What Makes You Bike? Exploring Persuasive Strategies to Encourage Low-Energy Mobility

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Abstract. This paper explores three persuasive strategies and their capacity to encourage biking as a low-energy mode of transportation. The strategies were designed based on: (I) triggering messages that harness social influence to facilitate more frequent biking, (II) a virtual bike tutorial to increase biker's self-efficacy for urban biking, and (III) an arranged bike ride to help less experienced bikers overcome initial barriers towards biking. The potential of these strategies was examined based on self-reported trip data from 44 participants over a period of four weeks, questionnaires, and qualitative interviews. Strategy I showed a significant increase of 13.5 percentage points in share of biking during the intervention, strategy II indicated an increase of perceived self-efficacy for non-routine bikers, and strategy III provided participants with a positive experience of urban biking. The explored strategies contribute to further research on the design and implementation of persuasive technologies in the field of mobility.

Keywords: Low-energy mobility · Persuasion · Biking · Cycling · Behavior change · Transportation · Sustainability · Socially influencing systems

1 Introduction

Cities around the world are growing at an unprecedented pace, creating a manifold of new opportunities to meet and exchange ideas and goods. At the same time, however, they generate more traffic. Creating a transport system that supports high-quality life in urban areas requires shifting from high-energy modes of transportation, such as private cars or even public transport, to sustainable low-energy urban mobility, such as walking and biking [21]. Doing so reduces emissions of greenhouse gases, provides health benefits, and enhances the quality of urban life. However, an adoption of new modes of transportation requires a substantial behavior change [11]. Beyond hard policy measures, persuasive strategies embedded in technologies can be useful in facilitating such behavioral change [8],[12],[19]. The aim of this work is to explore such strategies and suitable technologies to promote sustainable low-energy mobility.

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A promising low-energy mode for urban mobility is biking, as it is easily accessible, fast, low-cost, and uses less space than most other modes of transportation. Although previous work has covered mode choices and bike use, little attention has been paid to a change of choice from high-energy modes to biking as a low-energy mode and how this can be supported by persuasive technologies. Heinen et al. [14] classified five groups of determinants for bike commuting. Amongst them are psychological factors; these are attitudes, perceived social norms and habits, which can be at the center of persuasive strategies. Gatterslaben & Appleton [13] applied the transtheoretical model of behavior change [18] to bike commuting. Their findings suggest that different strategies are needed depending on current attitudes and behavior of individuals. Froehlich et al. [9] developed a mobile phone application that semi-automatically sensed and revealed information about transportation behavior. In combination with a personal ambient display, the app engaged users with the goal of increasing green transportation choices (e.g. walking, biking, public transport). Although some statements from qualitative interviews indicated the willingness for such change, no evaluation of actual change in mobility behavior was conducted. A similar but more recent study by Gabrielli and Maimome [10] examined the effect of a mobile app on supporting eco transport choices by citizens of an urban area. The transport choices and habits of the participants were influenced with several persuasion strategies and an overall increase of sustainable transport choices of 14%, as well as a higher environmental awareness among participants, was observed. However, the study design did not include a control group to better attribute behavior change to the experimental intervention. Even more recently, Flüchter et al. [7] found a positive impact of social normative feedback on e-bike commuting.

In accordance with the literature [14], a preliminary survey conducted at the beginning of this research showed that safety concerns are one of the main barriers for adapting biking as a regular mode of transportation. Therefore, the strategies in this study were designed with a focus on perceived safety of biking. All study participants were given access to bikes in order to prevent issues with bike availability and to concentrate research on motivational aspects.

The research question tackled in this paper is: What types of persuasive strategies can lead to a modal shift towards low-energy mobility by increasing bike use? Three different strategies were designed and evaluated in a pretest-posttest control group experimental design.

Section 2 presents the developed persuasive strategies. Section 3 describes the data collection and data analysis. Results are shown in section 4 and discussed in section 5. The paper ends with a conclusion and an outlook towards future research in section 6.

2 Deployed Persuasive Strategies

We designed and developed three strategies for this study.

Strategy I: Frequent Biking Challenge

In this strategy, the following principles of persuasion (see also [6], [8], [20]) have been combined: triggering, recognition, competition, cooperation, and comparison. The overall hypothesis is that this strategy increases bike use.

