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How to use smartphone apps to encourage cycling: Clues from a Living Lab with SMART in Enschede

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Abstract
Reduction in car use is one of the most effective ways to tackle congestion related problems. Using positive incentives to stimulate the use of the bike is one possibility to reduce car use, and cycling is a sustainable transport mode that uses little space and good for health. There is evidence that positive incentives may be more effective than punishing travellers for undesirable behaviour. The SMART app uses challenges with rewards, feedback, and message functions to promote cycling in a real-world living lab environment, in the Dutch region of Twente, and it automatically tracks travel data. We found from a mockup app study that earning points from challenges which can be redeemed for in-kind gifts is the most promising reward to change travel behaviour. However, few studies focus on what challenge to provide. Beyond commercial cycling apps like Strava, CycleMaps, BetterPoints, the SMART also focuses on the effectiveness test of multiple challenges over a year-long term and identify the mediating factors and the possible moderators for cycling behaviour change. As a result, we are better able to establish which type of challenges is most successful and what the effects are on car use. Preliminary results are summarized in this article.

Keywords:
Travel behavioural change, long term analysis, positive incentives

Introduction

Road transport contributes to more than 70% of all GHG emissions from transport in 2014, and transport represents about 25% of Europe's greenhouse gas emission and is the main cause of air pollution in cities (European Commission, 2016). Car driving is also associated with unhealthy behaviour (e.g.,(Gordon-Larsen et al., 2009). Active modes of transport (i.e., cycling and walking) are not only environmentally friendly, but also seen as healthy alternatives (Park, Rink, and Wallace 2006, Hamer and Chida 2008). In particular, for short trips within cities, which may be easily incorporated into a daily routine, there is a large potential to adopt and also maintain the shift towards this behaviour.

Positive interventions or "soft measures", such as personal travel planning, subsidies, providing feedbacks, rewards, PT discount could stimulate the use of sustainable transport options (e.g. Ben-Elia, Ettema, & van Delden, 2013; Bamberg, & Schmidt, 2003, Cairns, et al., 2008). Unlike fiscal regulations to discourage car use, positive intervention is promoted to change the behaviour since it provides a way to prevent socio-

economic inequity (i.e. poor people cannot afford to use the car anymore, whereas rich people are less affected or not at all) (Eliasson & Mattsson, 2006). In fact, such soft measures can have a significant effect on car use reduction as has been proven in several Voluntary Travel Behavior Change (VTBC) schemes, such as the Spitsmijden project (peak hour avoidance), (Ben-Elia & Ettema, 2011), the Travel Marketing–IndiMarks projects (Brög, Erl, Ker, Ryle, & Wall, 2009) (Zhang, Stopher, & Halling, 2010), and the Casteddu Mobility styles program in Italy to promote the use of light rail (Sanjust, Meloni, & Spissu, 2014). Those successful studies used several similar interventions, such as rewarding sustainable behaviour, providing feedback about behaviour, encouraging behavioural change by goal setting and planning, and raising awareness of sustainable travel options by providing travel information. We draw on the same types of interventions to test the effectiveness of them of cycling promotion.

In the age of big data, mobile phones and software platforms are becoming useful tools to collect travel behaviour data and deliver interventions. Using mobile phone to collect extensive and dynamic data for human travel behaviour has been proven in many ways better than traditional travel survey data, that mobile phone data provides greater accuracy for the locations of origins and destinations when compared to self-reporting of multiple addresses that survey participants may not know well enough to convey (Geurs, Thomas, Bijlsma, & Douhou, 2015). Moreover, mobile phone data is widely applied to estimate travel modes and travel routes, with high estimation accuracy (Wang, He, & Leung, 2017) (Stopher, Clifford, Swann, & Zhang, 2009), which can be visualized in real time in software platforms to show travellers trip histories. That makes the feedback intervention in real time and more accurate. Additionally, the historical travel data can be analyzed to provide personalized goal setting and planning.

