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What role does free-floating car sharing play for changes in car ownership? Evidence from longitudinal survey data and population segments in Copenhagen

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ABSTRACT

Free-floating car sharing (FFCS) offers greater flexibility than station-based car sharing but seems to affect car ownership less. This study looks into characteristics of people who changed or did not change car ownership over time and how an increase or decrease relates to FFCS membership, demographic and attitudinal factors. The study is based on FFCS users (n = 776) and non-users (n = 720) in Copenhagen surveyed two times within a 2.5-year period. Five population segments were created: car dependents, car avoiders, and car limiters who showed constant but different levels of car ownership; car aspirers who increased, and car sellers who decreased car ownership over time. The segments' profiles range from car dependents who show high affective car motives, high perceived mobility necessities and car dependency at the one end, and car avoiders who seem more driven by environmental norms and an instrumental relation to the car, at the other end of the scale. A multinomial regression predicting whether car owners increased or decreased the number of cars in the household during the project period found a positive effect of FFCS membership for decreasing car ownership. However, the effect was no longer significant when adding the intention to reduce car ownership at the time of the first survey. Main factors that remained significant for changed car ownership included a change in household composition, access to a private parking space and the initial number of cars in the household. The paper discusses strategies to increase the contribution of FFCS to car ownership reduction.

1. Introduction

Privately owned cars take a lot of space in cities, they contribute to congestion, noise and air pollution and thereby reduce citizens' quality of life. Free-floating car sharing (FFCS) could – together with other smart transport solutions – help to reduce environmental and health impacts from transport by reducing the need to own a car. However, comparative studies indicate that effects of FFCS on car use and ownership are small compared to effects achievable by station-based car sharing (Becker et al., 2017, 2018; Namazu and Dowlatabadi, 2018). Recent studies that find comparatively high effects of FFCS (Jochem et al., 2020; Le Vine and Polak, 2019) are based on customers' own effect assessment and hypothetical purchase decisions, both of which may have led to an overestimation of effects.

This study aims to estimate the effect of FFCS on car ownership based on longitudinal data of users and non-users of FFCS. While most car sharing studies focused on average effects (Jain et al., 2020), this study will additionally examine the profiles of sub-groups of people who showed an increase or decrease in the number of cars they owned. This knowledge will facilitate tailored policy and marketing strategies to increase the contribution of FFCS to car ownership reduction and social inclusion.

1.1. Effects of free-floating car sharing

While several international studies showed positive environmental effects of car sharing (e.g. Chen and Kockelman, 2016; Martin and Shaheen, 2011), these calculations were mostly based on effects found for station-based car sharing. An early study by Cervero and Tsai (2004) found that 63% of car sharing users did not change their car ownership, while 29% showed a reduction in the number of cars in the household and 8% an increase, while the percentages in a control group of non-users were 80%, 8%, and 12%, respectively. However, in contrast to Cervero and Tsai (2004), most studies were either based on retrospective

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data and hypothetical car purchase decisions or did not use a control group design. In doing so, they did not take into account that car sharing members differ from non-members from the start and that there are other factors that could have affected them than the membership itself. Indeed, car sharing users have different transport patterns than non-users: When comparing members and non-members in the same city and age group, Kopp et al. (2015) found that FFCS members had more trips and showed more multimodal and intermodal transport behaviour. In addition, they cycled more and drove less. Recent studies highlight that only a smaller part of the differences in car ownership and car use between users and non-users can be directly attributed to car sharing (e.g., Mishra et al., 2015, 2019).

In a Swiss study (Becker et al., 2017) about equal proportions of free-floating car sharers reported to have increased and decreased their car usage since joining the service. In addition, public transport and non-motorized means of transport were used less by FFCS members, while the opposite was found for members of station-based car sharing services. Based on data of a follow-up survey, it was estimated that 6% free-floating car sharers reduced their car ownership due to membership (Becker et al., 2018), effects that are rather small compared to the effects found for station-based car sharing. In a study from Canada, station-based car sharers were almost five times more likely to abolish a car than free-floating users and free-floating cars were mostly used to complement other means of transport, while station-based cars were more often used as a replacement for privately owned cars (Namazu and Dowlatabadi, 2018). The different use and effects can be explained by the different concepts of both forms. Membership of station-based car sharing requires a regular fee, which reduces the price for the single trips. Like a private car, the car is generally returned close to where people live. FFCS requires no regular membership fee but costs more for single trips, and the service is more flexible as it allows one-way trips. The operating area is however restricted and thereby the service is rather optimised to replace short urban trips, similar to the use of taxis.

