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The complexity of changes in modal choice: A quasi-experimental study

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A B S T R A C T

Background: Changes in modal choice is argued to be one way to reduce the emission of greenhouse gases. Increasing modal choices in favour of more environmentally friendly travel modes requires a better understanding of how these choices are actually made. The first aim of this study is therefore to examine how modal choice is related to subjective experiences as perceived accessibility, perceived satisfaction, and habit, both before and after an intervention promoting public transport. The second aim is to examine how modal choice is affected by the intervention. Finally, the third aim is to examine how subjective experiences as perceived accessibility, perceived satisfaction, and habit are affected by the intervention.
Method: The design used is a before- and after-study with free public travel passes as the intervention (30- or 14-days free travel pass). Altogether, 52 travelers – distributed on two intervention groups and one control group – participated in the study. The 30-days free travel pass group constitutes 18 participants, the 14-days free travel pass group constitutes 19 participants while the control group constitutes 15 participants. During the before-period the participants were asked to register their modal choice using a digitalized application downloaded on their smart phones (the TravelVu app), to complete a short app-based questionnaire, and a web-based questionnaire. During the after-period, they were once again asked to register their modal choice and to complete a web-based questionnaire. All data collected were analyzed by variance or correlation analyses using the change between before- and after period as the dependent variable.
Results: The results show that walking was more common than the use of public transport and car, which in turn were more common than the use of bicycle. Perceived accessibility, perceived satisfaction, general health, life quality as well as habit were all rated fairly high. Over time, the use of public transport increased while the use of car decreased overall. With increased use of public transport, the perceived accessibility decreased, but on the other hand, the life quality increased. There was no difference in perceived accessibility, perceived satisfaction, or habit between the three groups, but the participants became overall more satisfied with the standard of their experiences of their everyday travel (cognitive evaluation). At the same time, they became less reflective of their choice of travel mode and less interested in trying out new alternative travel modes during the after- compared to the before period.
Conclusion: The intervention did not affect the modal choice or the subjective experiences. Over time, the participants did however increase their use of public transport and their cognitive evaluation of their everyday travel overall, while they decreased their use of car and became less reflective and less interested in trying out new alternative travel modes. These changes might be attributed to their participation in the present study.

1. Introduction

The transport sector is a major contributor to the climate change problems that the society faces today. The consumption of fossil

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fuel from transport sector stands for 23 % of the emission of greenhouse gases globally (IEA, 2019). Private car use is often referred to as a less sustainable way for mobility than public transport (Collins & Chambers, 2005). In contemporary societies, the ability to be mobile is a crucial prerequisite to access opportunities (jobs, private and public services, social relations). The possession of an adequate mobility capital, or «motility» (Kaufmann, et al., 2004), becomes an essential pre-condition for the construction and maintenance of relations and social connections (Pflieger, Kaufmann, Pattaroni, & Jemelin , 2009; Urry, 2007). Developing initiatives that allow societies to embrace more sustainable modal choices is a prerequisite for creating more sustainable mobility for livable urban futures (Marsal-Llacuna et al., 2015; Nikitas, 2018; Wey & Huang, 2018). Public transport, cycling, e-biking and walking are considered the conventional sustainable alternatives to car (Bagloee et al., 2016; Dill, 2009; Fujii, Gärling, & Kitamura, 2001; Heinen, Harshfield, Panter, Mackett, & Ogilvie, 2017; Redman, Friman, Gärling, & Hartig, 2013; Zhao et al., 2018). In many of the cities, public transport counts for an important travel mode share, while mode share of cycling varies between the cities. Cities are striving to promote those modes share via different approaches, i.e., increasing the use of both public transport and cycling point to an intermodality style which is in the form of public transport plus cycling (Kuhnimhof, Chlond, & Huang, 2010; Olafsson, Nielsen, & Carstensen, 2016). Car sharing (Roblek, Meško, & Podbregar, 2021) and its impact on urban sustainability has also been addressed.

1.1. Modal choice

A number of studies have been carried out to investigate the determinants of present modal choice, and their significant effects (Acker et al., 2007; Berg, Henriksson & Ihlström, 2019; Cao, 2015; Cervero & Day, 2008; Cheng, Chen, De Vos, Lai, & Witlox, 2019; Naess, 2006; Næss, 2013). Those studies contributed to a comprehensive knowledge foundation for understanding the dependencies of travel behavior from different perspectives among which, individual and environmental aspects formed the key factors. However, to increase people's use of sustainable transport modes, it is important to understand the psychological decision-making process of modal choice, and the factors that trigger the change of the travel behaviour (Dill & Voros, 2007; Haustein & Møller, 2016; Ma & Dill, 2015).

The factors influencing especially commuter's modal choice have been explored by Yang, Wang, Liu and Zhou (2018) and five categories of factors are presented; 1. Travel demand characteristics, 2. Travel mode characteristics, 3. Socio-demographic characteristics, 4. Subjective attitudes and perceptions, and 5. Environmental characteristics. The present study will focus on subjective experiences and perceptions (i.e., mainly factor 4 above) in relation to modal choice measured by a GPS based application (the TravelVu app).

1.2. Perceived accessibility, perceived satisfaction, general health, life quality, and habit

The subjective experiences in focus are perceived accessibility, perceived satisfaction, and self-reported habit. General health and life quality is also included to control for these aspects as possible confounding factors.

Lättman, Friman, and Olsson (2016), focused on social inclusion and perceived accessibility in day-to-day travel, and in line with this they also developed an instrument for evaluating perceived accessibility, in contrast to objective measures of accessibility. This instrument, the Perceived Accessibility Scale (PAC), has since been used for evaluating and understanding accessibility with different travel modes (Lättman, Olsson, & Friman, 2016, 2018). The question raised in the present study will, however, focus on how perceived accessibility is related to actual modal choice and especially changes in modal choice.

Another important concept for modal choice might be perceived satisfaction with daily travel which can be evaluated with the Satisfaction with Travel Scale (STS; Friman et al., 2013). Satisfaction with travel was shown to influence emotional well-being and it was also shown that active modes and car driving were more related to well-being than public transport (Friman et al., 2017).

Finally, habit of using a specific transport mode might be a barrier of behavioral change (cf. De Bruijn & Gardner, 2011). Heinen and Ogivie (2016) showed that commuters with a higher variability (in modal choice) at baseline assessments were more likely to change their way of travelling (cf. Sivasubramaniyam, Charlton & Sargisson, 2020).

1.3. Free public transport

In an attempt to understand modal choice, different user groups have been identified, such as car "shedders", "keepers", accessors, and those already car sharing (Sochor, Strömberg & Karlsson, 2015). This shows that some groups are more prone for change than others and the concept of a transportation "smorgasbord" was introduced to capture the development of services that could promote a positive, sustainable modal change based on different user needs, preferences, and motives.

An example of an intervention supporting a transfer to a more sustainable modal choice is free public transport passes. Forward (2019) has showed that a free public transport pass can have a positive effect on attitude towards use of public transport. The study performed by Forward included 34 participants (41 participants were given a 15-days free public transport pass, but only 34 used the pass). The author showed that 50 % of the participants still used public transport three months later. The data was based on a straightforward question, i.e., "Have you travelled by public transport the last two weeks?". It has also been found that car drivers and pedestrian commuters were less likely to use a combination of modes compared to cyclist, car passengers, and public transport traveller commuters (Sivasubramaniyam, Charlton & Sargisson, 2020). When a new metro station was used as an intervention (Sun, Zhao, Webster, & Lin, 2020) it did not increase active travel or reduced car use. In all these intervention studies, diaries or questions were asked about participants travelling choices.