Many recent research projects have involved mobile phone in delivering interventions and collecting travel data (Carreras et al., 2012) (Gabrielli et al., 2014) (Hu, Chiu, & Zhu, 2015), (Broll et al., 2012), (Bie et al., 2012) (Poslad, Ma, Wang, & Mei, 2015) (Sanjust et al., 2014) (Jariyasunant et al. 2013), (Froehlich et al., 2009), (Gabrielli et al., 2014) (Jylhä, Nurmi, Sirén, Hemminki, & Jacucci, 2013), These approaches are generally inspired by Fogg's framework (B. J. Fogg, 2002) (B. Fogg, 2009), that integrate and design the successful intervention schemes, and attempt to convince users to behave more sustainably. However, the results from above studies were not ideal, since most of the studies had small sample size and lack long-term research environments (Brynjarsdóttir et al., 2012),(Gabrielli et al., 2014). Besides, above recent studies lack the focus on promoting cycling.

Commercial apps that focus on behavioural change, have seamless serve to end-users that can lead to broad recruitment. We learned from those commercial apps that it is a way to improve positive incentive studies. Moreover, there are already numerous commercial apps such as Strava, CycleMaps, Cyclemeter that promote cycling by using gamification methods or persuasive solutions. Other apps such as BetterPoints and CommuteGreener are providing real rewards to promote cycling with successful recruitments, 15,000 active users for BetterPoints for a six-month pilot, and CommuteGreener was with 50.000 users engaged via Facebook until 2015. All those projects (see table 1) show a potential to encourage cycling, but lack rigorous scientific analysis to evaluate their effects. Strava, CycleMaps and Cyclemeter work as a fitness app, that track and analyze cycling or running trips, explore new routes, and provide the social network to compete with friends. No challenges and rewards make these apps only target on regular cyclists and exclusive for habitual car users. The CommuteGreener targets for all types of travellers, rewards them if they travel more sustainable compared with baseline, which is an ideal behaviour change design. However, it is difficult to define the baseline and changes in reality. Therefore, CommuteGreener asks users to self-report the baseline, and the changes they made, which results in high registered users but low rate of real participants (10% of registered users) (Matushkina & Nevalennaya, 2010). BetterPoints automatically track users travel behaviour, and reward users for each mile of cycling, walking or running, which is also attractive for car users. However, the challenge in BetterPoints is to encourage users to do their best to gain as many rewards as possible. Many goal-setting reaches showed that specific and challenging goals led to higher performance than easy or "do your best" goals (E. A. Locke, 1968) (E. a Locke & Latham, 2002).

Last but not least, BetterPoints and other apps show that a commercial app can provide anonymity, a real-world context, unlike a typical lab experiment, can create a natural environment, which leads the participants to be unaware that their behaviour is being monitored (List & Levitt, 2006), so real behaviour data can be detected.

Therefore, to design or involve a commercial app into scientific research, and test the interventions in real life city situations with actual travellers can obtain a long-running and a large recruitment behaviour change experiment. To test innovative technologies in a real-world context is the initial focus of living lab experiments (Pallot, Trousse, Senach, & Scapin, 2010) (Mulder & Stappers, 2009), which started to emerge at the beginning of 2000. The SMART app (jointly developed by Mobidot and the municipality of Enschede) provides us with an opportunity to run the living lab, since it has the similar commercial background as BetterPoints, but additionally involved self-chosen challenges to make the goal more specific and challengeable, and it tracks travel behaviour data to provide detailed travel histories, with traffic information in addition. The objective of this paper is to test the effectiveness of positive interventions in a living lab environment, supported by SMART app, for cycling promotion for a monthly short-term and a year-long term and to identify the mediating factors and the possible moderators.

The paper is organised as follows. Section 2 explains the methodology, with the description of the design of the pilot study and data collection. Section 3 presents the results of the analyses and Section 4 provides conclusions.

Table 1 Overview of Apps focus on cycling promotion

Apps	Target users	Functions/Interventions	Incentives	Challenge types	Disadvantage
Strava	Target for athletes (cyclist and runners)	Explore new routes, Compete with friends.	No		Cannot attract habitual car users
CycleMaps Cyclemeter	For normal cyclists	Provide bike route information, Explore and plan bike routes, Compete with friends.	No		Cannot attract habitual car users
BetterPoints	For cyclists or runners	Challenge and goal setting, Provide feedback, Show progress. Providing incentives	yes	Earn a reward for each mile of walk, cycle or run.	Simple goal setting scheme. Cannot show trip routes but only total distances that made.
Commute Greener	All type of travelers	Provide traffic information, public transport alternatives, Suggest ride share partners, Compete with friends Providing incentives	yes	Earn incentive points if travel greener than baseline.	No automated tracking, self-report.