Triggering. Participants received emails (Fig. 1) between 3 to 5 times a week, providing them with information about their performance in the challenge and acting as a trigger for biking [8]. Emails were chosen as they are likely to be regularly read as opposed to a webpage or a mobile app providing the same information. They were sent in the evening to influence mobility planning for the next day. The regular email updates also contained a set of notifications tailored to each participant, such as daily weather forecasts and entertaining elements. The purpose of these notifications was to keep the sent emails useful and engaging for the participants. Additionally, the emails provided motivational facts about biking and suggestions on when to use a bike.

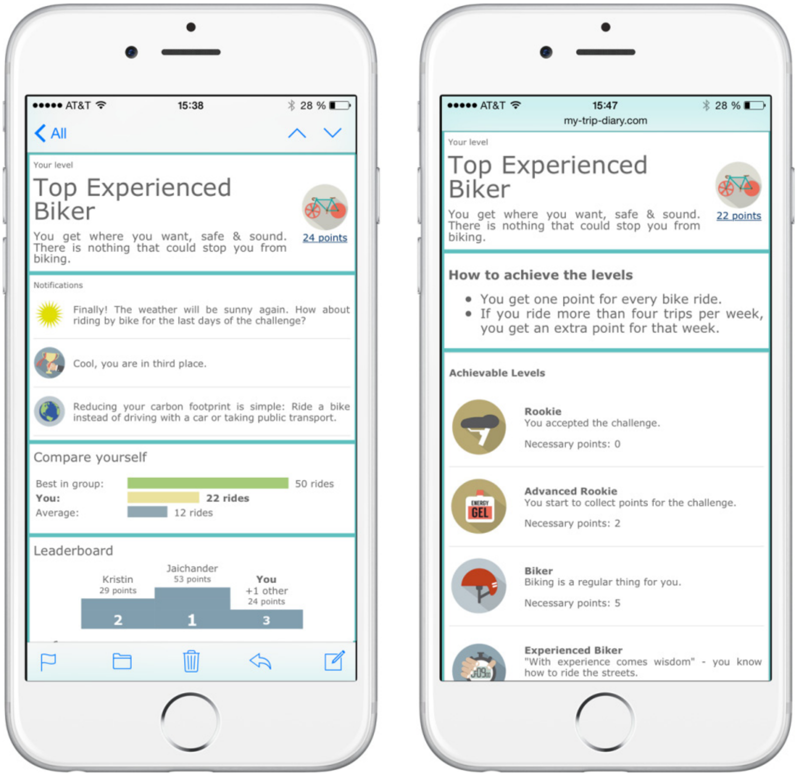

Fig. 1. Left: Regularly sent email updates: Notifications, comparison chart and leaderboard. Right: Explanation of the point scheme and achievable levels within the Frequent Biking Challenge.

Recognition. Based on the number of reported bike trips, participants received points and were awarded different statuses depending on the total number of points. These status levels had titles, were visualized with images and had an exploratory slogan. For example, participants achieving 5 points were recognized with the status "Experienced Biker" and the slogan: "With experience comes wisdom. You know how to ride the streets." Such recognition typically increases enjoyment [4] and influences future behavior [15].

Competition. The email updates furthermore included a leaderboard, showing one's own rank based on the achieved points in comparison to the other participants of the group. It was visualized with a podium for places 1, 2 and 3, followed by a list of the other ranks. Such salient metrics for people to observe their performances among other participants typically promotes competition, which consequently influences their thoughts and behavior [15].

Cooperation. At start, a collective goal (achieving 100 points collectively) was included in the email to facilitate cooperation among participants [15]. This was visualized with a bar graph that showed the sum of points from all participants and how much more were needed to reach the collective goal. The collective goal was reached in the second week of the challenge. Four days later it was replaced with the "compare yourself" comparison chart.

Social Comparison. The "compare yourself" design element allowed participants to compare their number of their bike rides to the average of bike rides and the best participant within the group. This possibly influences motivation as people tend to look for self-enhancement [22] and self-improvement [6],[23].

Strategy II: Virtual Bike Tutorial

The concept of perceived self-efficacy "is concerned with judgments of how well one can execute courses of action required to deal with prospective situations" [3]. Prior studies, such as Chittaro [5], used a persuasive game to increase the perceived self-efficacy[1] of passengers in the situation of an aircraft accident. In this study, the concept of perceived self-efficacy was used in relation to perceived risk and safety, thereby assessing how users perceive their control over their own safety in a biking context. The related assumption is that an increased self-efficacy towards biking will help to overcome safety barriers and hence encourage more biking.