Schoenau and Müller (2017) argue for a more objective measure of modal choice. In the present study, a GPS based application (TravelVu app) is therefore used to assess the participants modal choice. Sjöman, Ringenson and Kramers (2020) have previously used

the TravelVu app for registration of driven kilometers and economic incentives. The authors followed nine participants over a six month period and concluded that most participants were not sensitive to the costs of car use. The authors also concluded that logging was automatic, and very seldom trips were missed. The TravelVu app has also been used to study modal change among frequent car drivers who, during a test period, got access to an e-bike (Söderberg f.k.a. Andersson et al., 2021). The results showed that the share of e-bike trips in the treatment group increased from 0 % to 17 %, whereas the share of car trips decreased from 74 % to 53 %. Interestingly, the share of conventional cycling also increased during the test period (from 4 % to 12 %), although not significantly. The share of public transport trips and walking trips stayed at approximately the same levels, meaning that the whole increase of cycling trips was at the expense of car travel. The control group showed no significantly differences between the two measurement occasions. However, later on, also the control group had access to the e-bikes and after this test period this group showed similar mode changes to the original treatment group. The share of car trips decreased even more in this group and the share of conventional bicycle trips increased from 2 % to 12 %, which in this group was a significantly increase.

1.4. Aim

Increasing modal choices in favour of more environmentally friendly travel modes requires a better understanding of how these choices are actually made. The main objective of this quasi-experimental study is therefore to examine the effect of a free public travel pass on modal choice. The first aim is to examine how modal choice is related to subjective experiences as perceived accessibility, perceived satisfaction, and habit, both before and after the intervention. The second aim is to examine how modal choice is affected by the intervention. Finally, the third aim is to examine how subjective experiences as perceived accessibility, perceived satisfaction, general health, life quality, and habit are affected by the intervention. The prediction was that the free public travel pass would affect modal choice. How perceived accessibility, satisfaction and habit is related to modal choice and especially changes in modal choice is however difficult to predict.

2. Method

2.1. General procedure

In this quasi-experimental study, an intervention promoting the use of public transport was evaluated using the digitalized application (TravelVu app), as well as questionnaires. Employees at Botkyrka Municipality in Stockholm County were offered a free public travel pass for 14 or 30 days. In addition, a control group was recruited among residents living in different municipalities in Stockholm County. The four municipalities included in the study are located in Stockholm County, which had approximately 2.4 million inhabitants in 2019 (www.scb.se). Botkyrka Municipality is an outer suburb and has approximately 500 inhabitants per square kilometre, while Stockholm, Solna, and Sundbyberg municipalities are located in the central region of Stockholm County and have 4000–6000 inhabitants per square kilometre. According to Johansson (2020), the inhabitants of Stockholm County make, on average, 2.0 trips per day. In Botkyrka Municipality, 59% of the trips are made by car while 24% are made by public transport and 7% by bicycle, and in the central region of Stockholm County 36% of these daily trips are made by public transport while 23% are made by car and 10% by bicycle.

The design used in the present paper is a before- and after-study. During the before-period the participants were asked to register their modal choice using the TravelVu app (for further details see *Instruments* below) and to complete a short app-based questionnaire including background questions. A few days later they received an e-mail with a link to a web-based questionnaire. During the before-period, data was collected in June-August 2019 for those receiving free travel passes and in May-July 2019 for those in the control group. The intervention was then introduced as a free public travel pass (for 30 or 14 days) that could be used on buses, undergrounds, trains, and some ferries in the Stockholm County. During the after-period, the participants were once again asked to register their modal choice using the TravelVu app and to complete a web-based questionnaire. During the after period, data was collected in October-November 2019 for those receiving free travel passes and in September-October 2019 for those in the control group.

2.2. Participants

Botkyrka Municipality, in Stockholm County, e-mailed 858 employees, inviting them to participate in the study. Those interested in participating responded by e-mail directly to the authors to receive further information. A total of 68 employees validated and, if needed, corrected the trip-information (times, distance, mode, route) suggested by the TravelVu app for at least four days, and completed the web-based questionnaire during the before-period. Among these 68 employees, the 50 who had registered the use of car

Table 1
The number, gender and age of the participants receiving the free public travel pass for 30- or 14-days as well as for those in the control group.

	30-days free travel pass	14-days ree travel pass	Control
Number	18	19	15
# women	12	15	9
Mean age	50	41	43
SD	10.72	10.62	11.76

or motorcycle as drivers and/or passengers were selected together with an additional 10 employees among the remaining who had not registered any use of car. Finally, the 60 selected employees were randomly distributed into two groups with 30 employees in each and offered a free public travel pass for 30 and 14 days, respectively. Eighteen of those who received the 30-days free travel pass and 19 of those who received the 14-days free travel pass corrected at least four days registered by the TravelVu app and completed the web-based questionnaire during the after-period. Table 1 shows the number, gender, and age of those with data on modal choice, perceived accessibility, perceived satisfaction, habit, general health, and life quality, during the before- as well as the after-period.

Everyone who corrected at least four days registered by the TravelVu app or completed the web-based questionnaire during the before-period or corrected at least four days or completed the web-based questionnaire during the after-period were offered cinema tickets (one ticket after each task). The total possible value of the cinema tickets was approximately EUR 40 for each person.

To recruit a control group, 2000 postal letters were sent to a random selection of residents aged 20–64 years, 50% men and 50% women, living in three different municipalities (Stockholm Municipality, 1000 residents; Solna Municipality in Stockholm County, 500 residents; Sundbyberg Municipality in Stockholm County, 500 residents). Addresses were retrieved by the Swedish Registration Service (SPAR), which also conducted the randomization. Those interested in participating in the control group replied by e-mail to the authors to receive further information. Finally, 15 residents that completed all instruments and data collections in the same way as the experimental groups were included in the analysis. To match the 30-days and the 14-days free travel pass groups, these 15 residents were selected because they had registered similar car use during the before-period. Everyone in the control group were offered cinema tickets or lottery tickets in the same way as those in the experimental groups.

2.3. Instruments

Modal choice was measured with the TravelVu digitalized application (a smart phone app) which registered all traveling before and after the intervention. The participants downloaded the app on their smart phone and accepted the agreements before they were asked to complete a short app-based questionnaire including a number of background questions. The app automatically analysed the information from the smart phone (i.e., the participants did not have to activate the app when travelling) and the participants were presented with a travel diary suggestion (see Fig. 1) which included information about the trip (times, distance, mode, route). The first time participants stopped at a location they were asked to enter the purpose of the stop. When stopping at the same location again a