SMART app

The positive incentives were provided through the SMART app. The app has four main functionalities shown in Figure 1. The left panel of Figure 1 depicts the SMART app dashboard. Users can explore the whole functions of the app from this page. The figures in the right panel are screenshots from other pages

of the SMART app. The first functionality is travel information. This can be actual traffic information in which users are notified in case of road works or large scale events. Based on this, SMART can also suggest travel alternatives to help the user to optimize their travel plans. SMART also provides feedback by showing the historic travel pattern (upper panel). This feedback may encourage behaviour change. If users are aware of their current (bad) behaviour, it may stimulate them to improve their behavior. However, it is quite hard to measure the effect of this type of feedback, and its direct effect may be limited, because it does not require a commitment of the user. The second functionality (second panel) are challenges to which users commit themselves, i.e., they need to fulfil a challenge during the challenge period. The commitment to fulfill a challenge may be enhanced when users get rewarded upon completion of the challenge. When the challenge is fulfilled, the system will immediately give the corresponding amount of points. The earned points can then be redeemed for various discounted products and services (third panel). Finally, social incentives to encourage cycling (bottom panel) are also in the SMART app. This includes a competition with rankings to compare ones own behavior with others, and group challenges in which participants can invite friends to fulfill challenges together.

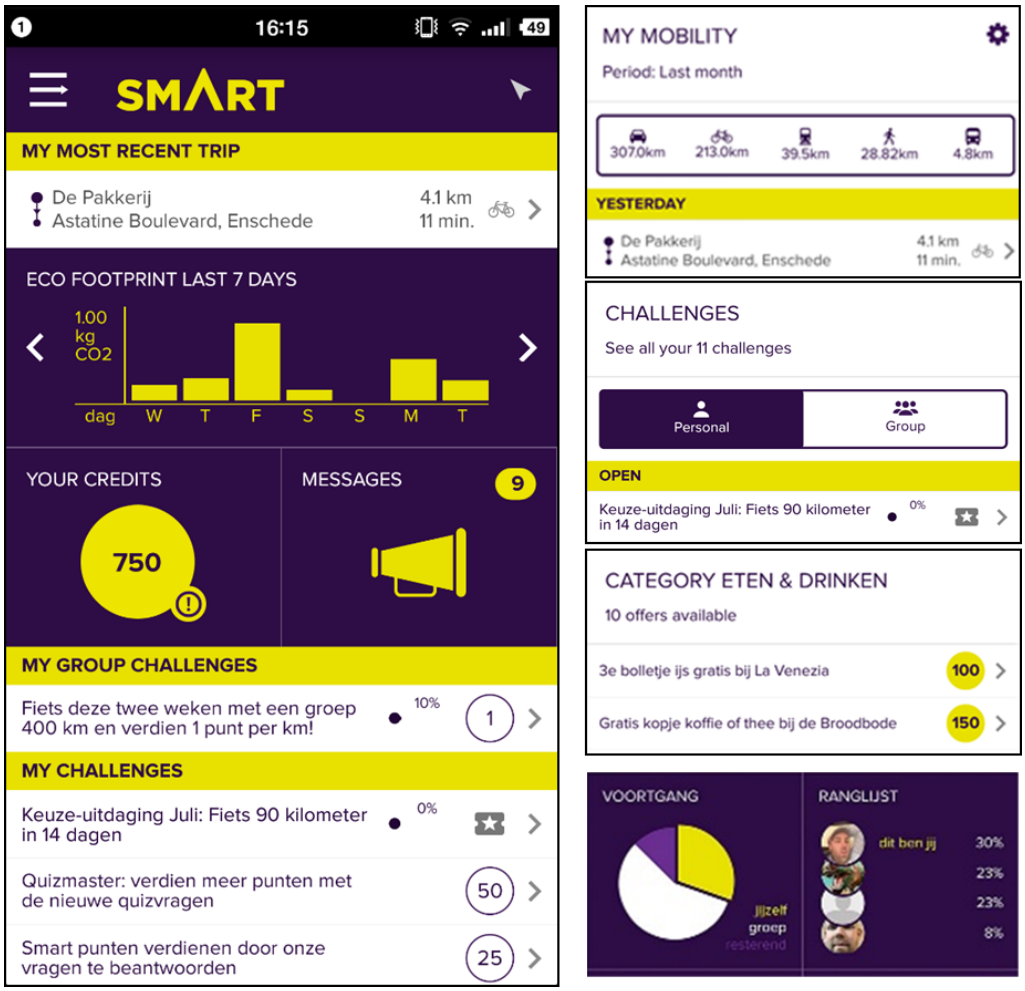

Figure 1: SMART Dashboard (left) and functionalities (right). From top to bottom: feedback on historic travel patterns, challenges, rewards, and social / group incentives.