Participants were provided with a short video tutorial on safe urban biking. The safety related information is based on safety guidelines from city officials from New York City, Boston and Vienna. The core concept of the training session is based on the content of a city biking school program. An expert-interview with an experienced biking instructor was conducted in order to gain knowledge on how biking in the city can be taught most effectively to novice bikers.

After the tutorial, a participant should experience the effects of different biking-related decisions in an interactive video training session. The procedure started with a first-person-view video where the participant saw a typical biking scene. The video was then stopped and the participants had to decide on how to continue the ride. (Fig. 2) The consequences of each possible decision were shown in a subsequent video. Different real-life scenarios (e.g. conflict with pedestrian) were tested and partici-

[1] Chittaro referred to it as "safety locus of control". See Ajzen [1] for a discussion on the difference between these concepts.

pants could learn about the consequences of their decisions. An increase of perceived self-efficacy due to that intervention was expected. To measure that, a self-efficacy in biking questionnaire[2] had to be completed by the participant before and after the video training session. The same questionnaire was also included in the survey at the end of the experimental period.

Fig. 2. Screenshot of the Virtual Bike Tutorial showing a conflict situation with a pedestrian

Strategy III: Bike Buddy Program

The start of a new physical exercise is often supported by an experienced person such that guidance and training is provided. In order to apply this kind of learning to the biking context, participants received a one time "bike buddy experience". The hypothesis in this regard is that for novice bikers, the experience of biking in an urban environment will change the perceived safety and risk of doing so. It was expected that this would lead to more positive attitudes towards biking and an overall increase of biking within the participants.

Bike buddies were recruited out of the potential participants for this study who were regular bikers and comfortable biking with new bikers. Bike buddies and participants were matched based on where they live and what routes they usually take. The bike buddies furthermore received instructions for the ride, covering safety aspects and clarifying the goal of showing the participant a safe and enjoyable biking route. They therefore were asked to find a safe and easy route for the planned bike ride and preferable inspect this route prior to the ride. They were also requested to set up a meeting point (ideally at the participant's home) for conducting the ride.

Several persuasive principles were implemented [6],[8]. ***Authority***, by having the bike buddy as a guide for the bike ride. ***Reduction***, by reducing the effort of the user to find a safe route (complex behavior) in the city to a simple behavior (follow the bike buddy). ***Tunneling***, by guiding participants along the route and allowing them to

[2] Items were adapted from a self-efficacy in driving questionnaire. [2]

experience the potential benefits of biking. Finally, ***tailoring***, by providing tailored information and personalized support to the user.

3 Data Collection and Analysis

The experiment took place in Cambridge/Boston, Massachusetts area over the period of four weeks in October 2014. A sample of 44 participants continually reported their trip data on a daily basis.

3.1 Sample

Study participants were recruited primarily through mailing lists at the Massachusetts Institute of Technology (MIT). The ideal participants were non-routine bikers (biking not more than three times a week). 55 participants met that requirement and were randomly assigned to one of three experimental groups or the control group. Typical route distance was not included as selection criteria, but as potential participants knew that they would join a biking related study it is likely that people with longer routine routes were less prone to join.

Participants were primarily part of the MIT community. Students made up a large portion of the sample. Therefore, the study sample is not representative of a broader population. Furthermore, the sample most likely exhibits self-selection bias. The process by which participants were recruited encourages those who want to bike, but do not have the means to do so, to join.

44 participants reported their trip data continuously over the period of four weeks. Group sizes were n=12 for (I) Frequent Biking Challenge, n=11 for (II) Virtual Bike Tutorial, n=11 for (III) Bike Buddy Program and n=10 for the control group. Out of all participants, 33 had no access to a bike and were provided with a one-month local bike sharing scheme subscription. 24 participants were provided with a helmet. As prior research shows that there are significant gender differences regarding utilitarian bike use [14], the sample should be balanced in terms of gender. The 44 participants that continually reported their trip data consisted of 22 women and 22 men.