A recent study including FFCS users in different European cities (Jochem et al., 2020) and a study on early FFCS adopters in London (Le Vine and Polak, 2019) reported comparable high effects of FFCS on car reduction. However, as estimations were based on cross-sectional data and customers' hypothetical car purchase decisions and own effect assessments, they should be interpreted with care. In their multivariate analysis, both studies showed that car reduction was related to the numbers of cars and children in the household as well as the frequency of FFCS use. Jochem et al. (2020) additionally found an effect of using another car sharing service, bike sharing, or belonging to an older age group as well as the city people lived in. For early adopters in London, higher education and income negatively related to car ownership impacts (Le Vine and Polak, 2019). The effect Jochem et al. (2020) found for the use of other forms of sharing services indicates that it was probably not FFCS alone that led to the reported car-reducing effect. Similarly, the different effects for different cities could be related to different mobility cultures and to what extent a city and its traffic infrastructure, policies and social norms facilitate multimodal transport and car-free living (Haustein and Nielsen, 2016; Klinger et al., 2013).

According to a qualitative study by Jain et al. (2020) a reduction in car ownership is often initiated by changes in one's life situation, where access to shared cars only plays a contributing role in the decision to sell a car. Several studies found life events related to changes in car ownership level and/or modal shifts, most importantly residential relocation, changes in employment and changes in the number of persons in the household (e.g. Clark et al., 2016; Prillwitz et al., 2006; Yamamoto, 2008). As the example of relationship dissolution (Oakil et al., 2018) illustrates, life events can change practical needs for a car due to changed activities and destinations or lead to an economic situation, where a car is no longer affordable. As life events interrupt daily routines and travel habits, they can also initiate a deliberation process, where actual travel behaviour and car ownership is reconsidered (Janke and Handy, 2019). To identify the effects of car sharing on changes in car ownership, it is therefore important to control for changed living circumstances.

1.2. Car sharing users and user segments

Free-floating car sharers do not only differ from station-based car sharers and non-sharers by their transport behaviour but also by their individual characteristics: Free-floating car sharers are younger and more often men, which is typical for early adopters of new technologies (e.g. Munnukka, 2007; Le Vine and Polak, 2019). In 2015, 70% of free-floating users in Switzerland (Basel) were men, as were 60% of station-based car sharers (Becker et al., 2017). However, the gender gap decreases the longer the product is on the market (Schleufe, 2014). Similarly, users are no longer only young people. In Germany, in 2010/2011, approximately 60% of FFCS users were younger than 36 years (car2go: Firnkorn and Müller, 2012; DriveNow: Kopp et al., 2013), while in Switzerland in 2015, it was only half of the members (Becker et al., 2017).

Station-based car sharers have earlier been identified as people with a high environmental awareness and with a more functional, or even negative, attitude towards private cars (e.g. Burkhardt and Millard-Ball, 2006; Grischkat et al., 2014). This does not seem to be the case for free-floating car sharers: in Becker et al. (2017) no difference in environmental concern was found and a higher percentage of free-floating car sharers (13%) than station-based car sharers (6%) and non-sharers (12%) agreed that the car also serves as a status symbol for them. In the same study, free-floating car sharers considered it more important to save money and were more eager to try new things. Also qualitative interviews with Italian free-floating carsharers revealed that environmental motives did not play a relevant role for user motivation (Mattia et al., 2019). By contrast, flexibility, excitement related to the use of specific car models, and economic benefits compared to car ownership were highlighted.