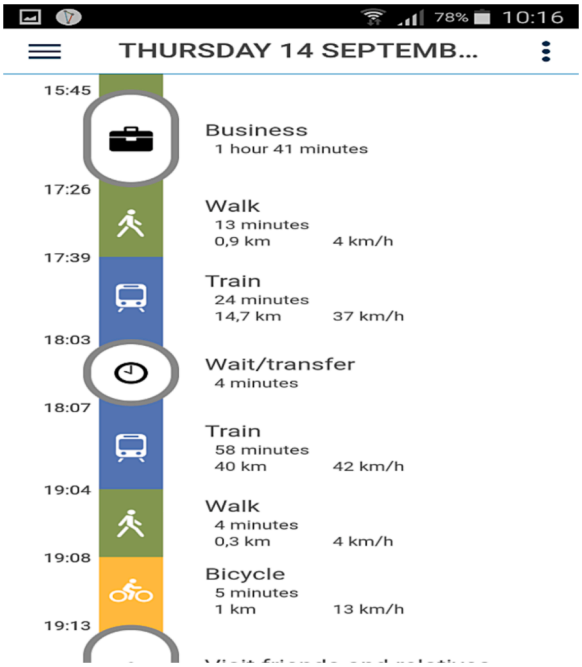

Fig. 1. An example of the travel diary participants was to validate (correct).The app collected a complete timeline with movements and stops which were aggregated into trip legs (describing all parts of a trip) and trips (defined by having an activity/errand at the end of the trip), see Fig. 2. In the present paper, only trip legs have been analyzed, i.e., activities/errands have not been included. Only the four most frequently used modes of transport (car, public transport, bicycle, and walking) were further analyzed. These four modes of transport constituted 94–99 % of all trip legs. Trip legs shorter than three minutes were added to the following trip leg. If a short trip leg was followed by an activity, it was added to the previous trip leg instead. When there was no other trip leg neither before nor after, the trip leg was included in the analyses as a separate trip leg. These criteria means that if a walk from home to a public transport mode took two minutes it was included in the public transport trip leg. If the walk, on the other hand, took three minutes it was regarded as a separate trip leg. A two-minutes' walk, from home to the shop (not to another travel mode) was also seen as a unique trip leg.

purpose was automatically suggested in the travel diary (e.g., home, work, shopping). The participants were asked to validate the suggested travel diary and make corrections if needed (to modes, purposes, times, distances etc.). When the travel diary was correct (with or without corrections), the participants marked the day as "correct", and the data was included in the analysis. In total, the participants were asked to validate (and if necessary correct) four days during the before- and the after-period, respectively.

Perceived accessibility was measured using the perceived accessibility scale (PAC) which is aimed at capturing the individual perspective of overall accessibility of daily travel, regardless of travel mode, or combination of modes (Lättman et al. 2018). It was measured on a 7-point scale (*1 = totally disagree, 7 = totally agree*) using four items: "Considering how I travel today, it is easy to do my daily activities.", "Considering how I travel today, I am able to live my life as I want to.", "Considering how I travel today, I am able to do all the activities I prefer.", and "Access to my preferred activities is satisfying considering how I travel today." An index was then calculated by taking the mean of the four items. Cronbach's alpha was 0.92.

Perceived satisfaction was measured using an adapted version of the satisfaction with travel scale (STS) which is designed to include both affective and cognitive components related to daily travel (Ettema et al., 2011). While the original instrument used 9-point bi-polar scales (e.g., −4 to 4) the adapted version (Friman, Gärling, Ettma, & Olsson, 2017) used 7-point unipolar scales. The item used was "How would you describe your experiences of your everyday travels? I.e., regular trips that you make to work, school, shops, training, healthcare, etc.?" together with nine rating scales. Three of the rating scales measure positive activation with endpoints: *very bored – very enthusiastic, very fed up – very engaged;* and *very tired – very alert*, while three measure positive deactivation with endpoints: *very stressed – very calm; very worried – very confident;* and *very hurried – very relaxed*. Finally, three rating scales measure cognitive evaluation: *worked very poorly – worked very well; very low standard – very high standard;* and *worst imaginable – best imaginable*. An index was then calculated for each of the three STS factors by taking the mean of the three items, respectively. Cronbach's alphas for positive activation, positive deactivation and cognitive evaluation were 0.86, 0.73, and 0.72, respectively, during the before-period and 0.82, 0.64, and 0.84 during the after-period.

Habit was measured on a 7-point scale *(1 = I absolutely disagree; 7 = I absolutely agree)* using four items "I'm largely a person who do things the same way every day and like routines.", "My choice of travel modes this past week has been more or less automatic.", "I'm interested in trying out new alternative travel modes to take me to my activities.", and "I often reflect on what travel mode I choose when I get to my activities.".

General health was measured on a 5-point scale (*1 = bad, 5 = excellent*) using one item: "How would you rate your general health?".

Life quality was measured on a 5-point scale (*1 = bad, 5 = excellent*) using one item: "How would you rate your general quality of life?".

The two latter items were included in the present study as health and life quality related issues might constitute a barrier for modal change, and changes that occur during, or after, the intervention create confounding factors.

Additional questions included participants' age and gender (presented under *Participants* above). It also included questions about education, work, residence, accessibility of different travel modes, and income. Finally, it included instruments to measure stages of change (based on the transtheoretical model of change, TTM), and decision making (based on the theory of planned behaviour, TPB). None of this is presented in the present paper but results regarding stages of change and decision making can be found in Wallén Warner, Björklund and Andersson (2021).

2.4. Statistical analyses

Firstly, the change in modal choice (trip legs with use of car, public transport, bicycle and walking) and subjective experiences (PAC:1 index, STS-factors: positive activation, positive deactivation, and cognitive evaluations; habit: 4 items; general health: 1 item, and life quality: 1 item) between the before- and after-period were calculated. The change value was calculated by subtracting the after-value from the before-value. Hence, if a participant used public transport to a greater extent before the intervention, compared to after, it resulted in a positive value for change in use of public transport. The calculations of change have not considered number of trips legs for a specific individual, i.e., an individual that has completed a large number of trip legs is treated in the same way as an individual that has completed a lower number of trip legs. The relationships between changes were then examined using the Pearson's correlations.

Secondly, five mixed ANOVAs were conducted to examine differences between groups as well as between the before- and after-

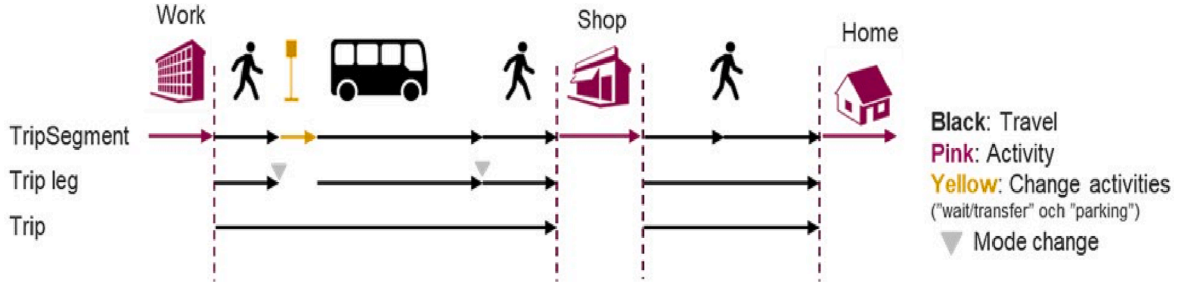

Fig. 2. Description of the data collected by TravelVu and how it is aggregated into trip legs and trips (Adell, unpublished).

period with modal choice, perceived accessibility, perceived satisfaction, habit, general health, and life quality being repeated measures. In these ANOVAs, the two variables: group (between participant variable) and time (within participant variable) were always included, i.e.., three groups and two times. The last factor in one of the five ANOVAS was either modal choice proportion, PAC scores, STS scores, Habit ratings or Health ratings. When significant effects for main or interaction effects were found, pairwise comparison was used to examine these interactions further. Bonferroni corrections were applied for multiple testing.

