

# CHALLENGED TO BIKE: ASSESSING THE POTENTIAL IMPACT OF GAMIFIED CYCLING INITIATIVES

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**1 ABSTRACT**

2 Cycling is promoted by a variety of initiatives and events all around the world. Given the  
3 popularity of such campaigns, there is surprisingly limited literature assessing their effectiveness  
4 and investigating the involved social processes. This paper presents findings from two case studies  
5 of gamified biking initiatives which have been evaluated using both quantitative-statistical and  
6 qualitative-interpretative methods: (1) a small-scale research experiment (“Frequent Biking  
7 Challenge”) and (2) an annual national biking campaign (“Bike to Work”).

8 The two case studies provide insights into their general effects, on changes for different groups of  
9 bikers, the effectiveness of different elements of the interventions, and the methodological  
10 requirements for evaluating short and long-term impacts of campaigns aiming at increasing biking  
11 in cities. Both initiatives successfully encouraged people to bike more in the short run, 25% in the  
12 experimental group and 36% participating in the campaign increased their amount of biking during  
13 the intervention period. However, effects vary for different groups of bikers and only the “Bike to  
14 Work” campaign shows a lasting effect with 26% of those participating in previous years  
15 continuing to bike more. The results show that in order to induce long-term behavior changes,  
16 gamified biking initiatives have to be embedded into everyday life, enable social interactions and  
17 provide mutual encouragement.

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22 *Keywords:* Mobility behavior change, cycling, gamification, soft policy measures, bike to work,  
23 evaluation  
24

## 25 INTRODUCTION

26 Growing cities as well as increasing greenhouse gas emissions are driving factors for a global  
27 rethinking of transportation systems. Biking can be seen as a central element to that, as it is a  
28 low-emission, low-cost, healthy and space efficient mode of transportation. To increase bike  
29 usage, cities are investing in cycling infrastructure and are implementing bike share programs.  
30 Additionally, numerous initiatives, publicity campaigns and events are being supported to promote  
31 biking. The aims of such “soft” policy measures typically include motivating car users to  
32 voluntarily switch to more sustainable modes of transport, e.g. cycling (1). Evidence on the  
33 effectiveness of such interventions is, however, either inconsistent, can hardly be generalized, or is  
34 non-existent at all (2).

35 With growing popularity of gamification approaches for triggering behavior changes in  
36 different contexts, the use of game elements like incentives or rewards in products, services and  
37 campaigns aiming at modal shift is also on the rise (3). Some examples are bike programs, such as  
38 “bike-to-work” events, which can be found globally (4). Such promotional programs often use  
39 elements like competition, lotteries, team experience or awards, adding an emotional quality to the  
40 more objective arguments for biking, such as health benefits, time saving or climate change  
41 mitigation.

42 Yet, just as for other soft policy measures, studies on the actual effectiveness of gamified biking  
43 campaigns are still scarce: Rose & Marfurt (5) evaluated the impacts on travel behavior change of  
44 a major one-day bike-to-work and found that 27% of those riding to work for the first time due to  
45 the event continued to do so. For a similar one-day initiative to promote active transport to school  
46 no clear effect could be shown (6). Piatkowski et. al. (7) identified different groups participating in  
47 one-day bike-to-work events and identified barriers to increased commuter cycling. Despite the  
48 small number of existing literature on the general effects of gamification in the mobility context,  
49 the findings indicate its usefulness to provoke behavior and attitude change. Playful elements  
50 enrich the user's motivation and engagement in specific activities as well as in exploring new  
51 possibilities and options (8–10). Concurrently, the success of interventions strongly depends on  
52 the nature of the gamified system, the applied game mechanics and the types of players (8). Due to  
53 the contextual complexity of daily life and daily mobility routines, also other behavior than  
54 originally intended may be triggered by gamified interventions (9, 11). Hence, a better  
55 understanding of potential reactions to soft policy initiatives is key to designing successful  
56 interventions.

57 The contribution of this paper is to examine the strategies employed in gamified biking  
58 campaigns with the aim of changing accustomed mobility behavior patterns. Results from from  
59 two case studies focusing on promoting commuting by bike through the use of game mechanics are  
60 presented. The first study describes an experimental intervention called “Frequent Biking  
61 Challenge” which we carried out in a small-scale randomized controlled trial over a period of four  
62 weeks during fall 2014 in the Cambridge/Boston area in Massachusetts, USA (12). It was  
63 complemented by a long-term qualitative evaluation nine months after the initial trial. The second  
64 case study presents an evaluation study accompanying the 2015 Austrian national cycling  
65 initiative called “Bike to Work”, a one-month campaign that promotes bike commuting which has  
66 been conducted annually since 2011. Both examples are comparable in terms of objectives,  
67 intervention period and gamification elements, although the nature of the two examples  
68 (small-scale experiment vs. established national event) causes significant differences in the sample  
69 sizes and hence explanatory power of the results. Still, each intervention and the comparison of  
70 them provide valuable insights into drivers of the success of biking campaigns.

71 Based on the hypotheses that gamified biking initiatives can trigger mobility behavior changes

72 for specific target groups, the case studies are discussed with respect to the following questions:

- 73 • How and to what extent are gamified biking initiatives affecting behavior change?
- 74 • Which aspects of gamified biking initiatives are most effective for inducing behavior change?
- 75 • Which groups can be identified within participants of by gamified biking initiatives to increase
- 76 biking on their work trips?
- 77 • Which methods can be used for assessing the potential short- and long-term impact on mobility
- 78 behavior?