Challenges

There are several challenges for everybody at any time, in order to keep people motivated to join and use SMART. These include: introduction challenges to get to know the SMART app and its functions, event

challenges to go to events (like concerts or attraction parks) in a sustainable way, bus challenges to promote the use of the bus in Enschede, walking challenges to focus on health benefits of walking, peak avoidance challenge to encourage people to travel outside the rush hours, and fun challenges to celebrate people staying with SMART. The most important challenges are the monthly bicycle challenges which encourage people to cycle more. At first, the idea was to personalize these challenges as people start from a different base. SMART users who already cycle a lot would get more difficult challenges than SMART users who hardly cycle. Unfortunately, personalization appeared to be too complicated from an operational point of view. Therefore we introduced the choice challenge, as shown in Table 2. Users themselves had the option to choose one out of five/six levels, from very easy to very difficult. The more difficult the challenge is that the user chooses, the more points the user can get by accomplishing that challenge. The relation between challenge difficulty and rewards is as a simple linear function, with a constant (baseline points) to make sure the users that rarely cycle can still gain reasonable points if they cycle for a short distance or a few trips. This enabled us to provide equal opportunities for everyone and at the same time personalize the challenge level. One of the drawbacks, however, is that users can choose challenges and win points without changing their behaviour. In that case they choose a level that is too easy for them. In contrast, if personalized challenges are too difficult, users may be discouraged participate. The advantage of the choice challenge is that users can choose their own level. It is, therefore, less likely they will be discouraged to participate because a challenge is too difficult. We included three main types of choice challenges with a challenge period of 14 days. These are location challenges (number of cycling trips to a fixed location), cumulative challenges (number of total cycling trips or cycling kilometres), and rate challenges (number of days to ride at least 10 kilometres by bike, and number of kilometres to be ridden by bike on at least 10 days) (see table 2). After the challenge period, there was a follow up with questions, asking users experiences with the challenges and whether or not they changed their behaviour to achieve this challenge.

Table 2Monthly Choice Challenge options and rewards

Challenge types	Challenge options (related reward in points)		Month
Cumulative (Distance) challenge	**The number of bike trips to be made within 14 days**		May, August
	Choice:	2, 5, 10, 25, 50 trips	
	Rewards	60, 90, 150, 330, 630.	
	The number of bike kilometres to be ridden within 14 days		December,
	Choice:	5, 20, 50, 100, 200 km	
	Rewards	50, 110, 230, 430, 832.	
	The number of bike kilometres to be ridden within xx days		January 2018
	Choice:	30, 60, 90 km in 14 days or 60 km in 3 or 7 days	
	Rewards	150, 270, 390, 510, 390	
	The number of bike trips or kilometres to be made within 14 days		April, July, October
	Choice:	5, 10, 50, trips, or 5, 50 200 km	
	Rewards	90, 150, 630, or 50, 230, 830	
Rate challenge	**The number of days to ride a bike at least 10 kilometres**		February 2018
	Choice:	1, 3, 6, 9, 12 days	
	Rewards	70, 150, 270, 390, 510	
	The number of bike kilometres to be ridden on at least 10 out of 14 days.		November
	Choice:	1, 2, 5, 10, 15 km per day	
	Rewards	70, 110, 230, 430, 630	
Location	**The number of bike trips to go to a certain location within 14 days**		March, June, September

Figure 2 shows the participation rate of challenges. Overall, 40 – 50% of SMART users participate in a challenge, and most of them participate in monthly challenges. This indeed indicates that monthly challenges are popular. We also find that many of those users participate in several challenges. However, there is still a significant part of users that do not participate in challenges. These users may be more passive

(only using the information functionalities) or maybe just trying the app. A positive point is that the turnover is quite low, i.e., the increase in new users is relatively moderate, but many new users stay for a longer period. Figure 2 also shows the fraction of users that completed the monthly challenge. Interestingly, there is quite some variation between months, indicating that some challenges may be easier to fulfil than others. This would indicate that for some challenges the lowest level would still be too difficult or that people cannot properly estimate the effort they have to make to complete the challenge.