3. Results

Table 2 shows that the change in use of car was negatively correlated with the change in use of public transport and in walking. The change in use of bicycle was also negatively correlated with the change in walking (however, this coefficient decreases to −0.21, and is no longer statistically significant, when the three observations with highest increase in cycling respectively walking are omitted). Hence, the participants' decrease of car use is substituted by travelling by public transport and walking (the latter includes walking to the public transport). Furthermore, the change in perceived satisfaction (positive activation) was positively correlated with the change in use of car, and negatively correlated with the change in walking. This means that increased car use was related to increasing enthusiasm, engagement, and alertness, whereas increasing walking was related to a decrease in these aspects of satisfaction. Finally, there were negative correlations between the change in use of public transport and the change in perceived accessibility as well as in the change in use of bicycle and the change in fondness of routines (Habit 1).

There were positive correlations between the change in perceived accessibility and the change in perceived satisfaction (cognitive evaluation) as well as in the change in reflection on choice of travel mode (Habit 4). There was also a positive correlation between the change in reflection on choice of travel mode (Habit 4) and the change in perceived satisfaction (positive activation) as well as with the change in the interest in trying new travel modes (Habit 3). In addition, the changes in the three factors of perceived satisfaction (positive activation, positive deactivation, and cognitive evaluations) were highly inter-correlated. Finally, general health was positively corelated with automatic choice of travel mode (Habit 2) as well as with life quality. Life quality was also positively correlated with the change in use of public transport. Hence, if the participants increased their use of public transport their perceived accessibility decreased, but on the other hand, their life quality increased.

Table 3 shows the mean values for the proportion of modal choices as well as the estimation of subjective experiences for the participants who were offered the 30-days and 14 days free travel passes as well as the control group, for the before- and after-period, respectively. A high mean score indicates a high usage of the modal choice in question, a high perceived accessibility, a high satisfaction, strong habits (Habit 1 + 2), weak habits (Habit 3 + 4), good health and good life quality.

Walking was the most common and the use of bicycle the least common modal choice for all three groups both during the before- and the after-period. The use of car and public transport was fairly similar. Furthermore, all three groups rated perceived accessibility, perceived satisfaction, habit, general health, and life quality, fairly highly during the before- as well as the after-period. However, there seems to be some differences between the groups, i.e., the control group rated reflection of choice of travel mode (Habit 4) somewhat lower than the groups receiving the free travel passes. This was tested using ANOVAs below.

A 3 (groups) by 2 (time) by four (modal choice) mixed ANOVA was conducted (see Fig. 3). The analyses revealed a main effect of

Table 2
Pearson correlations for the *changes* in modal choices as well as subjective experiences between the before- and after-period. Only significant Bonferroni corrected correlations are presented. n = 52.

	Car	PT	Bicycle	Walk	PAC	STS: PD	STS: PA	STS: CE	Habit 1	Habit 2	Habit 3	Habit 4	Health
Car													
PT	-0.48**												
Bicycle	ns	ns											
Walk	-0.62**	ns	-0.50**										
PAC	ns	-0.38**	ns	ns									
STS: PD	ns	ns	ns	ns	ns								
STS: PA	0.45**	ns	ns	-0.31*	ns	0.60**							
STS: CE	ns	ns	ns	ns	0.28*	0.44**	0.44**						
Habit 1	ns	ns	-0.29*	ns	ns	ns	ns	ns					
Habit 2	ns	ns	ns	ns	ns	ns	ns	ns	ns				
Habit 3	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns			
Habit 4	ns	ns	ns	ns	0.36**	ns	0.37**	ns	ns	ns	0.37**		
Health	ns	ns	ns	ns	ns	ns	ns	ns	ns	-0.30*	ns	ns	
LQ	ns	31*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0.33*

PT = Public transport; PAC = Perceived accessibility scale; STS: PD = Satisfaction with travel scale: positive activation; STS: PA = Satisfaction with travel scale: positive deactivation; STS: CE = Satisfaction with travel scale: cognitive evaluations; Habit 1 = I'm largely a person who do things the same way every day and like routines; Habit 2 = My choice of travel modes this past week has been more or less automatic; Habit 3 = I'm interested in trying out new alternative travel modes to take me to my activities; Habit 4 = I often reflect on what travel mode I choose when I get to my activities; Health = General health; LQ = Life quality.
ns = non significant;
* $p < 0.05$.
** $p < 0.01$.

Table 3
Mean values and standard variation (in parenthesis) for the proportion of modal choices as well as the estimation of subjective experiences for the before- and after-period, respectively.

	30-days free travel pass		14-days free travel pass		Control	
	Before	After	Before	After	Before	After
Car	0.25 (0.20)	0.27 (0.26)	0.29 (0.22)	0.23 (0.16)	0.21 (0.09)	0.13 (0.13)
PT	0.18 (0.17)	0.20 (0.19)	0.17 (0.13)	0.22 (0.13)	0.23 (0.14)	0.26 (0.16)
Bicycle	0.04 (0.09)	0.03 (0.10)	0.05 (0.08)	0.05 (0.08)	0.08 (0.13)	0.12 (0.20)
Walking	0.48 (0.14)	0.45 (0.18)	0.43 (0.15)	0.46 (0.12)	0.44 (0.16)	0.46 (0.14)
PAC	5.18 (1.49)	5.33 (1.12)	4.93 (1.68)	4.87 (1.71)	5.65 (1.55)	5.33 (1.50)
STS: PD	4.92 (0.93)	4.91 (0.96)	4.79 (1.15)	5.00 (1.26)	5.24 (1.04)	5.36 (1.08)
STS: PA	4.57 (0.80)	4.43 (0.65)	4.40 (1.19)	4.33 (1.17)	4.62 (0.96)	4.58 (1.14)
STS: CE	4.91 (0.91)	5.24 (0.60)	4.96 (1.01)	4.98 (1.26)	5.24 (0.60)	5.56 (0.60)
Habit 1	4.61 (1.38)	5.06 (1.26)	5.68 (1.29)	5.53 (1.17)	4.40 (1.72)	4.67 (1.54)
Habit 2	4.94 (1.92)	5.00 (1.61)	5.32 (2.03)	6.37 (0.83)	5.73 (1.28)	6.00 (1.25)
Habit 3	4.39 (1.82)	3.94 (1.59)	4.68 (2.16)	3.79 (2.30)	4.20 (2.01)	4.00 (1.64)
Habit 4	5.11 (1.60)	4.28 (1.64)	5.16 (1.68)	4.32 (2.43)	3.87 (1.92)	3.40 (1.64)
Health	3.72 (0.89)	4.00 (0.69)	3.79 (0.98)	3.74 (0.87)	4.00 (1.07)	4.07 (1.03)
LQ	3.78 (1.06)	3.94 (0.87)	3.74 (1.05)	3.74 (1.05)	4.00 (0.76)	3.87 (0.92)

PT = Public transport; PAC = Perceived accessibility scale; STS: PD = Satisfaction with travel scale: positive activation; STS: PA = Satisfaction with travel scale: positive deactivation; STS: CE = Satisfaction with travel scale: cognitive evaluations; Habit 1 = I'm largely a person who do things the same way every day and like routines; Habit 2 = My choice of travel modes this past week has been more or less automatic; Habit 3 = I'm interested in trying out new alternative travel modes to take me to my activities; Habit 4 = I often reflect on what travel mode I choose when I get to my activities; Health = General health; LQ = Life quality.
All items were measured on 7-point scales, except for the General health and Life quality, which were measured on 5-point scales.

modal choice ($F(3, 147) = 50.2$, $p < 0.05$, $MSe = 0.05$). Pairwise comparisons revealed that the proportion of walking was higher than the proportion of use of public transport and car, which in turn was higher than the proportion of use of bicycle. The interaction effect of time by proportion of modal choice ($F(3, 147) = 2.70$, $p < 0.05$, $MSe = 0.01$) revealed that the overall use of car decreased over time (although this was not the case for the 30-days travel pass group) and that the proportion of public transport usage increased over time overall, i.e., no interaction effects of group.