79

80 The following two sections provide comprehensive descriptions of the case studies, each  
81 focusing on the intervention design, the methods used for evaluating the effects, and the results of  
82 the analysis. In the subsequent section, the main research questions are discussed by comparing the  
83 dominant characteristics and outcomes of the case studies. The last part of the paper includes  
84 conclusions and provides an outlook on further research, which will build on the findings  
85 presented in this paper.

86

## 87 **CASE STUDY 1: FREQUENT BIKING CHALLENGE**

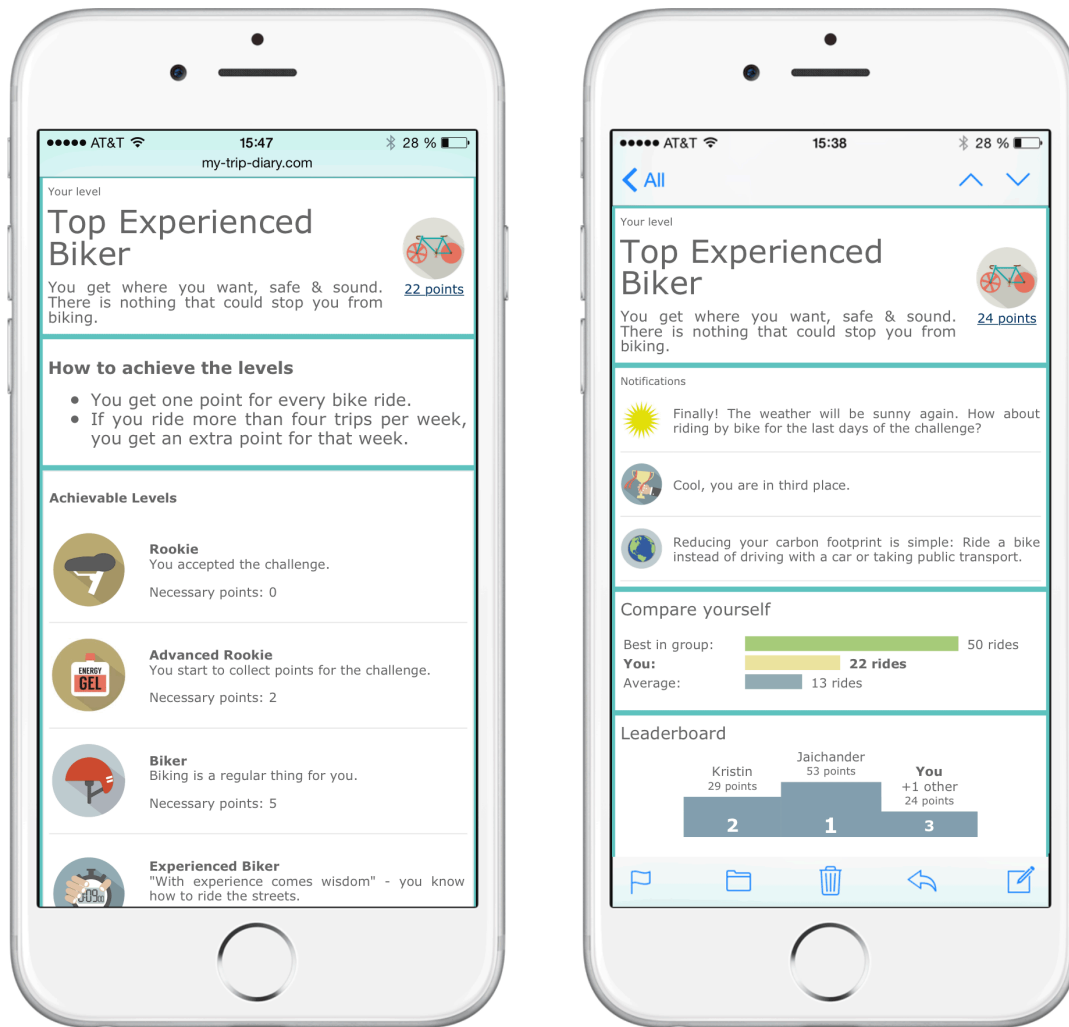
88

### 89 **Intervention Design**

90 As part of a larger study to promote biking with different persuasive strategies we carried out  
91 small-scale experiments in fall 2014 (12). The “Frequent Biking Challenge” was one intervention  
92 within these experiments designed for encouraging participants to collect points for their bike rides  
93 in order to achieve different experience levels. We developed a web-based application (see figure  
94 1) to visualize level names and descriptions, badges and a competition element in form of a  
95 leaderboard. At the beginning of the study all participants were invited to jointly reach a total  
96 number of points. After this collective goal was fulfilled, a social comparison feature was installed,  
97 showing the number of individual bike rides in comparison to the average rides of all participants  
98 and to the current front-runner’s number of rides.

99 Information was communicated to the participants via email. During the first week, participants  
100 received email updates on a daily basis; after that the frequency was reduced to three to four times  
101 per week. The emails were sent in the evenings in order to influence the planning of the next day  
102 by various messages. Figure 1 illustrates the visualization of levels and an example of an  
103 information update.