3.2 Data Collection

Participants reported their trips on a daily basis. The collected mobility data included trip purpose and used mode(s). Participants were provided with a web-application that sent the data to a webserver with a relational database. To get continuous trip data, participants were automatically reminded via email in case they forgot to input their trips for the day. The trip diary included a calendar to navigate through the days, a help section, and a statistics graphic where users could see the amount of reported trips and how they were distributed among different modes of transportation. A settings section allowed the users to set a time for the daily reminders, put in custom trip purposes and to set their time zone.

Online questionnaires were used to measure perceived risk and perceived safety in biking at the beginning and end of the experimental period. Open questions were also included at the final questionnaire to ask for perceived behavior change. Interviews were conducted in order to gain further insight on the effect of the strategies. Six participants and six bike buddies from the Bike Buddy Program, two participants of each the Frequent Biking Challenge, the Virtual Bike Tutorial and the control group agreed to be interviewed after the experimental period.

3.3 Data Analysis

Analysis of Quantitative Trip Data. Based on the self-reported mobility data the modal split between modes was computed per person per day. To correct for bad weather, all days with precipitation above average were excluded from the analysis.[3] As can be seen in (1), the difference between the daily bike share of each participant of an experimental group $y_{g,d}$ and the mean of daily bike share within the control group $\bar{y}_{c,d}$ was computed for each day. The sum of these daily differences was divided by the number of days N_{pre} before or N_{post} after the (start of the) intervention.

$$z_{g,pre} = \frac{1}{N_{pre}} \sum_{d=1}^{N_{pre}} \left(y_{g,d} - \bar{y}_{c,d}\right) \ , \ z_{g,post} = \frac{1}{N_{post}} \sum_{d=1}^{N_{post}} \left(y_{g,d} - \bar{y}_{c,d}\right) \quad (1)$$

As can be seen in (1), the result is a value for average bike-share above control per participant before the intervention $z_{g,pre}$ and after the (start of the) intervention $z_{g,post}$. This approach provides a per-day correction of data which is more accurate than just comparing uncorrected per participant pre- and post-intervention mean values between experimental and control group.[4] Based on the computed values a one-sided paired sample t-test[5] was used to test the hypothesis of an increase in bike-share above the control group value.

As an indicator for the dependence between the share of biking and the share of high-energy modes Pearson r correlations have been computed at per participant level. To test for a difference in the means of perceived risk and perceived safety scores, a paired sample t-test was conducted.

Analysis of Qualitative Interview and Questionnaire Data. Qualitative content analysis [16] was used to analyze data obtained through ex-post-interviews and open question surveys. Category application was carried out in a deductive way, with aspects of analysis based on existing theoretical and empirical work.

4 Results

The effect of the presented strategies on actual bike use has to be viewed in light of many other factors with influence in this regard. The analysis of the gathered qualita-

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[3] Weather data from NOAA [0] was used for that. Average precipitation was 4.8 mm.

[4] For that reason, the common method for pre post control designs of ANCOVA (analysis of covariance) was not applied.

[5] Shapiro-Wilk tests were conducted prior to all t-tests to check for normal distribution.

tive data showed that good biking infrastructure, such as protected bike lanes, makes biking more attractive and is perceived as safe. Knowing a route with good cycling infrastructure or otherwise comfortable interaction with motorized traffic helped participants to bike. Travel distance and difference in travel time compared to other possible modes of transportation played another crucial role. The analysis of the interviews suggests, that participants who could gain significant time savings by taking a bike instead of walking or using public transportation were more motivated to bike. Financial aspects like the upfront costs of buying a bike or the cost of using a bike sharing scheme were also taken into consideration, especially by the financially constrained study participants. For actual day to day bike use, situational factors such as weather, having to wear elegant clothing or having a lot to carry was reported as influential for the decision on whether or not to bike.

The reported mobility data showed an overall increase of bike trips that was mainly fueled by the participants that were provided with access to bikes. Participants with positive experiences while trying out biking subsequently considered buying a bike in the future. The study-participation and especially the use of the trip diary raised general awareness of biking and the experimental period was described as a time of personal reflection on mobility. One participant mentioned: “I also now consider what form or transportation I take before I take it because the trip diary made me consider the different forms of transportation.” Another one reported that she wanted to show that she is able to bike more. A self-monitoring effect was also reported by other participants. One told that he was regularly checking the provided statistics in the trip diary out of curiosity to see his personal statistics. But thinking actively about possible modes of transportation made participants also more aware of problems associated with urban biking: “I watched people get checked by car doors all the time and other bikers not obey lights or pedestrians”.

