clear that any theoretical conclusions from this study should be considered carefully. The general takeaway that both Physical Separation and Impedance affect the subjective cycling experience and that sometimes good conditions in both are necessary for optimal outcomes still stands but for more detailed interpretations further research is necessary.

Additionally, it should be mentioned that videos likely cannot bring across all aspects of cycling that are relevant for the subjective experience. A possible explanation for the better affective appraisals of commuting with a bike in contrast to driving a car or taking public transport is that cyclists experience the right amount of arousal (Gatersleben & Uzzell, 2007). The physical activity of cycling may contribute to that and a mere video from the view of a cyclist does not provide that. Cycling in real life also comes with a much broader perceptive experience that cannot be replicated through a video. Thus, research regarding Impedance when cycling in real life might be fruitful; examples for Physical Separation already exist (e.g., Teixeira et al., 2020).

There is already comprehensive knowledge about measures that can promote cycling (e.g., Pucher & Buehler, 2008). The present work provides further evidence that cycling facilities separated from motorized traffic likely bear more favorable outcomes than the approach of vehicular cycling (Reid, 2017). Furthermore, it emphasizes the importance of possible travel speed for cyclists. Traffic lights and congestion may be an obstacle for that. Thus, measures such as green waves for cyclists or providing them the right of way when feasible can improve the subjective cycling experience and thus promote cycling.

In the effort to make cities more livable, getting mobility issues right is arguably very important. Mobility crucially affects the air quality (Suades-González et al., 2015) and noise levels (Singh et al., 2018) within a city. Mobility infrastructure also plays an important role in making summers hotter in cities in comparison to rural areas (Wong et al., 2011). Having space-saving mobility infrastructure, lets city planners create more green spaces that evidently have many positive effects for humans (Kondo et al., 2018). In all of these issues, utilitarian cycling has the edge over driving a car. Bikes do not pollute, barely make noise and are a lot more space efficient (Nello-Deakin, 2019). Furthermore, commuting via bike positively affects your physical health (Oja et al., 2011) and seems to be more enjoyable than more sedentary transport modes (Chatterjee et al., 2020). Often, the question of lifestyle changes in light of the climate crisis is: How much are we willing to give up? Here, it seems that there is actually more to gain than lose.

References

Chatterjee, K., Chng, S., Clark, B., Davis, A., De Vos, J., Ettema, D., Handy, S., Martin, A., & Reardon, L. (2020). Commuting and wellbeing: A critical overview of the literature with implications for policy and future research. *Transport Reviews*, *40*(1), 5–34. https://doi.org/10.1080/01441647.2019.1649317

Chen, C., Weyland, S., Fritsch, J., Woll, A., Niessner, C., Burchartz, A., Schmidt, S. C. E., & Jekauc, D. (2021). A Short Version of the Physical Activity Enjoyment Scale: Development and Psychometric Properties. *International Journal of Environmental Research and Public Health*, *18*(21), 11035. https://doi.org/10.3390/ijerph182111035

Doorley, R., Pakrashi, V., Byrne, E., Comerford, S., Ghosh, B., & Groeger, J. A. (2015). Analysis of heart rate variability amongst cyclists under perceived variations of risk exposure. *Transportation Research Part F: Traffic Psychology and Behaviour*, *28*, 40–54. https://doi.org/10.1016/j.trf.2014.11.004

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/BF03193146

Gatersleben, B., & Uzzell, D. (2007). Affective Appraisals of the Daily Commute: Comparing Perceptions of Drivers, Cyclists, Walkers, and Users of Public Transport. *Environment and Behavior*, *39*(3), 416–431. https://doi.org/10.1177/0013916506294032

Huemer, A. K., Rosenboom, L. M., Naujoks, M., & Banach, E. (2022). Testing cycling infrastructure layout in virtual environments: An examination from a bicycle rider's perspective in simulation and online. *Transportation Research Interdisciplinary Perspectives*, *14*, 100586. https://doi.org/10.1016/j.trip.2022.100586

Ipcc. (2022). *Global Warming of 1.5°C: IPCC Special Report on Impacts of Global Warming of 1.5°C above Pre-industrial Levels in Context of Strengthening Response to Climate*

Change, Sustainable Development, and Efforts to Eradicate Poverty (1st ed.). Cambridge University Press. https://doi.org/10.1017/9781009157940

Kahneman, D., & Krueger, A. B. (2006). Developments in the Measurement of Subjective Well-Being. *Journal of Economic Perspectives*, *20*(1), 3–24. https://doi.org/10.1257/089533006776526030

Kondo, M., Fluehr, J., McKeon, T., & Branas, C. (2018). Urban Green Space and Its Impact on Human Health. *International Journal of Environmental Research and Public Health*, *15*(3), 445. https://doi.org/10.3390/ijerph15030445