104



105  
106 **FIGURE 1** Screenshots showing the levels (left) and information updates (right) of the  
107 **“Frequent Biking Challenge”**

108  
109 In particular, this approach focused on the following persuasive elements and hypotheses:

- 110
- 111 • **Triggering:** Mobility mode choices are altered by suggestions to ride a bike.
  - 112 • **Competition:** Behavior change is facilitated through a leaderboard that allows individuals to see where they stand in an overall ranking (13).
  - 113 • **Social comparison:** Enabling participants to compare their performance with the best and the average performance in a group motivates individuals to change their behaviour (13).
  - 114 • **Raised awareness:** By regularly reporting mobility choices participants become aware of otherwise intuitive behavior and start to question existing habits.
- 115  
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## 118 **Methods**

119 The experiment was conducted over a period of four weeks (29 days) in October 2014 in  
120 Greater Boston (MA). The first 12 days were used to gather baseline data (pre-intervention phase).  
121 After that, the experimental group participated in the “Frequent Biking Challenge” for 17 days  
122 (during-intervention phase). The control group did not receive any intervention. This small-scale  
123 experiment was intended to provide first insights into potential reactions and requirements for  
124 subsequent large-scale interventions.

## 125 *Study Sample*

126 Participants were recruited through mailing lists at the Massachusetts Institute of Technology  
 127 (MIT) and subsequently consisted mainly of students and to a lesser extend staff members. Based  
 128 on a questionnaire including current mobility patterns, only people biking less than three times a  
 129 week were selected as participants for the study. The resulting 29 participants were randomly  
 130 assigned to the experimental group (n=13) or the control group (n=16).

131 For the analysis, only data from participants who had reported at least 80% of their daily trips  
 132 was used in order to achieve a minimum level of data quality (experimental group: n=12; control  
 133 group: n=10), consisting of 11 women and 11 men. To ensure access to bikes, all participants were  
 134 provided with a one-month membership for the local bike-sharing scheme (Hubway) and a helmet  
 135 if required.

## 136 *Collection and Analysis of Data*

137 All participants had to report their daily trips using a web-based application. For each trip,  
 138 participants were instructed to select a trip purpose and the transport modes they used (single or  
 139 multi-modal): “walking” (minimum 5 minutes walks), “biking”, “public transport”, “car” and  
 140 “other”. Based on the collected data the share of biking among all modes  $y_d$  was computed per  
 141 person per day. In order to outweigh other effects than the introduced intervention influencing  
 142 mode choice (e.g. weather), a controlled share of bike trips per day  $x_{g,d}$  between the daily bike  
 143 share of each participant of the experimental group  $y_{g,d}$  and the mean of daily bike share within the  
 144 control group  $\bar{y}_{c,d}$  was computed for each day by

$$146 \quad x_{g,d} = y_{g,d} - \bar{y}_{c,d} . \quad (1)$$

147 To assess the effect of the intervention, we determine the average controlled share of biking for the  
 148 time before the intervention  $z_{g,pre}$  and the average controlled share of biking during the intervention  
 149  $z_{g,during}$  given by

$$150 \quad z_{g,pre} = \frac{1}{N_{pre}} \sum_{d=1}^{N_{pre}} (x_{g,d}), \quad z_{g,during} = \frac{1}{N_{during}} \sum_{d=1}^{N_{during}} (x_{g,d}), \quad (2)$$

151 with  $N_{pre}$  denoting the number of days before and  $N_{during}$  the number of days during the the  
 152 “Frequent Biking Challenge”. The pre- and during-intervention values of the average controlled  
 153 share of biking were then tested for normality with a Shapiro-Wilk test (14) and compared with a  
 154 one-sided paired-sample t-test. Per participant changes of bike share were tested with a  
 155 two-sample t-test comparing daily bike shares of the pre-intervention and during-intervention  
 156 days.

157 Additionally, qualitative data was obtained by a post-intervention online survey, through  
 158 interviews with four participants (two from each the control and experimental group) and finally  
 159 an open question email exchange with the study participants nine months after the initial study.

## 160 **Results**

161 There was a statistically significant ( $p < 0.05$ ) increase of the share in biking in the individuals’  
 162 modal split for three out of the 12 participants (25%) in the experimental group after starting the  
 163 intervention. The comparison of the controlled share of biking for the pre-intervention phase  $z_{g,pre}$   
 164 [M=-7.9%, SD=11.8%] and the controlled share of biking during the intervention  $z_{g,during}$   
 165 [M=5.5%, SD=30.8%] showed an increase of 13.5 percentage points [ $t(11)=2.079$ ,  $p = 0.031$ ].  
 166 This underlines that the “Frequent Biking Challenge” lead to an increase in bike use above control  
 167 group levels during the intervention.  
 168

169 The qualitative data collected directly after the intervention supported this result as participants  
170 reported, for instance, an increased awareness of biking as an alternative mode of transportation  
171 and to be slightly more engaged in doing so due to participating in the “Frequent Biking  
172 Challenge”. However, due to the overall small sample size these results must be taken as first  
173 insights that require further validation.