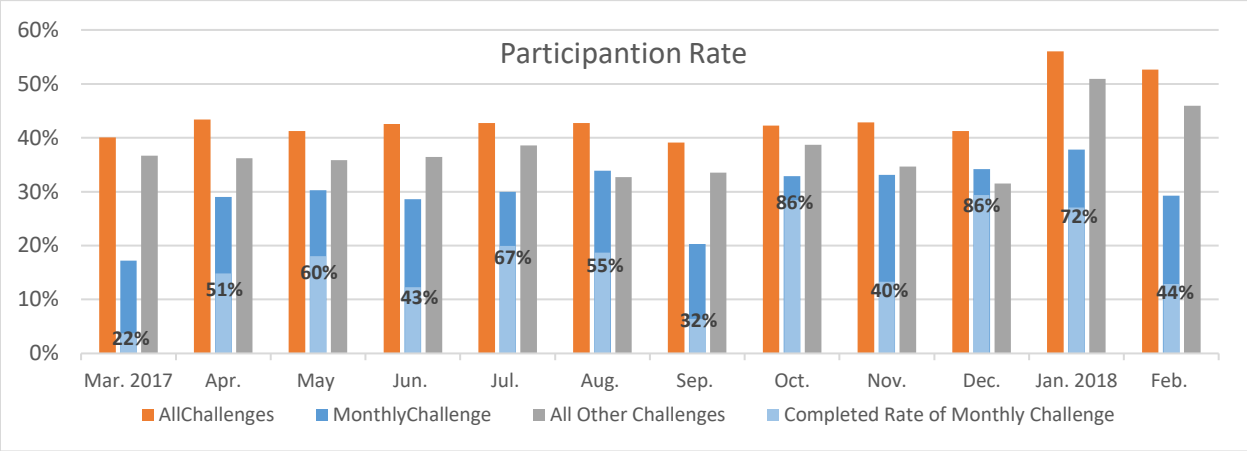

Figure 2: participation rate of challenges.

Users

There were several ways in which users were recruited. There was a general inflow due to various media outings and recommendations by friends. Other users were recruited for scientific experiments, but most users were recruited via specific campaigns such as the Enschede Cycle City campaigns, Charity campaigns (to cycle for a charity), Bike2Sport to stimulate teams to use the bike to sports events, and the SMART green campaign in which SMART bicyclists get faster green when they approach a certain traffic light. Once new users have installed SMART, the challenge is to keep people motivated to use the system. This is monitored by the number of active users: people who have at least recorded one trip per day (number of daily users) or during 10 days in a month (number of monthly users). Figure 3 gives an overview of the number of active users per day and month. The figure shows that many dips in the number of active daily users correspond with the weekends in which the rate of zero trips is larger than during workdays. Except from these dips, the number of daily and monthly users is quite stable and increases rapidly at the start of 2018. This rapid ascent can be attributed to the recent success of the Cycling City campaigns. One of the attractive parts of the campaign is that users get automatically one point per cycling or walking kilometre without the need to participate in cycling or walking challenges.