For more targeted efforts to increase the environmental effects of FFCS, it is not only relevant to know how FFCS users differ from non-users but also which different segments we can distinguish within this group. In market segmentation, we can differentiate between a priori and post-hoc segmentation. In a priori segmentation approaches, groups are created based on pre-defined rules so that each respondent can be clearly assigned to one of the postulated segments, for example captive and choice users (Jacques et al., 2013). More recently, transportation research has been dominated by data-driven post hoc approaches, in which individuals are grouped according to their similarity in a set of variables, mostly by cluster analysis (e.g. Anable, 2005; Haustein, 2012; Pronello and Camusso, 2011). The resulting multidimensional profiles, which often include psychological variables, can be used as a starting point for tailored measures to reduce car use (Haustein and Hunecke, 2013; Klöckner, 2015).

So far, comparably few studies have tried to examine segments within the group of car sharers. Garrett et al. (2021) examined user patterns and experiences of the first FFCS users in Copenhagen (Car2go) based on survey data in combination with qualitative interviews. Based on the results, they divided users into car-owning and car-free households. The latter emphasised the occasional practical need for a car, for example for transporting goods. They stated that the service had not increased their total number of trips but that it offered a more convenient alternative to other transport modes. Car owners used the service mainly to avoid driving their own car into the city. In contrast to the car-free users, they partly placed high symbolic value to the car. For them, FFCS did not seem to support multimodal transport but was rather used as a way to avoid it (in particular the use of buses).

Le Vine and Polak (2019) differed between FFSC customer who reported impacts of the service on their private car ownership (=decision not to buy a new car, abolishing or intention to abolish a car because of membership) and respondents not reporting such impacts (=no change in number of cars because of membership). They found customers

reporting impacts to be lower educated, more likely to live in household with fewer cars, to use the service more often for shopping activities, and to be less regular car users. The studies from London and Copenhagen both indicate that the service has no car reducing effect for more affluent car-owning households but may support car-free households in remaining car-free (for a while) by covering occasional car needs and by making car-free living more convenient.

As part of a study that offered regular public transport users free access to a station-based car sharing service, Nielsen and Haustein (2015) looked into the effect of this trial for different segments of participants. Based on transport related attitudes and norms, three car sharer segments were differentiated: *People with reduced mobility necessities*, *public transport lovers*, and *busy mobiles*. The three groups differed in their motivations to use car sharing and showed different modal changes and intentions for (remained) car-free living after participation.

Chatterjee et al. (2013) divided car sharers into *accessors* and *shedders* and explored both groups' motivations to become a car sharing member, the long- and short-term changes in their travel behaviour, and how that might have changed if not having become a car sharing member. While accessors used car sharing to gain occasional car access, shedders were either already contemplating to reduce car ownership before joining car sharing or were triggered to do so by life events. In case of the latter, car ownership often increased again when life circumstances changed.

Jain et al. (2020) suggested a more detailed segmentation of car sharers based on focus groups and interviews with car sharing members (and ex-members) in Melbourne, Australia. Users were segmented based on similarities in their choices related to lifestyle (family situation, job), mobility (e.g. car ownership, residential location), and travel (travel scheduling, mode choice) and related changes over time, following a mobility biographies approach (Lanzendorf, 2003, Müggenburg et al., 2015, Scheiner, 2018). Comparisons of these mobility trajectories resulted in five segments. Three of the identified segments (car dependents, car avoiders, car limiters) differed in car ownership from the start but did not experience major changes in car ownership since joining car sharing. The remaining two segments either increased (car aspirers) or decreased (car sellers) car ownership and car use after joining. The segments also differed in their user motives, perceived mobility necessities, and car related attitudes.

1.3. The present study

Since September 2015, Copenhagen and the surrounding area is served by the FFCS provider DriveNow (Share Now after merge with car2go in 2020). In the beginning, the entire car fleet consisted of electric vehicles but since 2018 other car types are also available. To examine the effects of the free-floating service, a longitudinal survey including users and non-users of the service was conducted, which serves as the data basis of this study[2]. Based on participants' car ownership and related intentions in the first survey and in a follow-up survey between 1 and 2.5 years later, five groups of car sharers were defined, inspired by the car sharer segments identified by Jain et al. (2020). Thus, an a-priori segmentation approach was chosen, where group membership was determined by specific rules resulting in segments, which by definition differed in car ownership levels and related changes over time. This makes it possible to compare the profiles of people who actually changed their car-related behaviour over time to those who did not. To shed light on the question of which role FFCS membership played for an increase or decrease in car ownership, regression models were estimated. Based on the segments' profiles and the factors identified as relevant for a change in car ownership, the paper suggests targeted measures to increase the social and environmental benefits of FFCS.