A 3 (groups) by 2 (time) by one (PAC) mixed ANOVA was then conducted. No significant effects were found. The interpretation is that perceived accessibility was experienced in the same way for the groups who was offered the 30-days and 14 days free travel passes as well as the control group, during the before- and after-period, respectively.

Furthermore, a 3 (groups) by 2 (time) by 3 (STS factors) mixed ANOVA was conducted. The results revealed a main effect of the STS

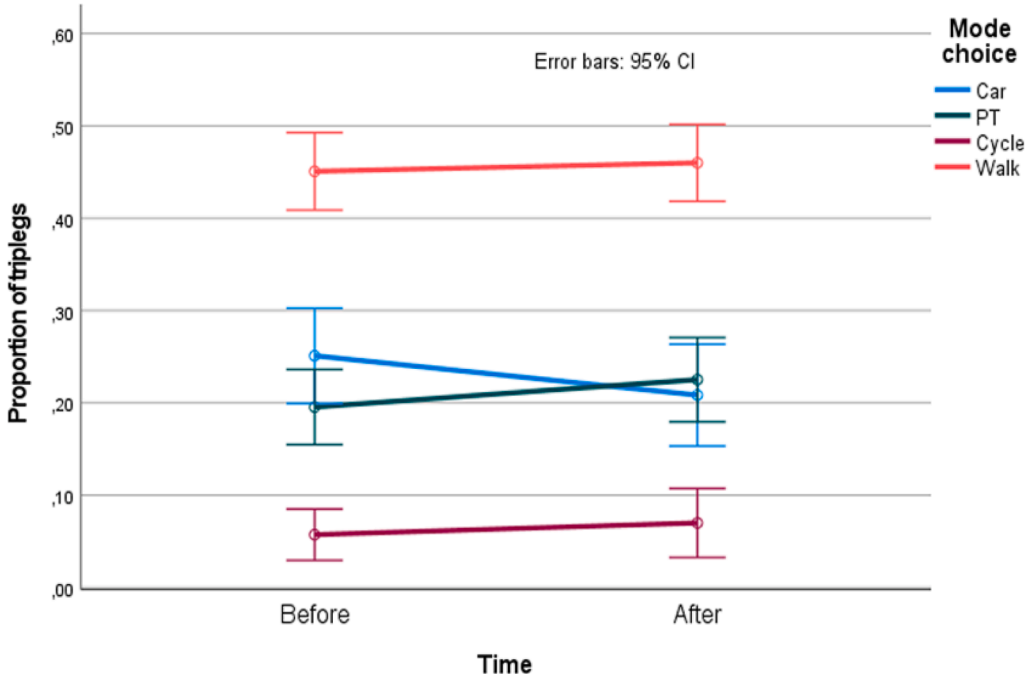

Fig. 3. The proportion of modal choice car, public transport (PT), bicycle, and walking, during the before- and after-period, respectively.

factors ($F(2, 98) = 25.54 p < 0.05$, MSe = 0.55). Pairwise comparisons revealed that positive activation was rated lower than positive deactivation and cognitive evaluation. The interaction effect of STS factors by time was significant ($F(2, 98) = 4.03 p < 0.05$, MSe = 0.15). Pairwise comparisons revealed that cognitive evaluation, but not positive activation nor positive deactivation, increased over time. This means that during the after-period, the participants experienced that their everyday travel worked better, kept a higher standard, and was approaching the best imaginable. Pairwise comparisons also revealed that positive activation was lower than both positive deactivation and cognitive evaluation during the before- as well as the after-period (see Fig. 4).

When correcting for multiple testing only one significant correlation was found between the habit items, namely between Habit 3 and Habit 4 (without correcting for multiple testing Habit 1 and Habit 2 was also correlated). The four items were therefore treated separately instead of creating indexes. A 3 (groups) by 2 (time) by 4 (habit items) was conducted. A main effect of habit ($F(3, 147) = 9.64$, $p < 0.05$, MSe = 4.3) as well as an interaction effect of time by habit ($F(3, 147) = 6.1$, $p < 0.05$, MSe = 1.3) were found (see Fig. 5). The main effect of habit revealed that all three groups rated automatic choice of travel mode (Habit 2) higher than interest in trying new travel modes (Habit 3) and the reflection of choice of travel mode (Habit 4). Pairwise comparisons of the interaction effect revealed that the automatic choice of travel mode (Habit 2) increased to some extent over time, while the opposite was true for interest in trying new travel modes (Habit 3) and reflection of choice of travel mode (Habit 4). During the before-period, automatic choice of travel mode (Habit 2) was rated higher than interest in trying new travel modes (Habit 3). During the after-period, automatic choice of travel mode (Habit 2) was rated higher than both interest in trying new travel modes (Habit 3) and reflection of choice of travel mode (Habit 4).

Finally, a 3 (groups) by 2 (time) by 2 (health and life quality items) mixed ANOVA was conducted. No significant effects were found. The interpretation is that changes in health and life quality were experienced in the same way for all three groups during the before- and after-period, respectively. This also suggests, to some extent, that the potential effect of intervention, was not confounded by health or life quality related issues.

Taken together, the results show that walking was more common than the use of public transport and car, which in turn were more common than the use of bicycle. Perceived accessibility, perceived satisfaction as well as habit were all rated fairly high. Over time, the use of public transport increased while the use of car decreased overall (although this decrease in use of car could not be seen in the 30-days free travel pass group). With increased use of public transport, the perceived accessibility decreased, but on the other hand, the life quality increased. There was no difference in perceived accessibility, perceived satisfaction, or habit between the three groups, but the participants became overall more satisfied with the standard of their experiences of their everyday travel (cognitive evaluation) at the same time as they became less reflective of their choice of travel mode and less interested in trying out new alternative travel modes during the after- compared to the before-period.