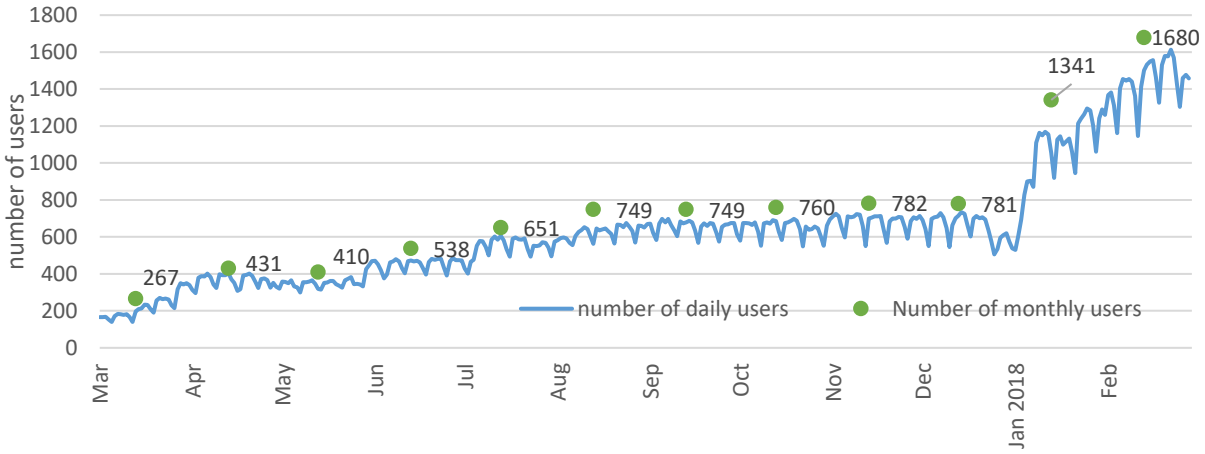

Figure 3: the number of active users per day and month (recorded trips during 10 days

Effects on cycling and car use

In the evaluation of the monthly choice challenges, we distinguish between participants and non-participants, and for the participants we distinguish between the trips made within the challenge period and outside the challenge period. It is important to note here that every month one monthly choice challenge was offered, but that the duration of the challenge was only 14 days (and that in practice this challenge period was even shorter when participants completed their challenge early). Therefore a comparison during the challenge and outside the challenge period (between completion of previous challenge and acceptance of next challenge) is possible. Note that we only included trips below 20 km, because beyond this distance cycling is not considered as a viable option (although this distance limit may be increased when more e-bikes are used). These trips cover almost all trips within the urban area of Enschede (and the neighbouring city of Hengelo) and therefore can also be regarded as urban trips.

When we compared the mode share of participants of the monthly choice challenges with other SMART users, we found there is clearly less car use and more bike use among users that accept the monthly choice challenge. However, we should be careful in interpreting these results as there are no before measurements to control for a possible bias between both groups. It is therefore not completely clear if the difference can be attributed to the challenges or to the fact that users that participated in the monthly choice challenges are just more motivated to cycle.

In the upper panel of Figure 4, we show the difference in modal shares between the challenge period and the outside challenge period. The figure clearly shows a significant increase in the bike share and a reduction in the car share during the challenge period. At least for the cumulative and rate challenges. Challenges with higher completion rates are also not less effective. This result is promising as it does not support the fear that participants (only) choose easy challenges they can fulfil without changing their behaviour.
On the contrary, Figure 4 clearly shows that challenges with the highest completion rates also yield most of the behavioural change. Challenges in which participants need to visit a specified location score poorly on both accounts, while challenges in which participants can choose the total cycling distance (cumulative challenges in centre panel) score best. The more difficult rate challenges (right panel) also score relatively good but appear to be less popular and slightly less effective.

Most respondents stated external circumstances (such as bad weather) as a reason when they failed to complete the challenge. The results from Figure 4 are further confirmed by the experienced sampling

questions. When they completed the challenge about 40% indicated they had cycled more (see Figure 5). Almost half of these people state they substituted car trips to achieve this. More than 50% also indicated that the SMART challenge was the reason for this. About 80% of the cyclists that indicated they had cycled more, also stated they would do this in the future. This result suggests that this behavioural change may be sustained.