174 The long term evaluation, which was conducted nine months after the initial study, showed that  
175 two out of the three participants with increased bike usage during the intervention (participants  
176 #61, #62, and #66) returned to their initial mobility habits afterwards. Quitting the newly achieved  
177 habit had different reasons: one participant mentioned seasonal influences as the reason why she  
178 got back to her initial mobility routines: *“I got out of the habit of daily biking over the winter, and  
179 now commute primarily on foot. I bike maybe once a week to run an errand or attend church, more  
180 or less what I was doing before the survey started“* (#61). For another participant access to bikes  
181 was the main issue, as participants have been provided with access to the local bike sharing  
182 scheme, and keeping their increased levels of biking has also been a question of renewing their  
183 subscription or buying a bike. *“I have since transitioned back to mostly walking. I feel that  
184 bike-share programs are not worth the cost, and unfortunately also lack a good place to store a  
185 personal bike”* (#66). The third participant with an increased level of biking has been able to  
186 sustain this habit over time: *“I renewed the Hubway membership subscription you gave me and  
187 have been biking about the same ever since”* (#62). However, although there was this one  
188 participant with a lasting behavior change in the experimental group, it is questionable if the  
189 intervention itself caused the transition or the mere provision of access to bikes was the decisive  
190 factor for the participant’s new biking habit. Therefore no clear conclusions can be drawn for the  
191 question if the overall intervention design of the “Frequent Biking Challenge” did lead to a long  
192 lasting behavior change.

193

## 194 **CASE STUDY 2: BIKE TO WORK**

195

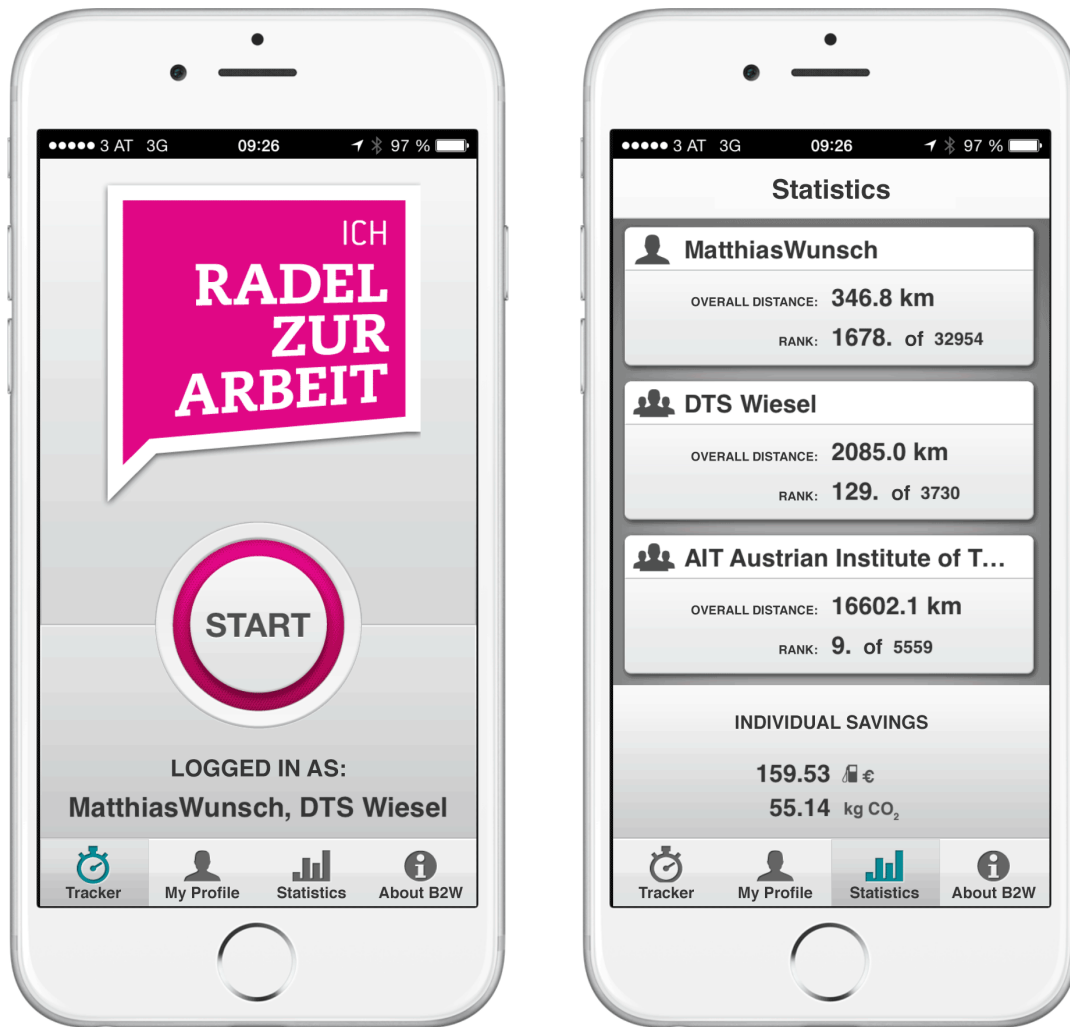
### 196 **Intervention Design**

197 The “Bike to Work” initiative (in German: “Radelt zur Arbeit”, [www.radeltzurarbeit.at](http://www.radeltzurarbeit.at)) is  
198 designed to encourage people to cycle on their commute. It is conducted by an Austrian biking  
199 advocacy group with financial support from the Austrian government. “Bike to Work” has been  
200 held for the fifth time in 2015 and is taking place each year during May. In 2015 over 14,800  
201 participants joined the campaign, making it the largest of this kind in Austria.

202 Participants are required to sign up on the campaign’s website and to form teams of two to four.  
203 They can also volunteer as so-called company coordinators which help their colleagues with  
204 registration and the creation of teams. Furthermore, they typically promote the campaign within  
205 the company. The initiative provides incentives in form of different prizes (e.g. vouchers for  
206 leisure activities or bike gear). These are distributed by (1) having a lottery for all teams achieving  
207 a minimum of 50% bike commutes for each member and (2) giving prizes to participants who are  
208 randomly called, if they biked on the day they receive the call.