4. Discussion

The first aim of this study was to examine how modal choice is related to subjective experiences as perceived accessibility, perceived satisfaction, and habit, both before and after an intervention consisting of free travel passes. The results revealed that

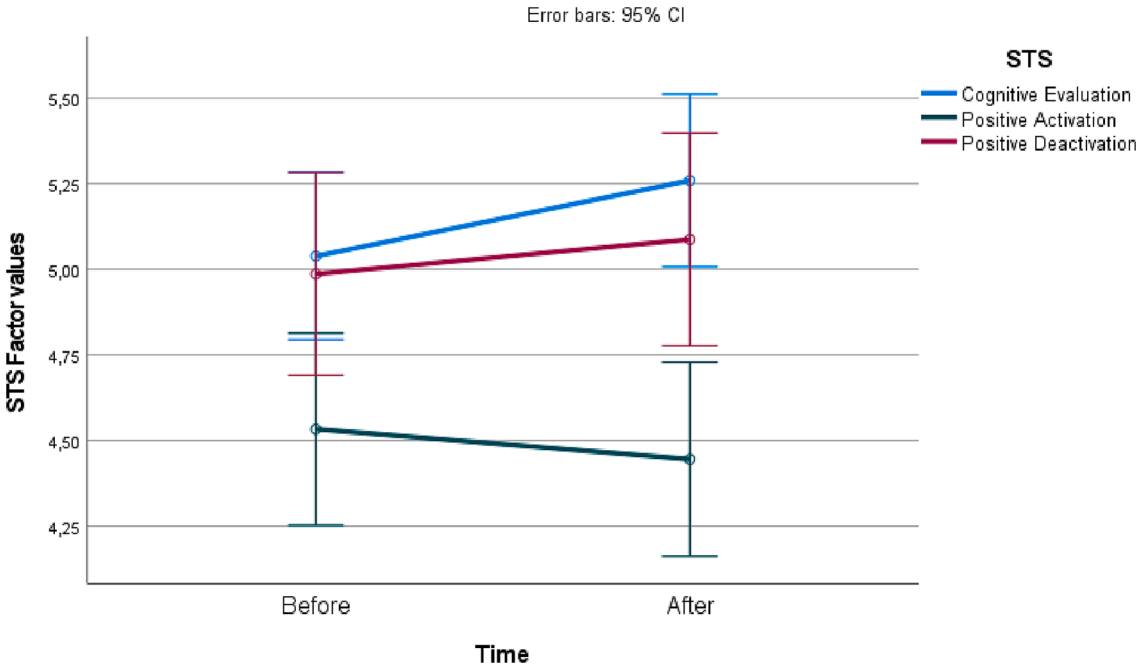

Fig. 4. Mean values of cognitive evaluation, positive activation, and cognitive deactivation, during the before- and after-period, respectively.

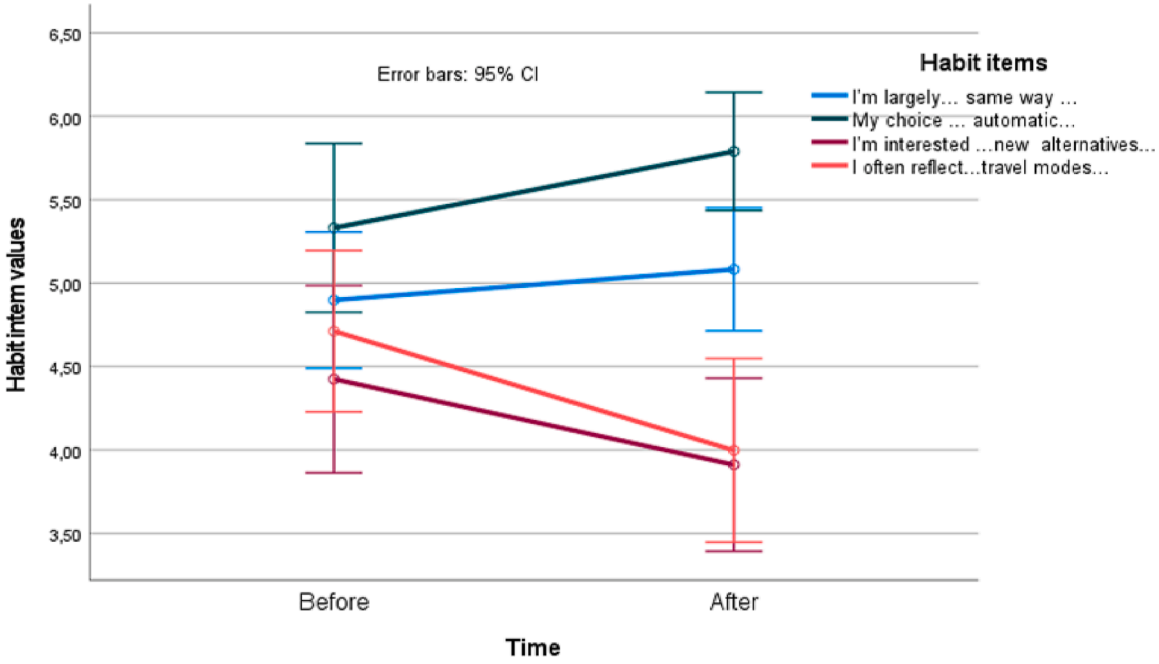

Fig. 5. Mean values of fondness for routines (Habit 1), automatic choice of travel mode (Habit 2), interest in trying new travel modes (Habit 3), and reflection of choice of travel mode (Habit 4).

walking was more common than the use of public transport and car, which in turn were more common than the use of bicycle both before and after the intervention. Moreover, the use of car was negatively correlated with both the use of public transport and walking, suggesting that the proportion of trips combining public transport and walking increased (i.e., public transport was preferred over other modes in the event of car users modal change). With increased use of public transport, the perceived accessibility decreased, which is in line with other findings that the perceived accessibility with public transport use is lower than with other travel modes (Lättman et al., 2018). At the same time, life quality increased. One possible explanation for this result is that some participants perceive a decreased accessibility when travelling with public transport, whereas others perceive a higher life quality (cf. Sochor, Strömberg & Karlsson, 2015), and this may be due to their mobility capital (i.e., that a participant experience both decreased accessibility and increased life quality regardless of group affiliation). As the importance of different aspects of the mobility capital (i.e., the physical, cognitive, financial, spatial, and temporal resources) varies between individuals (cf. Kaufmann & Audikana, 2020). Further analyses showed that general health and life quality did not change overall, over time. What really caused the increased use of public transport is impossible to say. Using the TravelVu app and completing the questionnaires included in the study did however require great commitment from all participants (regardless of group affiliation). One possible explanation could therefore be that the study itself triggered the modal change.

The second aim was to examine how modal choice was affected by the intervention. The results revealed no overall effect of the intervention (free travel passes) as the use of public transport increased while the use of car decreased overall for all groups (even the control group). These results suggest that the intervention itself was not responsible for the modal change obtained. The positive findings of a free public travel card by Forward (2019) were therefore not replicated. This may however also be explained by the participants' mobility capital and thus the change in modal choice may be explained by any of a variety of aspects. While one individual might value the physical effort higher than the financial aspect, someone else might value other aspects. Hence, both differences in mobility capital and the weights given to these aspects manifest themselves in modal choice and the willingness to change. This is in line with previous research (Sjöman, Ringenson & Kramers, 2020) which showed that most participants were insensitive to the costs associated with the use car. Instead, convenience, in the sense of how easy, effortless, and smooth the service is, seems to be more important (Berg, Henriksson & Ihlström, 2019). Another, or complementary, explanation for the modal change effect in all three groups is that individuals who agreed to participate in the study might have reached further in their transition to change than those not willing to participate (Wallén Warner, Björklund & Andersson, 2021).The three groups might even have different reasons for increasing their use of public transport overall and decreasing their use of the car. The participants in the two groups receiving free travel passes worked in the outer suburb, and depending on where they lived, might have found it hard to use public transport or bicycle to get to work. Initially, they might therefore have been less willing to change their travel mode but then felt encouraged to do so when receiving the free travel passes. The participants in the control group, on the other hand, lived in the central region of Stockholm County with good access to public transport. They might therefore have been more willing to change their travel mode from the very beginning (and therefore participated in a study). This is of course highly speculative, but it fits with the results and makes it hard to completely discard the free travel passes as a possible successful intervention.