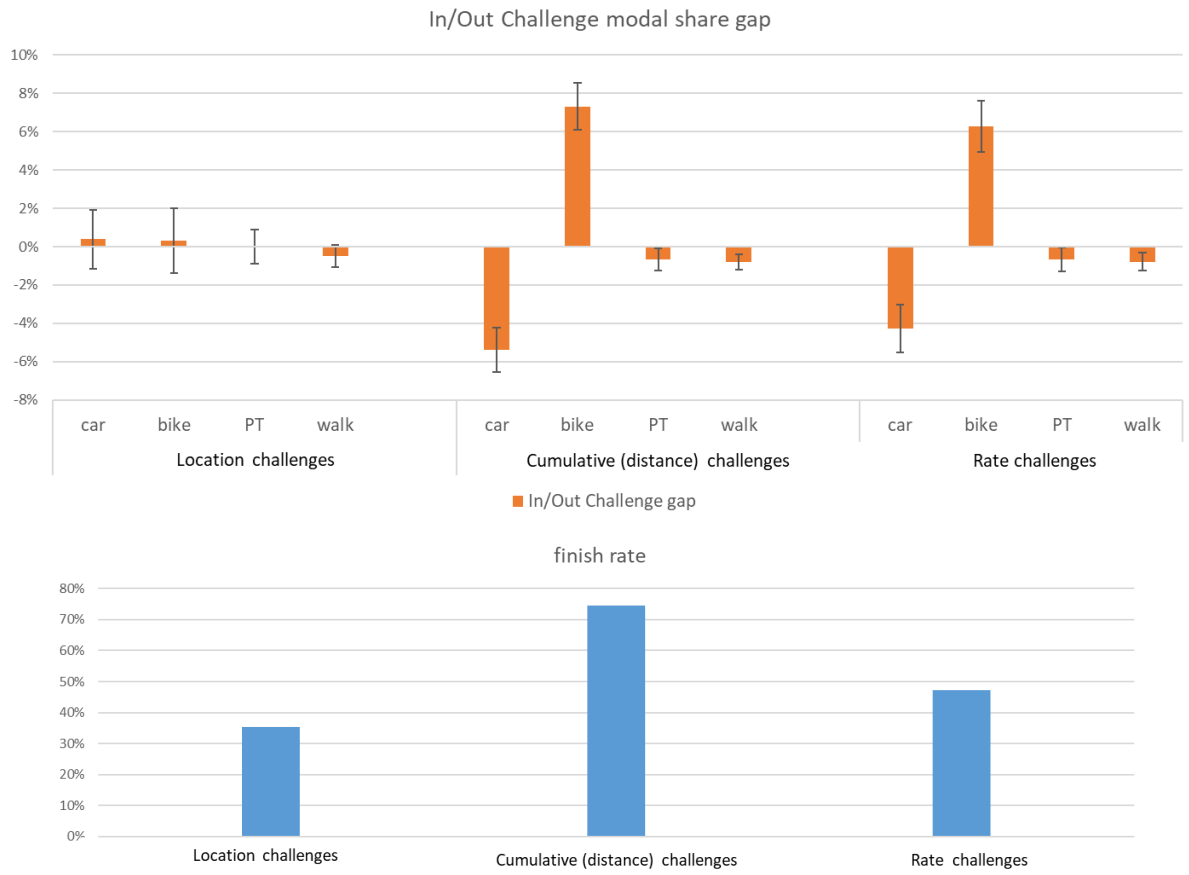

Figure 4: difference in modal share between in and outside challenge period (upper panel) and the average completion rate of the challenge (lower panel) per type of challenge.

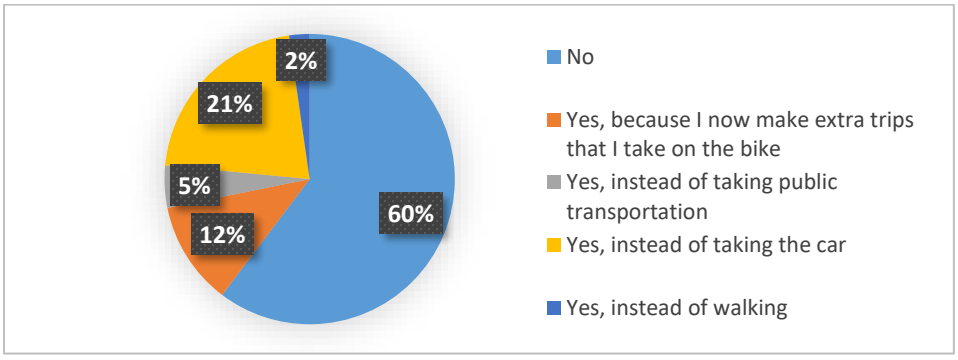

Figure 5 experience sampling question: Have you started cycling more often during the duration of the choice challenge?

Future

We conclude that monthly choice challenges can be an effective way to encourage cycling, and that the challenge is probably most effective when it is easy to comprehend and accomplish. Most users choose challenges that lead to an improvement in cycling behaviour, but too difficult challenges may be counterproductive. However, these results are still on a highly aggregated level. In the next step, we will use individual data and modelling approach to improve our analysis. One of the important remaining questions is whether the behavioural change will be sustained when no challenges are provided. Or do people fall back towards their former behaviour, even if they say they will continue cycling more. In other words, do people cycle more over time, also outside the challenge periods? And how long should we provide users with these types of challenges to obtain sustained behaviour change? To answer this question, we not only need to look at individual data, but probably also need to extend the total observation period beyond one year.

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