209 Participants can either track their daily commutes with a smartphone app, or log into a website  
210 to insert the distances covered by bike. The team performance and the individual mileages are  
211 shown within the app and on the website. Figure 2 shows the tracking tab and the statistics tab of  
212 the “Bike to Work” smartphone app.

213



214  
215 **FIGURE 2** Screenshots of the “Bike to Work” (German: “Radelt zur Arbeit”) app showing  
216 the tracking tab (left) and the statistics tab (right).  
217

218 For this case study, the following persuasive elements and hypotheses are regarded:

- 219 • **Commitment:** Participants agree to bike commute within the month of the initiative and strive  
220 to remain consistent with this commitment, which is also likely to be reinforced by other  
221 team-members.
- 222 • **Competition:** Behavior change is motivated by comparing individual performance to other team  
223 members and by comparing team performance to other teams.
- 224 • **Tangible incentives:** Behavior change is motivated through the chance to qualify for a lottery by  
225 reaching a concrete goal (minimum of 50% bike commutes per member in each team during the  
226 intervention period).
- 227 • **Raised awareness:** By regularly reporting mobility choices participants reflect on otherwise  
228 intuitive behavior and start to question existing habits.  
229

## 230 **Methods**

### 231 *Study Sample*

232 Out of the 14,809 subscribers of this year’s initiative 498 individuals participated in the study  
233 by answering a standardized online questionnaire. Out of all survey respondents, 157 provided



234 additional qualitative data by responding to open questions in the questionnaire. A question  
235 regarding mode shifts was added to the questionnaire at a later time during running the survey  
236 resulting in n=92 for this item. Within the sample, nine participants have been additionally enlisted  
237 for semi-structured qualitative in-depth telephone interviews.

238 Study participants were recruited with a link on the campaign's website and on different social  
239 media channels and they were eligible to participate in a lottery offering the winners bike racks for  
240 their work place. This opportunity may have caused a selection bias, as regular bikers might be  
241 more interested in having sufficient biking infrastructure and might be generally more interested in  
242 the initiative.

#### 243 244 *Collection and Analysis of Data*

245 The standardized online questionnaire included questions about the respondents' overall  
246 perception of the "Bike to Work" campaign, biking behavior before and during the initiative,  
247 potential long-term effects, and the influence of different motivational factors encouraging biking.  
248 In addition, participants could provide supplementary comments. The content of the in-depth  
249 telephone interviews was audio-recorded and partly transcribed for the analysis process. The  
250 qualitative data was analyzed using thematic analysis according to Braun & Clarke (14).

251 In order to compare the distribution of motivational factors between groups of participants  
252 Pearson's chi-squared tests with Yates' continuity correction were applied. Estimates of  
253 proportions within all participants are based on sample means. 95% binomial confidence intervals  
254 are based on Clopper-Pearson (16) and fulfill the requirements according to Brown et al. (17). The  
255 statistical analyses were conducted using R (18).

#### 256 257 **Results**

##### 258 *General Satisfaction with the Initiative and Mode Shifts*

259 Participants of "Bike to Work" have been very positive about the initiative. The question: "How  
260 do you like 'Bike to Work 2015'?" with a scale ranging from 1 "Not at all" to 7 "Very good" the  
261 initiative achieved a mean rating of 6.33 [SD=1.00]. This result has been confirmed by the  
262 in-depth interviews were all respondents expressed their satisfaction with "Bike to Work".  
263 Regarding mode shifts due to participation a reduction of car use was reported by 38.5% [95% CI  
264 28.4%, 49.2%] of the respondents and a reduction in public transportation use was reported by  
265 34.0% [95% CI 24.5%, 44.7%].

##### 266 267 *Changes in Bike Commuting Frequency*

268 "Bike to Work" brings together people with very different rates of bike commuting. As can be  
269 seen in table 1, the general biking behavior is mainly structured as follows: 54.6% report that they  
270 usually commute by bike almost on a daily basis ("daily bikers"), 23.9% bike several times a week  
271 ("regular bikers"), and the remaining 21.5% ("occasional bikers") bike less often than that. The  
272 teams described in the qualitative data reflected this mix of participants, resulting in a group  
273 dynamic of having regular bikers motivate occasional bikers.

274 Table 1 furthermore shows the change in bike commuting frequency during the campaign.  
275 Within the full sample 36.1% increased their frequency of bike commuting during „Bike to Work“.

276

277 **TABLE 1 Overview of group sizes for regularity of biking and change in frequency of bike**  
 278 **commuting during the campaign**

| Usual frequency of bike commuting | Occasional bikers        | Regular bikers       | Daily bikers   | Full Sample |
|-----------------------------------|--------------------------|----------------------|----------------|-------------|
|                                   | never to (almost) weekly | several times a week | (almost) daily |             |
| Number of respondents*            | 107                      | 117                  | 272            | 496         |
| Share among all respondents       | 21.4%                    | 23.9%                | 54.6%          | 100.0%      |
| <b>Change during Bike to Work</b> |                          |                      |                |             |
| Biked more often                  | 77.6%                    | 52.1%                | 12.9%          | 36.1%       |
| Biked the same                    | 21.5%                    | 47.9%                | 87.1%          | 63.7%       |
| Biked less often                  | 0.9%                     | 0.0%                 | 0.0%           | 0.2%        |
| Total                             | 100.0%                   | 100.0%               | 100.0%         | 100.0%      |

\* Two respondents skipped this question.