[2] For more background information on the study, see Haustein and Jensen (2020).

2. Method

2.1. Procedure and participants

Data were collected based on a longitudinal online survey addressed to DriveNow members and a sample of licensed drivers aged 18–65 years living in DriveNow's operational area, who can be considered as potential users of the service. In March 2017, Arriva (the operator of DriveNow in Denmark) sent out a survey link to people who were already members of DriveNow (existing users) as well as people who just signed up for DriveNow (new users). New users were recruited continuously from early March 2017 to early September 2019 (30 months). People were automatically contacted again one and two years later if that was still within the timeframe of the study.

Data of potential users were collected via an online panel of the market research institute EPINION. The panel consists of approximately 240,000 members covering all regions of Denmark. A sample of 500 participants were collected every 6 months. Also in this group, the same people were contacted again one and eventually two years later. At the beginning of July 2019, all DriveNow members who had answered once but not again received a reminder.

This study is based on DriveNow users and non-users who participated two or three times in the survey. Before-after data always refers to the first and last survey people participated in. Table 1 shows the sample size of the different sub-samples included in this study and how they differ in single characteristics. When comparing DriveNow users with the group of potential users, they are more often male, younger, highly educated, more often have children in the household and more often live in Copenhagen (or Frederiksberg – a separate municipality within Copenhagen). However, when comparing differences between first DriveNow users (existing users) and those who signed up later (new users), we find that later users are closer to the general population on these variables, which was expected based on experience from other cities (e.g. Schleufe, 2014). All differences between users and potential users presented in Table 1 are significant ($p < .05$), apart from differences in education level ($p > .10$).

2.2. Measures

Major parts of the online questionnaires used for existing and potential users were identical as they aimed to measure differences between both groups in the use of different transport modes, car ownership, related intentions, and mobility-related attitudes as well as changes within groups over time.

2.2.1. Travel behaviour, car ownership and intention to change

With regard to transport mode choice, the respondents were asked on how many days in the previous week different transport modes were used. Respondents were additionally asked, how many kilometres by car they had travelled the previous week. Car ownership referred to the number of cars in the household respondents had access to (not including car sharing cars). Moreover, it was asked whether people had acquired and/or abolished a car within the past 12 months. Intended changes in car ownership were captured with a multiple choice item, with which respondents could allocate themselves to a specific stage of behavioural change in terms of car ownership (Bamberg, 2013; Prochaska and DiClemente, 1983). It included seven answer options: not considering to acquire or abolish a car within the next 6 month (1); considering to acquire (2), abolish (3), or replace (4) a car within the next 6 month; having concrete plans to acquire (5), abolish (6), or replace (7) a car within the next 6 month. For the purpose of this study, two new variables were created: the intention to acquire a car (answer option 2 or 5) and the intention to abolish a car (option 3 or 6).

Table 1
Sample characteristics.

Group	n	%	Gender (% men)	Mean age	Higher education	Children in household	Living in Copenhagen/Frederiksberg
Potential users	720	48.1	46.1	51.3	61.3	30.6	30.8
Users (all)	776	51.9	78.9	42.1	65.8	37.4	66.2
New users	283	18.9	71.9	42.3	59.8	39.4	56.5
Existing users	493	33.0	82.8	41.9	69.0	36.2	71.8
Sum	1496	100.0	62.2	46.7	63.5	33.9	49.2