Lamb, W. F., Wiedmann, T., Pongratz, J., Andrew, R., Crippa, M., Olivier, J. G. J., Wiedenhofer, D., Mattioli, G., Khourdajie, A. A., House, J., Pachauri, S., Figueroa, M., Saheb, Y., Slade, R., Hubacek, K., Sun, L., Ribeiro, S. K., Khennas, S., De La Rue Du Can, S., … Minx, J. (2021). A review of trends and drivers of greenhouse gas emissions by sector from 1990 to 2018. *Environmental Research Letters*, *16*(7), 073005. https://doi.org/10.1088/1748-9326/abee4e

Lim, T., Kalra, A., Thompson, J., Caldwell Odgers, J., & Beck, B. (2022). Physiological measures of bicyclists' subjective experiences: A scoping review. *Transportation Research Part F: Traffic Psychology and Behaviour*, *90*, 365–381. https://doi.org/10.1016/j.trf.2022.09.007

Lusk, A. C., Furth, P. G., Morency, P., Miranda-Moreno, L. F., Willett, W. C., & Dennerlein, J. T. (2011). Risk of injury for bicycling on cycle tracks versus in the street. *Injury Prevention*, *17*(2), 131–135. https://doi.org/10.1136/ip.2010.028696

Nello-Deakin, S. (2019). Is there such a thing as a 'fair' distribution of road space? *Journal of Urban Design*, *24*(5), 698–714. https://doi.org/10.1080/13574809.2019.1592664

Novaco, R. W., Stokols, D., Campbell, J., & Stokols, J. (1979). Transportation, Stress, and Community Psychology. *American Journal of Community Psychology*, *7*(4), 361–380. https://doi.org/10.1007/BF00894380

Oja, P., Titze, S., Bauman, A., de Geus, B., Krenn, P., Reger-Nash, B., & Kohlberger, T. (2011). Health benefits of cycling: A systematic review: Cycling and health. *Scandinavian Journal of Medicine & Science in Sports*, *21*(4), 496–509. https://doi.org/10.1111/j.1600-0838.2011.01299.x

Pucher, J., & Buehler, R. (2008). Making Cycling Irresistible: Lessons from The Netherlands, Denmark and Germany. *Transport Reviews*, *28*(4), 495–528. https://doi.org/10.1080/01441640701806612

Reid, C. (2017). The Rise and Fall of Vehicular Cycling. In C. Reid, *Bike Boom* (pp. 143–160). Island Press/Center for Resource Economics. https://doi.org/10.5822/978-1-61091-817-6_7

Rhodes, R. E., & Kates, A. (2015). Can the Affective Response to Exercise Predict Future Motives and Physical Activity Behavior? A Systematic Review of Published Evidence. *Annals of Behavioral Medicine*, *49*(5), 715–731. https://doi.org/10.1007/s12160-015-9704-5

Schaeffer, M. H., Street, S. W., Singer, J. E., & Baum, A. (1988). Effects of Control on the Stress Reactions of Commuters1. *Journal of Applied Social Psychology*, *18*(11), 944–957. https://doi.org/10.1111/j.1559-1816.1988.tb01185.x

Schimek, P. (2018). Bike lanes next to on-street parallel parking. *Accident Analysis & Prevention*, *120*, 74–82. https://doi.org/10.1016/j.aap.2018.08.002

Schneider, R. J., & Willman, J. L. (2019). Move closer and get active: How to make urban university commutes more satisfying. *Transportation Research Part F: Traffic Psychology and Behaviour*, *60*, 462–473. https://doi.org/10.1016/j.trf.2018.11.001

Sera, F., Armstrong, B., Tobias, A., Vicedo-Cabrera, A. M., Åström, C., Bell, M. L., Chen, B.-Y., de Sousa Zanotti Stagliorio Coelho, M., Matus Correa, P., Cruz, J. C., Dang, T. N., Hurtado-Diaz, M., Do Van, D., Forsberg, B., Guo, Y. L., Guo, Y., Hashizume, M., Honda, Y., Iñiguez, C., … Gasparrini, A. (2019). How urban characteristics affect vulnerability to heat and cold: A multi-country analysis. *International Journal of Epidemiology*, *48*(4), 1101–1112. https://doi.org/10.1093/ije/dyz008

Singh, D., Kumari, N., & Sharma, P. (2018). A Review of Adverse Effects of Road Traffic Noise on Human Health. *Fluctuation and Noise Letters*, *17*(01), 1830001. https://doi.org/10.1142/S021947751830001X

Smith, O. (2017). Commute well-being differences by mode: Evidence from Portland, Oregon, USA. *Journal of Transport & Health*, *4*, 246–254. https://doi.org/10.1016/j.jth.2016.08.005