279  
 280 Among the occasional bikers, more than three out of four (77.6%) biked more often than usual  
 281 during the month of the initiative. This group, which can be regarded as the ones drawn into more  
 282 regular biking by the campaign, account for 16.7% of all “Bike to Work” participants [95% CI  
 283 13.6%, 20.3%]. One reason for this change was that the campaign acted as a trigger to try bike  
 284 commuting. Interviewee #99 who moved to a new town six weeks before joining “Bike to Work”  
 285 used to go to work by car despite the short distance of 1.7 km (1.1 mi). Getting an information  
 286 about the campaign from her employer, knowing about other teams that participated in the  
 287 previous year and having a colleague who already biked daily to team up with made her start to  
 288 ride the bike for her commute. Participant #351 rediscovered biking due to the campaign: “*I used*  
 289 *to live in a small town and biked a lot back then, but as I moved to a bigger city and had small kids*  
 290 *I almost never used the bike. Now I have rediscovered biking*”. Another reason for the high share  
 291 of increased bike use during the initiative within the occasional bikers can be found in the  
 292 eligibility criteria for the lottery (minimum of 50% bike commutes per team member), which  
 293 required a significant change of the participants’ mobility behavior. This led to a temporary change  
 294 in order to achieve the goal: “*It is okay for one month. But for me it is also very cumbersome*”  
 295 (#367).

296 Although the general frequency of bike commuting in the group of regular bikers is already  
 297 comparatively high, still 52.1% increase their bike use during the initiative. The analysis suggests  
 298 that this stems mainly from changes in situations where participants usually would not have  
 299 chosen to ride the bike to work, mostly regarding days with bad weather. Typical statements for  
 300 this group include: “[*Bike to Work*] is indeed motivating us all to ride the bike, even when the  
 301 weather is bad” (#106), “*I ride now even when it is raining whereas previously I would have taken*  
 302 *public transport*” (#246), “*Before [Bike to work] I took the car when there was rainy weather.*  
 303 *Now I am riding my bike and even if there are some scattered showers I will be fine*” (#224).

304 Among the group of daily bikers a comparatively low number of 12.9% increased their bike  
 305 use, which can be expected given the fact that this group is already mainly using a bike to get to  
 306 work. The increase can be mainly attributed to the same weather related effects.

307  
 308  
 309

310 *Long-Term Effects*

311 Participants of our survey who also participated in the “Bike to Work” initiative in previous  
 312 years (n=381) were asked for the resulting long-term effect. Based on the responses it is estimated  
 313 that 26.4% [95% CI 23.8%, 29.0%] of “Bike to Work” participants increase their level of bike  
 314 commuting in the long run after they experienced the benefits of bike commuting due to the  
 315 initiative, which is much in line with findings of Rose and Marfurt (5). “*I will extend ‘Bike to  
 316 Work’ and will continue to bike to my workplace. I realized through this initiative how great it is to  
 317 bike to my work. I am very enthusiastic and enjoy it every day*” (#099) In retrospective respondent  
 318 #229 notably stated: “*Bike to Work 2014 has been the trigger to switch completely to the bike  
 319 within the city and closer distances. Meanwhile, I am using the car just for trips over 100 km  
 320 [62.1mi] or for hauling. I sold my own car and I almost never need public transport*”. Although  
 321 such drastic changes might be the exception rather than the rule, the data indicates a long lasting  
 322 effect of the initiative. Additionally, 4.7% of the respondents stated that they had increased their  
 323 bike commuting for a short period of time after “Bike to Work” but subsequently returned back to  
 324 their usual mobility patterns.

325

326 *Motivational Aspects*

327 The results of the analysis of questionnaire data and qualitative data provide valuable insights  
 328 into the motivational drivers of behavior changes in the course of the “Bike to Work” campaign  
 329 and show that some of them differ depending on the usual frequency of bike commuting. Table 2  
 330 shows the compliance to different motivational factors according to the responses in the  
 331 questionnaire survey and highlights the factors which are dependent on the usual rate of biking.

332

333

334 **TABLE 2 Relevance of motivational factors during participation in “Bike to Work”**

| <i>Group</i>                      | <i>Occasional bikers</i>         | <i>Regular bikers</i>        | <i>Daily bikers</i>    | <i>Full Sample</i> | $\chi^2$ | <i>p-value</i>   |
|-----------------------------------|----------------------------------|------------------------------|------------------------|--------------------|----------|------------------|
| Usual frequency of bike commuting | never to (almost) weekly (n=103) | several times a week (n=116) | (almost) daily (n=266) |                    |          |                  |
| <b>Motivational factor</b>        |                                  |                              |                        |                    |          |                  |
| Environmental protection          | 57.3%                            | 54.3%                        | 53.8%                  | 54.6%              | 0.378    | 0.828            |
| <b>Health benefits</b>            | <b>69.9%</b>                     | <b>59.5%</b>                 | <b>45.9%</b>           | <b>54.2%</b>       | 18.982   | <b>&lt;0.001</b> |
| <b>Team spirit</b>                | <b>58.3%</b>                     | <b>45.7%</b>                 | <b>41.0%</b>           | <b>45.8%</b>       | 8.927    | <b>0.011</b>     |
| <b>Motivate others to bike</b>    | <b>14.6%</b>                     | <b>42.2%</b>                 | <b>44.0%</b>           | <b>37.3%</b>       | 29.056   | <b>&lt;0.001</b> |
| Prizes                            | 31.1%                            | 33.6%                        | 38.7%                  | 35.9%              | 2.228    | 0.328            |
| Biked distance                    | 31.1%                            | 39.7%                        | 35.3%                  | 35.5%              | 1.762    | 0.414            |
| Individual statistics             | 38.8%                            | 32.8%                        | 30.8%                  | 33.0%              | 2.158    | 0.340            |
| Biking enthusiasm of colleagues   | 16.5%                            | 20.7%                        | 15.4%                  | 16.9%              | 1.616    | 0.446            |

p-values are the results of Chi-Squared test for independency between all three groups. Bold numbers indicate significant dependences of the factors on the groups (p<0.05).