2.2.2. Attitudinal factors related to car use and mode choice

Based on the Theory of planned behaviour (Ajzen, 1991) and extensions with regard to mode choice (Hunecke et al., 2007), the questionnaire intended to measure six mobility-related psychological constructs that were expected to either be related to the use of FFCS or subject to change during membership. Each of these constructs were measured with two items on a 5-point agreement scale (1 = totally disagree, 5 = totally agree). Symbolic-affective car attitudes included *car excitement* and *car autonomy* (Hunecke et al., 2007). Two additional items on *car dependency* were included to examine how people's perceptions regarding the need to own a private car changed during membership. Items on *perceived mobility necessities* (PMN) were included to assess respondents' perceptions of mobility-related consequences of their personal living circumstances, which have been identified as a barrier to car use reduction (Haustein and Hunecke, 2007; Thorhauge et al., 2020). *Weather resistance* was included due to its relation to car use (Haustein and Hunecke, 2007) and as results from an earlier study in Copenhagen indicated that people more sensitive to bad weather conditions were more frequent FFCS users (Garrett et al., 2021). Finally, two items assessing respondents' *personal norm* related to mode choice were included, that is whether people felt personally obliged to use environmentally-friendly transport modes (Bamberg et al., 2007; Haustein et al., 2009). Table 2 provides a list of the items.

2.2.3. Motives related to membership of free-floating car sharing

The questionnaire also included questions specifically to DriveNow users and non-users. In the first survey, users were asked for the relevance of different reasons for signing up for DriveNow. Each of the reasons could be assessed on a 5-point agreement scale. In the second and third survey, questions about their last trip with DriveNow were included. Users were asked to include the trip purpose, the transport mode DriveNow replaced, and the trip length. In addition, the questionnaire asked how frequent DriveNow was generally used privately and/or for business trips. Non-users were asked if they knew DriveNow and if so, why they had not signed up for it based on a multiple-choice question stating different reasons.

2.2.4. Background variables

The same background questions were included for both user groups. These included age, gender, occupation, highest completed education, income, household composition, postal code, ownership of a bike and a season ticket for public transport. Apart from smaller adjustments of items not relevant for this paper, the questionnaires were the same across the survey waves. Due to the longer length of their survey, FFCS users were only asked for demographics in the follow-up questionnaire when they had changed their job, household composition or residential location since last survey participation.

2.3. Analysis

2.3.1. Segmentation

To compare different population segments depending on car use and ownership and related changes over time, data was analysed in three steps. In a first step, a principal component analysis was conducted to explore if the resulting factors matched with the attitudinal dimension we aimed to measure and allowed for the construction of related mean scales. In a second step, the sample was divided into segments of behaviour change related to car ownership and use based on a comparison of data from the first and last survey wave. Finally, we analysed how the identified FFCS segments differed in terms of attitudinal factors, the motivation to join the service and their use thereof. In addition, we examined how they changed their mode choice over time and how they differed in socio-demographic variables. Differences between segments were tested with Chi^2-tests or ANOVAs, depending on the scale of measurement. When we tested for differences between single segments, we used post-hoc test with Bonferroni correction. Changes over time within segments were tested with paired t-tests.

2.3.1.1. Attitudinal factors. The attitudinal items related to mode choice and mobility were included in a principal factor analysis using Varimax

Table 2
Results of a principal component analysis.

	1 Car independency	2 Personal norm	3 Weather resistance	4 Perceived mobility necessities	5 Car autonomy	6 Car excitement
I can easily handle my everyday life without a car.	0.882	0.147	0.193	−0.166	−0.113	−0.027
It's easy for me to conduct my daily trips without a private car.	0.893	0.126	0.202	−0.144	−0.085	−0.024
The organization of my everyday life requires a high level of mobility.	−0.164	0.074	−0.016	0.861	0.155	0.089
I have to be mobile all the time to meet my obligations.	−0.113	0.038	−0.006	0.892	0.062	0.115
Due to my personal values, I feel obliged to use environmentally friendly modes of transport.	0.142	0.908	0.109	0.052	−0.027	0.021
I feel obliged to contribute to environmental protection trough my choice of transport modes.	0.101	0.918	0.096	0.057	−0.014	0.030
Driving a car means fun and passion to me.	−0.091	−0.017	−0.071	0.107	0.351	0.773
I enjoy applying my driving competence.	0.032	0.066	0.032	0.101	0.058	0.892
Driving a car means freedom to me.	−0.066	−0.030	−0.099	0.114	0.766	0.396
To me the car is a flexible and independent means of transport.	−0.120	−0.018	−0.035	0.117	0.899	0.068
I ride my bike in all weather conditions.	0.292	0.150	0.835	−0.030	−0.106	−0.014
The weather or the season does not influence whether I cycle or not.	0.109	0.075	0.922	0.006	−0.022	−0.020
Cronbach's alpha	0.87	0.84	0.80	0.77	0.68	0.73