As for perceived safety and risk, the hypothesis has been that for non-routine bikers the experience of biking in an urban environment will lead to an increase in perceived safety and decrease in perceived risk of doing so. However, comparing the scores of these two variables for the beginning and end of the experimental period did not show a change.

4.1 Mode Shifts

The analysis on an individual level provides an overview on how the share of modes shifted. A change in mobility patterns towards more biking could be rooted in a decrease in use of high-energy modes (car and public transportation), but could also stem from a decrease in walking. The former is of special interest for this research. Pearson r correlations have been calculated as a basic indicator for the dependence of mode share over the four weeks in which the mobility data was recorded. These correlations show a statistically significant ($p<.05$) negative dependency of bike use and use of high-energy modes for at least 16 out of 44 (36%) participants, ranging from $r=-.97$ to $r=-.40$. As can be expected there are also statistically significant ($p<.05$) negative correlations between bike use and walking for 13 out of 44 (30%) participants, ranging from $r=-.94$ to $r=-.41$.

4.2 Strategy I: Frequent Biking Challenge

As shown in Fig 3, an increase in bike share occurred. It rose from 2% in week one to 15% in week two to 33% in week three. Week four showed a decrease to 23%. The change from pre- to during-intervention values of bike share was 13.5 percentage points[6] above the control group at statistically significant levels (p=0.03). Results based on interviews show that the constant reminders of possible mobility choices and the trip diary, which separated mobility patterns into several smaller parts, helped a participant "break the prospect of biking to/from down into achievable goals for myself, e.g. bike from home to the train station or from the train to work […]" The daily reminders were described as interesting and funny. The interviews also inform that cooperation and competition could have been more effective when involving social ties to other participants in the group.

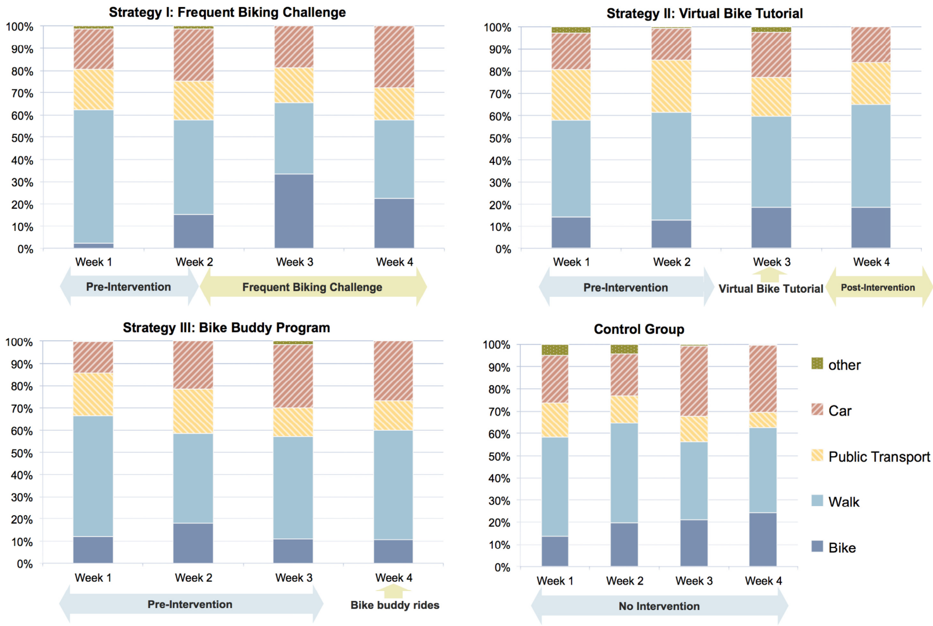

Fig. 3. Modal split during the experimental period

4.3 Strategy II: Virtual Bike Tutorial

The participants in the self-efficacy group conducted the tutorial in weeks two and three of this study. The results demonstrate an increase of biking share within all trips after the intervention from about 14% in week one and two to 19% in weeks three and four. When compared to control group shares, the change in bike use is not statistically significant for this strategy.