Survey question: “What motivated you while you were participating in Bike to Work?” Participants could select the items that they agreed with (dichotomus scale).

335

336

337 The motivator with the highest compliance rate among all factors was “environmental  
338 protection”. At the same time, this motivator does not stand out for its persuasive effect on  
339 non-regular bikers as it is equally important for all three groups.

340 Health benefits achieved the second highest compliance rate showing that bike commuting is  
341 seen as a way to live a healthier life and to include physical activity into everyday routines. This  
342 has also been confirmed by statements within the interviews: “*Otherwise I would often be too lazy*  
343 *to do some sports in the evening after I got home from work. But by commuting by bike one has to*  
344 *use the bike to get home as well and one has to pedal*” (#224). Here bike commuting and the  
345 decision to bike is even a way of committing oneself to do a physical activity. Commuting by bike  
346 may take more time than available alternatives, but it acts as a physical workout at same time. By  
347 that the choice for bike commuting can be a reasonable one as the loss in time is compensated by a  
348 gain in health and fitness. If doing sports is substituted with bike commuting on long distances  
349 altogether this can even be time efficient: “*Although I need over an hour one way, overall I am*  
350 *saving time*” (#082). In that light “Bike to Work” provides a framework to start or increase bike  
351 commuting as a way of ‘doing something’ about one’s health. As health benefits were mentioned  
352 significantly more often by occasional bikers (69.9%) and regular bikers (59.5%), this aspect is a  
353 more prominent motivator during the Bike to Work participating for them than for daily bikers at  
354 45.7% [ $\chi^2=16.2$ ,  $n=369$ ,  $p<0.001$  and  $\chi^2=5.46$ ,  $n=382$ ,  $p=0.019$ ].

355 Team spirit (i.e. doing something together as a team) was at least related to three social  
356 processes influencing participants: First, commitment, as participation required each team member  
357 to obey the 50% bike trips rule in order to qualify for the lottery. Second, increased visibility of  
358 mode choices, as daily transportation choices become subject to judgements by others. “*On days I*  
359 *commute by car I’ll get some ‘friendly’ remarks from colleagues*” (#224) Third, competition, as for  
360 some of the participants being in a team also meant competing with others. “*We have two teams*  
361 *and this year there was quite some competition going on*” (#310). “*Teams within our company that*  
362 *biked about the same as we did sent an email stating: ‘Look, we have overtaken you in the*  
363 *ranking*” (#224). Being motivated by team spirit was mentioned significantly more often by  
364 occasional bikers at 58.3% compared to regular bikers (45.7%) or daily bikers (41.0%) [ $\chi^2=2.96$ ,  
365  $n=219$ ,  $p=0.08$  and  $\chi^2=8.24$ ,  $n=369$ ,  $p=0.004$ ], showing the importance of participating together  
366 with colleagues and friends and that this is more relevant and more motivating for occasional  
367 bikers.

368 Motivating others to bike was a driving factor primarily for regular and daily bikers to join  
369 “Bike to Work” ( $p<0.001$ ). “*I daily bike to work anyway, but with this initiative more people get*  
370 *motivated and some may stick with it*” (#089). Several respondents reported on the effectiveness in  
371 this respect, e.g. “*Because of Bike to Work I could motivate two colleagues to bike commute*”  
372 (#210). “*Since we have started two years ago I could persuade my brother in law as well as*  
373 *colleagues of mine to bike commute, especially as I am riding even during winter*” (#106). This  
374 result also demonstrates the interrelation of motivational factors for frequent bikers (daily and  
375 regular bikers) and occasional bikers, as “Bike to Work” provides them with an opportunity to  
376 promote biking and get non-bikers and occasional bikers excited about the idea of bike  
377 commuting. This effect can be seen in Table 2 in the higher compliance for “motivate others to  
378 bike” for the regular and daily bikers and the higher proportion of “team spirit” for the occasional  
379 bikers. This result has been present in most of the qualitative data as well: “*This initiative is ideal*  
380 *to raise my colleagues’ awareness for biking*” (#437) The formation of teams consisting of  
381 occasional and regular bikers (“*Some in my team are already biking a lot; others were not so much*  
382 *before the initiative.*” #310) may also set norm for the regularity of bike commuting. This role of  
383 already frequently biking people is comparable to previous findings pointing at their role for

384 awareness raising and motivating others (7).

385 Although prizes and the possibility to win them in the lottery are a main feature of this initiative,  
386 they rank only fifth within the list of motivators and are relevant for 35.9% of participants. This  
387 leads to the conclusion that the social interactions and mutual engagement introduced by the  
388 campaign are the true top features. However, prizes could be an important trigger to motivate  
389 people to join the campaign in first place. For them as for the remaining motivational factors  
390 (personal statistics, biked distance, enthusiasm of colleagues) no significant differences between  
391 the three groups of bikers emerged.