rotation. While the eigenvalue criterion resulted in a four-factor solution, the scree plot clearly supported the six-factor solution that followed the theoretical assumptions about the allocation of single items to factors. The results of the 6-factor solutions is included in Table 2. The six factors explain 83% of the total variance. Six new variables were created based on the means of the two items belonging to the same factor. With Cronbach's alpha between 0.68 and 0.87, the internal consistencies are considered as acceptable.

2.3.1.2. Segmentation of users and non-users. Based on Jain et al.'s (2020) description of car sharer segments in terms of car use and ownership and related changes over time (see second column in Table 3), we set up coding rules combining data from the first and last survey of the same participants of our study (see third column in Table 3).

We applied the same segmentation rules to users and potential users. As the distributions in Table 3 shows, the percentages are quite different. Among DriveNow users, car avoiders are the largest segment, accounting for more than one third of the sample, followed by car limiters, who are the second largest group among potential users. However, among potential users, car dependents are the largest group – its share is more than twice as large as among DriveNow users. Both segments who changed car ownership (or intend to do so) are larger among DriveNow users, though the discrepancy is much larger for car aspirers than for car sellers. This suggests that the FFCS service is more often used as a 'stepping stone' to increase car ownership than as a way to reduce car ownership. The distribution to segments differed significantly between users and potential users (Chi^2 (4, 1268) = 140.77, $p < .001$).

2.3.2. Effect of FFCS membership on changes in car ownership

Whether an increase or decrease in car ownership over time was related to FFCS membership, was examined by regression models, separately for people with and without a car in the household. For car-owning people (see Table 7), the dependent variables had three categories: having decreased car ownership, having increased car ownership and not having changed car ownership (reference category) and thus a multinomial regression was calculated. As a decrease in car ownership was not possible for car-free households, a logistic regression was estimated for this group (see Table 8). The dependent variable in both models was calculated based on differences between the number of cars reported in the first and last survey wave. As independent variables, the models for car owners and non-owners included being a new or existing member of FFCS (which might have different effects), the months between the first and second survey participation, attitudinal factors, demographic variables, and mode choice (see Table 7 and Table 8). A second model additionally controlled for the intention to change car ownership as FFCS users and non-users usually differ in this intention (Becker et al., 2018). The intention was not included from the start to see how controlling for the intention would influence the effect of other variables, in particular FFCS membership.

3. Results

This section starts with a description of the attitudinal profiles of the identified segments, which will support the interpretation of the group comparisons presented in the subsequent paragraphs. Segments will be compared with regard to the motivation to join FFCS, the use of the service, mode choice, and demographic variables. The last part of this section deals with the impact of FFCS membership on car ownership based on regression models.