6 These values refer to percentage points within the modal split.

Self-efficacy of participants that reported lower levels at the beginning of the intervention showed a slight increase. (Fig. 4) However, on average, no clear rise in perceived biking self-efficacy emerged. In line with that, the conducted interviews suggest that the tutorial content was more suited for people without prior biking experience whereas regular bikers did not perceive the scenarios as challenging and could not learn from them. As for the design of the intervention, participants underlined the experience as realistic and immersive.

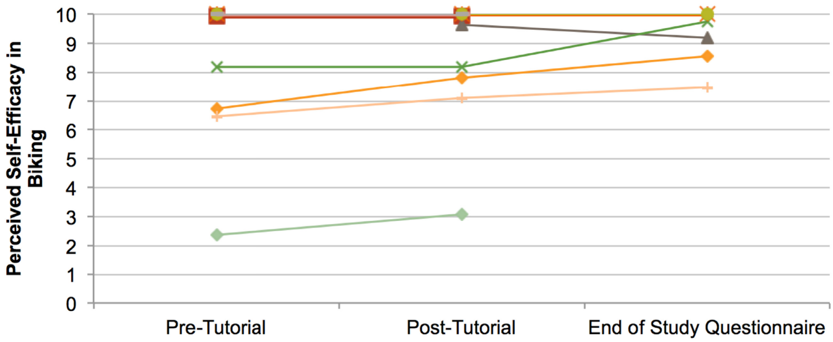

Fig. 4. Perceived self-efficacy in biking. Each line represents one participant.

4.4 Strategy III: Bike Buddy Program

Due to difficulties with scheduling, only six participants did the bike buddy rides in week 4 or after. Because the rides took place so late, no post-intervention trip data is available. The participants reported a positive experience with their "bike buddies" and perceived this strategy to be valuable for new bikers. In addition, they provided several suggestions on how this strategy could be improved. However, no clear rise in intention to bike more in the future emerged. The bike buddies were overall satisfied with helping less experienced bikers to overcome their fears and barriers. This indicates that voluntary work can be utilized in this matter.

5 Discussion

Strategy I (Frequent Biking Challenge) resulted in a significant increase in bike use above control group levels. To improve this strategy, the individual effect of the included principles should be studied. The gathered qualitative data at least suggests that competition and the collective goal elements should be designed in a way to allow social comparison also with familiar besides unknown participants. Notably, this strategy was the only one out of three that lasted for a long period of time (20 days), conveyed several main principles of socially influencing systems [20], and it used messages dependent on the actual behavior of participants, as recommended by Gatersleben & Appleton [13].

Although the design of strategy II (Virtual Bike Tutorial) was described as an immersive experience, it should be examined how to achieve a higher rise in perceived self-efficacy. Furthermore, it remains unclear if this change will actually lead to an increase in bike use. Due to scheduling issues and subsequent low actual participation the effect of strategy III (Bike Buddy Program) could not be examined by the quantitative trip data. The conducted interviews with the participants suggest that this one time biking experience did not change their intention to bike. Therefore it must be assumed, that this intervention design does not lead to a sufficient behavior change.

No change in perceived risk and perceived safety in biking could be identified. This indicates, that as most participants were already used to biking, they already had an estimate on the related safety and risk aspects. A change in actual bike use did not lead to a subsequent change of the individual evaluation of risk and safety associated with biking, at least not in the short term of this study. Our future research will therefore focus on more and other aspects that influence biking (e.g. bike availability, experience of biking or general attitudes). Furthermore, it will emphasize the use of qualitative methods to better assess why interventions show certain outcomes.

6 Conclusions and Future Research

This paper provides several contributions. Three persuasive strategies were designed for persuading people to bike as a low-energy mode of transportation and an evaluation of these were presented. The Frequent Biking Challenge showed an increase in bike use. Future research can focus on the individual principles applied as well as the analysis, for whom these are effective under which circumstances. The Virtual Bike Tutorial and Bike Buddy Program got promising feedbacks, but no clear conclusions about their outcomes can be drawn yet. Further evaluation of these strategies is needed and future research should focus more on novice bikers and evaluate the potential of these strategies to encourage them to bike. More elaborated technologies (e.g. immersive virtual environments) to simulate biking could improve the persuasive power of this design. This may be combined with a virtualized bike buddy experience, providing guidance to a user.

Overall, the presented study explored a set of strategies and features that shall act as a valuable base for future research on how to design and implement persuasive technologies [8] and socially influencing systems [20] in the field of mobility.

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