Finally, the third aim was to examine how subjective experiences as perceived accessibility, perceived satisfaction, and habit were affected by the intervention. The results revealed that perceived accessibility, perceived satisfaction as well as habit were all rated fairly high. Positive activation was rated lower than positive deactivation and cognitive evaluation. This suggests that the participants' everyday travels were experienced as less engaging (positive activation) compared to relaxing (positive deactivation) and of high standard (cognitive evaluation). In addition, the participants rated their automatic choice of travel mode higher than their interest in trying new travel modes and their reflection of choice of travel mode. Perceived accessibility, perceived satisfaction, and habit were not affected by the intervention (e.g., no differences were found between the three groups before or after the intervention). Perceived satisfaction was however affected by time, as the participants became more satisfied overall with the standard of their experiences of their everyday travel (cognitive evaluation). Also, habit was affected by time, as the participants overall became less reflective of their choice of travel mode and less interested in trying out new alternative travel modes. This suggests that the participants have changed their view of themselves, which might be an effect of taking part in the study by using the TravelVu app and completing the questionnaires included in the study. This would then support the suggestion that it is the study itself, not the intervention, that generated the changes found.

The relation between changes in modal choice and the participants' subjective experiences such as perceived accessibility, perceived satisfaction, and habit revealed a complex and interesting pattern. With increased use of public transport, the use of car as well as perceived accessibility decreased. Despite this decrease, perceived accessibility was rated high throughout the study. This suggests that this aspect is very important and choosing a travel mode which do not meet the unique specific subjective needs (the need varies between individual/households) is not an option (cf. Berg, Henriksson & Ihlström, 2019). If an alternative travel mode does not meet the needs, it would probably be abandoned, provided the resources needed, both socially and economically, are available for finding another solution.

Performing a quasi-experimental study like this one, has a number of limitations. To start with, very few employees corrected at least four days registered by the TravelVu app and completed the web-based questionnaire during the before-period, as well as corrected at least four days and completed the web-based questionnaire during the after-period (37 of 60 in the free travel pass groups). We were also forced to recruit a control group from a different population (i.e., residents in Stockholm, Solna, and Sundbyberg municipality). We do not know where the employees live or where the residents work but we know that the employees are mostly white-collar workers while the residents live in affluent areas. In an attempt to minimize the difference in modal choices between the groups, the residents were selected to match the employees on the use of car during the before-period. The number of dropouts is moreover a limitation throughout the study. Even though the statistical methods used are rather robust in handling low numbers of participants, they do not control for the selection bias dropouts create. We must therefore be very careful with the interpretation of results as well as the conclusion drawn. One reason for the large number of dropouts is probably the time and energy needed to validate (and if necessary correct) the days in the travel diary as suggested by the TravelVu app. A more intelligent (with extended learning abilities) and user-friendly app would probably have reduced the number on dropouts. Using the TravelVu app is however also one of the major strengths with this study. The app is sensitive and capture all trips conducted on a specific day in a more detailed and reliable way than self-reports often used.

5. Conclusion

In this quasi-experimental study, an intervention promoting the use of public transport was evaluated using the digitalized application (TravelVu app) as well as questionnaires. The intervention had no effect on modal choice or on participants subjective experiences such as perceived accessibility, perceived satisfaction, or habit. Over time, the use of public transport did however increase overall while the use of car decreased. The participants also became overall more satisfied with the standard of their experiences of their everyday travel (cognitive evaluation) while they became less reflective of their choice of travel mode and less interested in trying out new alternative travel modes. These changes might be attributed to their participation in the present study. Perceived accessibility did however not change over time which might be caused by the participants ability to choose a transport mood that meets their needs. It is therefore suggested that mobility capital and the weight given to different aspects of travelling is integrated in a complex way to create preferred modal choice. Greenhouse gas reduction by changes in modal choice seems to be a complex challenge.

6. Author statement

The authors have no conflict of interests.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

Aker, V. V., Witlox, F., & Wee, B. V. (2007). The Effects of the Land Use System on Travel Behavior: A Structural Equation Modeling Approach. *Transp. Plan. Technol., 30*, 331–353.

Bagloee, S. A., Sarvi, M., & Wallace, M. (2016). Bicycle lane priority: Promoting bicycle as a green mode even in congested urban area. *Transp. Res. Part Policy Pract., 87*, 102–121.

Berg, J., Henriksson, M., & Ihlström, J. (2019). Comfort first! vehicle-sharing systems in urban residential areas: The importance for everyday mobility and reduction of car use among pilot users. *Sustainability (Switzerland), 11*(9). https://doi.org/10.3390/su11092521

Cao, X. J. (2015). Heterogeneous effects of neighborhood type on commute mode choice: An exploration of residential dissonance in the Twin Cities. *J. Transp. Geogr., 48*, 188–196.

Cervero, R., & Day, J. (2009). *Suburbanization and transit-oriented development in China., 15*(2008), 315–323. https://doi.org/10.1016/j.tranpol.2008.12.011

Cheng, L., Chen, X., De Vos, J., Lai, X., & Witlox, F. (2019). Applying a random forest method approach to model travel mode choice behavior. *Travel behaviour and society, 14*, 1–10.

Collins, C. M., & Chambers, S. M. (2005). Psychological and situational influences on commuter-transport-mode choice. *Environment and Behavior, 37*(5), 640–661. https://doi.org/10.1177/0013916504265440

De Bruijn, G. J., & Gardner, B. (2011). Active commuting and habit strength: An interactive and discriminant analyses approach. *American Journal of Health Promotion, 25*(3), 27–37. https://doi.org/10.4278/ajhp.090521-QUAN-170

Dill, J. (2009). Bicycling for Transportation and Health: The Role of Infrastructure. *J. Public Health Policy, 30*, S95–S110.

Dill, J., & Voros, K. (2007). Factors affecting bicycling demand: Initial survey findings from the Portland, Oregon, region. *Transp. Res. Rec. J. Transp. Res. Board*, 9–17.

Ettema, D., Gärling, T., Eriksson, L., Friman, M., Olsson, L. E., & Fujii, S. (2011). Satisfaction with travel and subjective well-being: Development and test of a measurement tool. *Transportation Research Part F: Traffic Psychology and Behaviour, 14*, 167–175.

Forward, S. E. (2019). Views on public transport and how personal experiences can contribute to a more positive attitude and behavioural change. *Social Sciences, 8*(2), 1–23. https://doi.org/10.3390/socsci8020047

Friman, M., Fujii, S., Ettema, D., Gärling, T., & Olsson, L. E. (2013). Psychometric analysis of the satisfaction with travel scale. *Transportation Research Part A: Policy and Practice, 48*, 132–145. https://doi.org/10.1016/j.tra.2012.10.012

Friman, M., Gärling, T., Ettema, D., & Olsson, L. E. (2017). How does travel affect emotional well-being and life satisfaction? *Transportation Research Part A: Policy and Practice, 106*, 170–180. https://doi.org/10.1016/j.tra.2017.09.024

Fujii, S., Gärling, T., & Kitamura, R. (2001). Changes in drivers' perceptions and use of public transport during a freeway closure: Effects of temporary structural change on cooperation in a real-life social dilemma. *Environ. Behav., 33*, 796–808.