Spinney, J. (2011). A Chance to Catch a Breath: Using Mobile Video Ethnography in Cycling Research. *Mobilities*, *6*(2), 161–182. https://doi.org/10.1080/17450101.2011.552771

Suades-González, E., Gascon, M., Guxens, M., & Sunyer, J. (2015). Air Pollution and Neuropsychological Development: A Review of the Latest Evidence. *Endocrinology*, *156*(10), 3473–3482. https://doi.org/10.1210/en.2015-1403

Teixeira, I. P., Rodrigues da Silva, A. N., Schwanen, T., Manzato, G. G., Dörrzapf, L., Zeile, P., Dekoninck, L., & Botteldooren, D. (2020). Does cycling infrastructure reduce stress biomarkers in commuting cyclists? A comparison of five European cities. *Journal of Transport Geography*, *88*, 102830. https://doi.org/10.1016/j.jtrangeo.2020.102830

Vale, D. S., Saraiva, M., & Pereira, M. (2015). Active accessibility: A review of operational measures of walking and cycling accessibility. *Journal of Transport and Land Use*. https://doi.org/10.5198/jtlu.2015.593

Weber, A. M., & Trojan, J. (2018). The Restorative Value of the Urban Environment: A Systematic Review of the Existing Literature. *Environmental Health Insights*, *12*, 117863021881280. https://doi.org/10.1177/1178630218812805

Winters, M., Davidson, G., Kao, D., & Teschke, K. (2011). Motivators and deterrents of bicycling: Comparing influences on decisions to ride. *Transportation*, *38*(1), 153–168. https://doi.org/10.1007/s11116-010-9284-y

Wong, N. H., Jusuf, S. K., Syafii, N. I., Chen, Y., Hajadi, N., Sathyanarayanan, H., & Manickavasagam, Y. V. (2011). Evaluation of the impact of the surrounding urban morphology on building energy consumption. *Solar Energy*, *85*(1), 57–71. https://doi.org/10.1016/j.solener.2010.11.002

World Health Organization. (2018). *Global status report on road safety 2018*. World Health Organization. https://apps.who.int/iris/handle/10665/276462

Yli-Piipari, S., Barkoukis, V., Jaakkola, T., & Liukkonen, J. (2013). The effect of physical education goal orientations and enjoyment in adolescent physical activity: A parallel process latent growth analysis. *Sport, Exercise, and Performance Psychology*, *2*(1), 15–31. https://doi.org/10.1037/a0029806

Appendix

Abstract (German Version)

Mit einer vermehrten Verwendung aktiver Verkehrsmittel wie Fahrradfahren und einer gleichzeitigen Reduktion von Autofahrten kommen erhebliche Vorteile für die Umwelt sowie für die menschliche Gesundheit und Wohlbefinden. Um alltägliches Fahrradfahren zu fördern, ist eine adäquate Infrastruktur zentral. Der Fokus der Forschung bezüglich des Zusammenhangs zwischen Infrastruktureigenschaften und dem Radfahrerlebnis liegt hauptsächlich auf negativen Emotionen wie Stress. Allerdings liegt es nahe, dass Freude ein wichtiger Motivator für das Radfahren ist, wie bei körperlicher Aktivität generell. In dieser Studie wurde daher untersucht, wie die Infrastruktureigenschaften, physische Trennung vom motorisierten Verkehr und Widerstand, die Freude beim Radfahren beeinflussen. Stress, Sicherheitswahrnehmung und die Intention fahrradzufahren wurden ebenfalls gemessen. Mittels einer Online-Umfrage wurde allen Teilnehmenden vier Videos in zufälliger Reihenfolge aus der Perspektive eines Radfahrers gezeigt. Die Videos variierten entlang der unabhängigen Variablen Physische Trennung (Ja/Nein) und Widerstand (Niedrig/Hoch). Aus den vier Kombinationsmöglichkeiten ergab sich ein 2x2 experimentelles Versuchsdesign. Nach jedem Video wurden die Teilnehmenden aufgefordert, Fragen zu beantworten, um die abhängigen Variablen zu messen. Eine Repeated Measures ANOVA ergab signifikante Haupteffekte der physischen Trennung auf Freude, Stress, Sicherheitswahrnehmung und Intention fahrradzufahren sowie signifikante Haupteffekte von Widerstand auf Freude, Stress und Intention fahrradzufahren. Signifikante Interaktionen zwischen physischer Trennung und Widerstand bei allen vier abhängigen Variablen zeigen jedoch, dass manchmal gute Bedingungen in beiden unabhängigen Variablen für günstige Ergebnisse notwendig waren, während in einigen Fällen gute Bedingungen in einer ausreichten. Für die Praxis lässt sich ableiten, dass sowohl eine physische Trennung von motorisierten Verkehr als auch geringer Widerstand in der Radinfrastruktur zu einem positiven Radfahrerlebnis beitragen.