392 Another relevant aspect is the potential role of companies: They can support behavior changes  
393 of their employees as they may seek to encourage them to engage in healthy activities or contribute  
394 to increase ecological sustainability. In these situations, “Bike to Work” provided a useful  
395 framework. One company had created a corporate social responsibility project based and inspired  
396 on “Bike to Work” (#271). Another company was actively encouraging employees to join “Bike to  
397 Work” by providing information material, helping with the set-up process of the teams and even  
398 organizing a kick-off event (#411). Besides that, many private and public organizations help at  
399 least to distribute information about “Bike to Work” to their employees.

400

## 401 **DISCUSSION**

402 The two case studies presented in this paper share several characteristics: both aim at increasing  
403 the share of biking in the daily mode choices of participants (though one is only focusing on  
404 commuter trips), in both cases the intervention took place over a limited period of time (four  
405 weeks), and both used persuasive strategies and game mechanics for achieving behavior change.  
406 At the same time, the two examples also differ in specific aspects, particularly due to the types of  
407 intervention: the “Frequent Biking Challenge” was a nonrecurring, small-scale scientific  
408 experiment with limited sample size, and “Bike to Work” is an annual national campaign attracting  
409 thousands of participants each year. The subsequent discussion follows the initial questions of this  
410 study.

411

412 *How and to what extent are gamified biking initiatives affecting behavior change? Which aspects*  
413 *of gamified biking initiatives are most effective for inducing behavior change?*

414 As gamification elements like competition, points and rewards are effective measures for  
415 encouraging people to get involved in an intervention, participants of the “Frequent Biking  
416 Challenge” on one side did show higher levels of biking during the intervention period. However,  
417 these elements by themselves might not be sufficient for inducing enduring behavior change. On  
418 the other side, biking campaigns such as “Bike to Work”, unite long-standing frequent bikers,  
419 occasional and even non-bikers. They embed the idea of bike commuting into the everyday social  
420 context, such as collaborating with colleagues and put gamification elements on top of that.  
421 Furthermore, the requirement for participants to form small teams of two to four seems to even  
422 enhance all of these effects. Combining social interactions, mutual encouragement and  
423 gamification elements, caused many participants to increase the amount of biking trips in their  
424 daily routine and it can be assumed that a considerable share of 26% of participants will keep their  
425 increased levels of bike commuting in the long run.

426

427 *Which groups can be identified within participants of by gamified biking initiatives to increase*  
428 *biking on their work trips?*

429 It turned out that the effect of raised awareness of individual mobility habits is of importance,  
430 particularly for participants who have rarely biked before enrolling in an initiative. In both case

431 studies participants were required to observe their own behavior by collecting data on their daily  
432 mode choices, which eventually disclosed previously unconscious behavior patterns. This enabled  
433 participants to deliberately reflect on their mobility habits and discover unexpected qualities of  
434 alternative modes of transport. This novel awareness paved the way for perceiving the value of  
435 specific benefits connected to biking. In the case of the “Bike to Work” initiative the two main  
436 drivers the participants discovered were health gains and social benefits (team spirit).

437

438 *Which methods can be used for assessing the potential short- and long-term impact on mobility*  
439 *behavior?*

440 Regarding methodological aspects for assessing the impact of biking initiatives, the two case  
441 studies show that both quantitative and qualitative methods need to be combined for describing  
442 and understanding behavior changes. The “Frequent Biking Challenge” provides an approach for  
443 controlled assessment of biking share changes based on trip data delivering valid interpretations of  
444 actual behavior change. Applying its methods to a large-scale randomized controlled trial would  
445 allow to draw conclusions on the causal effect of an intervention on actual bike usage. The  
446 combination of quantitative and qualitative methods for evaluating the “Bike to Work” campaign  
447 provides a deeper understanding on the social processes that are introduced by the campaign and to  
448 have a better interpretation of quantitative survey data. The experiences presented in this paper  
449 should be taken up in future research for evaluating comparable initiatives in order to contribute to  
450 a better understanding of the potential effects of soft policy measures, in particular regarding  
451 approachable target groups (which social groups can be motivated in which way) and achievable  
452 modal shifts (which modes will be replaced by biking).

453

## 454 **CONCLUSIONS AND OUTLOOK**

455 In summary, this work showed that gamified biking campaigns can be very effective for raising  
456 awareness for biking and encouraging participants increase their level of cycling. Furthermore, the  
457 importance of social elements that foster mutual encouragement for adopting and maintaining new  
458 behavior was examined.

459 Future work must explore the quantifiable effects of gamified interventions on mode shifts in  
460 more depth in order to answer a variety of crucial questions, e.g. how to robustly estimate the  
461 reduction of distances driven by cars or use of public transport. Furthermore, the data from “Bike  
462 to Work” shows that people commute by bike even though they usually use alternatives that are  
463 taking substantially less time. One explanation can be found in an offsetting effect of other  
464 motivational elements, such as health benefits. However, as this should be taken into consideration  
465 when transportation mode choices are discussed future research should look into the relativity of  
466 travel times as well.

467 The experiences drawn from the presented studies will be collated in order to prepare a large  
468 scale experiment that will employ gamified elements in a “Biking Tourney” within the the greater  
469 Boston area. The campaign will be scientifically evaluated using a combination of quantitative and  
470 qualitative methods. The results are expected to provide deeper insight into the social dynamics of  
471 creating/stimulating behavior change in the absence of any tangible incentives.

472

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