Haustein, S., & Møller, M. (2016). Age and attitude: Changes in cycling patterns of different e-bike user segments. *Int. J. Sustain. Transp., 10*, 836–846. https://doi.org/10.1080/15568318.2016.1162881

Heinen, E., Harshfield, A., Panter, J., Mackett, R., & Ogilvie, D. (2017). Does exposure to new transport infrastructure result in modal shifts? Patterns of change in commute mode choices in a four-year quasi-experimental cohort study. *Journal of Transport and Health, 6*, 396–410. https://doi.org/10.1016/j.jth.2017.07.009

Heinen, E., & Ogilvie, D. (2016). Variability in baseline travel behaviour as a predictor of changes in commuting by active travel, car and public transport: A natural experimental study. *Journal of Transport and Health, 3*(1), 77–85. https://doi.org/10.1016/j.jth.2015.11.002

International Energy Agency (IEA), (2019). Global Energy & CO2 Status Report 2019. The latest trends in energy and emissions in 2018. Flagship report, March.

Johansson, M. (2020). *Resvaneundersökning 2019 [Survey of travel habits 2019]*. Region Stockholm: Trafikförvaltningen. Retrieved January 17, 2021 from.

Kaufmann, V., & Audikana, A. (2020). Mobility capital and motility. In *Handbook of urban mobilities* (pp. 41–47). Routledge.

Kaufmann, V., Bergman, M. M., & Joye, D. (2004). Mobility as Capital. *International Journal of Urban and Regional Research Motility, 28*(4), 745–756.

Kuhnimhof, T., Chlond, B., & Huang, P.-C. (2010). Multimodal travel choices of bicyclists: Multiday data analysis of bicycle use in Germany. *Transp. Res. Rec. J. Transp. Res., Board*, 19–27.

Lättman, K., Friman, M., & Olsson, L. E. (2016). Perceived accessibility of public transport as a potential indicator of social inclusion. *Social Inclusion, 4*(3), 36–45. https://doi.org/10.17645/si.v4i3.481

Lättman, K., Olsson, L. E., & Friman, M. (2016). Development and test of the Perceived Accessibility Scale (PAC) in public transport. *Journal of Transport Geography, 54*, 257–263. https://doi.org/10.1016/j.jtrangeo.2016.06.015

Lättman, K., Olsson, L. E., & Friman, M. (2018). A new approach to accessibility–Examining perceived accessibility in contrast to objectively measured accessibility in daily travel. *Research in Transportation Economics, 69*, 501–511.

Ma, L., & Dill, J. (2015). Associations between the objective and perceived built environment and bicycling for transportation. *J. Transp. Health, 2*, 248–255. https://doi.org/10.1016/j.jth.2015.03.002

Marsal-Llacuna, M.-L., Colomer-Llinàs, J., & Meléndez-Frigola, J. (2015). Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative. *Technol. Forecast. Soc. Change, 90*, 611–622. https://doi.org/10.1016/j.techfore.2014.01.012

Næss, P. (2013). Residential location, transport rationales and daily-life travel behaviour: The case of Hangzhou Metropolitan Area, China. Prog. Plan. *Residential location, transport rationales and daily-life travel behavior: The case of Hangzhou Metropolitan Area, China, 79*, 1–50.

Naess, P. (2006). Urban structure matters : Residential location, car dependence and travel behaviour. Routlegde Abingdon. DOI 10.4324/9780203099186.

Nikitas, A. (2018). Understanding bike-sharing acceptability and expected usage patterns in the context of a small city novel to the concept: A story of 'Greek Drama'. *Transportation Research Part F: Traffic Psychology and Behaviour, 56*, 306–321.

Olafsson, A. S., Nielsen, T. S., & Carstensen, T. A. (2016). Cycling in multimodal transport behaviours: Exploring modality styles in the Danish population. *J. Transp. Geogr., 52*, 123–130.

Pflieger, G., Kaufmann, V., Pattaroni, L., & Jemelin, C. (2009). How does urban public transport change cities? Correlations between past and present transport and urban planning policies. *Urban Studies, 46*(7), 1421–1437. https://doi.org/10.1177/0042098009104572

Redman, L., Friman, M., Gärling, T., & Hartig, T. (2013). Quality attributes of public transport that attract car users: A research review. *Transp. Policy, 25*, 119–127. https://doi.org/10.1016/j.tranpol.2012.11.005

Roblek, V., Meško, M., & Podbregar, I. (2021). Impact of car sharing on urban sustainability. *Sustainability (Switzerland), 13*(2), 1–19. https://doi.org/10.3390/su13020905

Schoenau, M., & Müller, M. (2017). What affects our urban travel behavior? A GPS-based evaluation of internal and external determinants of sustainable mobility in Stuttgart (Germany). *Transportation Research Part F: Traffic Psychology and Behaviour, 48*, 61–73. https://doi.org/10.1016/j.trf.2017.05.004

Sivasubramaniyam, R. D., Charlton, S. G., & Sargisson, R. J. (2020). Mode choice and mode commitment in commuters. *Travel Behaviour and Society, 19*, 20–32. https://doi.org/10.1016/j.tbs.2019.10.007

Sjöman, M., Ringenson, T., & Kramers, A. (2020). Exploring everyday mobility in a living lab based on economic interventions. *European Transport Research Review, 12*(5), 1–17. https://doi.org/10.1186/s12544-019-0392-2

Sochor, J., Strömberg, H., & Karlsson, I. C. M. (2015). An innovative mobility service to facilitate changes in travel behavior and mode choice. *22nd ITS World Congress, November 2013*, 12. https://doi.org/10.1111/apt.13065.

Sun, G., Zhao, J., Webster, C., & Lin, H. (2020). New metro system and active travel: A natural experiment. *Environment International, 138*(1–11), Article 105605. https://doi.org/10.1016/j.envint.2020.105605

Söderberg f.k.a. Andersson, A., Adell, E., & Winslott Hiselius, L. (2021). What is the substitution effect of e-bikes? A randomised controlled trial. *Transportation Research Part D, 90,* 102648.

Urry, J. (2007). Mobilities, networks and communities. *Knowledge, Communication and Creativity, May*, 67–76. https://doi.org/10.4135/9781446215548.n4

Wallén Warner, H., Björklund, G., & Andersson, J. (2021). Using a three-stage model of change to understand people's use of bicycle, public transport, and car. *Transportation Research Part F: Traffic Psychology and Behaviour, 82*, 167–177. https://doi.org/10.1016/j.trf.2021.08.002

Wey, W.-M., & Huang, J.-Y. (2018). Urban sustainable transportation planning strategies for livable City's quality of life. *Habitat Int., 82*, 9–27. https://doi.org/10.1016/j.habitatint.2018.10.002

Yang, Y., Wang, C., Liu, W., & Zhou, P. (2018). Understanding the determinants of travel mode choice of residents and its carbon mitigation potential. *Energy Policy, 115*, 486–493. https://doi.org/10.1016/j.enpol.2018.01.033

Zhao, C., Nielsen, T. A. S., Olafsson, A. S., Carstensen, T. A., & Meng, X. (2018). Urban form, demographic and socio-economic correlates of walking, cycling, and e-biking: Evidence from eight neighborhoods in Beijing. *Transp. Policy.*. https://doi.org/10.1016/j.tranpol.2018.01.018