3.1. Car sharer segments

3.1.1. Attitudinal profiles

As Fig. 1 shows, the five car sharer segments show distinct attitudinal profiles. In accordance with the findings of Jain et al. (2020), car dependents perceive the highest mobility necessities and show a high level of car dependency. Additionally, they show the most positive car attitudes both in terms of excitement and autonomy, while they have the lowest personal norm. The exact opposite is the case for car avoiders (to a slightly less extent also car aspirers), while car sellers take a middle position between these two types. When examining how the attitudinal factors changed over time, many of the factors remain unchained. The largest change is a decrease in perceived car independency of car aspirers ($M_1 = 3.9$; $M_2 = 3.6$, $p < .001$)[3]. For car sellers, we find a change in car independency in the opposite direction ($M_1 = 3.0$; $M_2 = 3.3$) but it misses the common threshold for significance ($p = .08$). Both car avoiders' ($M_1 = 3.6$; $M_2 = 3.8$) and car limiters' ($M_1 = 3.2$; $M_2 = 3.4$) personal norm increases during membership. An indication of whether these changes are a result of FFCS membership, is provided by examining whether the same changes are found within the respective segments of non-sharers. For (non-sharing) car avoiders, we actually also find a slight increase in personal norm ($M_1 = 3.4$; $M_2 = 3.5$, $p < .05$) but not for car limiters ($M_{1,2} = 3.2$, $p > .10$). Car sellers ($M_1 = 2.8$; $M_2 = 2.9$) and car aspirers ($M_1 = 3.7$; $M_2 = 3.5$) show changes in car independency in the same direction as their car sharing counterparts, but their changes are not significant ($p > .10$). The results indicate that at least parts of the attitudinal changes go back to car sharing membership.

In Fig. 2, we compared the whole group of car sharers with the comparison group on non-sharers (or potential sharers). What becomes clear is that the differences are rather small. FFCS users have a more pronounced personal norm to choose environmentally-friendly modes ($p < .001$) and at the same time enjoy driving more than potential users ($p < .001$), which can be seen as a contradiction but also as an attempt to enjoy driving in a more environmentally-friendly way when separating it from car ownership. In line with their lower level of car ownership, they feel more independent of owning a private car ($p < .001$).

3.1.2. Motives for membership

In line with the description of the segments by Jain et al. (2020), we also find differences in the motivation for joining car sharing services, although the differences are not that pronounced, as we observe a high general agreement to all motives, as Fig. 3 shows. Again, the largest differences exists between car dependents and car avoiders. Not surprisingly, for car avoiders and car aspirers (both car-free in the beginning) practical motives like the lower price of FFCS as compared to owning a car, the possibility to get a car without having to borrow one, and not having to care for maintenance, are more relevant than for car-owning segments, in particular car dependents to whom they differ significantly in post hoc tests ($p < .01$). In addition, car avoiders differ to car dependents by a higher relevance of environmental motives (post-hoc test, $p < .01$), which can be explained by their stronger personal norm. For car avoiders FFCS indeed seems to be a way of avoiding owning a private car, while car dependents use it as a car supplement, similar to a taxi but with the advantage of sitting in the driver seat oneself. Given car dependents' high score in car excitement (see Figure 1), it is surprising that they do not differ significantly from the other segments by a higher preference to drive oneself (as compared to a taxi) and by a higher agreement to driving fun as a motive to join ("It's fun to use DriveNow cars"). Asking participants only for their main motive(s) for FFCS membership might have resulted in more differentiated results.

3.1.3. Differences in the use of car sharing

Only half of included FFCS members used the service more than monthly. As Table 4 shows, car avoiders and car sellers used FFCS more frequently than people in the other segments, at least privately. For business trips, differences are less pronounced. When looking at the trip

[3] M_1 = Mean survey 1; M_2 = Mean survey 2

Table 3
Segmentation of car sharers.

Segments	Description of segments in Jain et al. (2020)	Operationalisation in the present study	Percentage among users	Percentage among potential users
Car dependents	High level of car use High level of car ownership Unchanged car ownership Most trips by car High car dependency and PMN	1 or more cars in the household Unchanged car ownership Car used at least on 4 days in past week	16.2	39.1
Car avoiders	Car-free household that uses car sharing to remain car-free Use car sharing to get occasional access to a car	Car-free household (first and second survey) No intention to acquire a car	35.3	19.1
Car limiters	Car users who use car sharing to limit further increase in car ownership	1-car-household Unchanged car ownership No intention to buy a car Car use less than 4 days in past week	21.8	29.8
Car aspirers	Acquired car during membership or have intention to acquire a car in near future	Car-free household (first survey) Increased car ownership *or* unchanged ownership and intention to acquire a car (survey 2)	17.0	5.3
Car sellers	Abolished a car before or during membership	Reduced car ownership from survey 1 to survey 2 *or* abolished car up to 12 month before survey 1	9.7	6.7

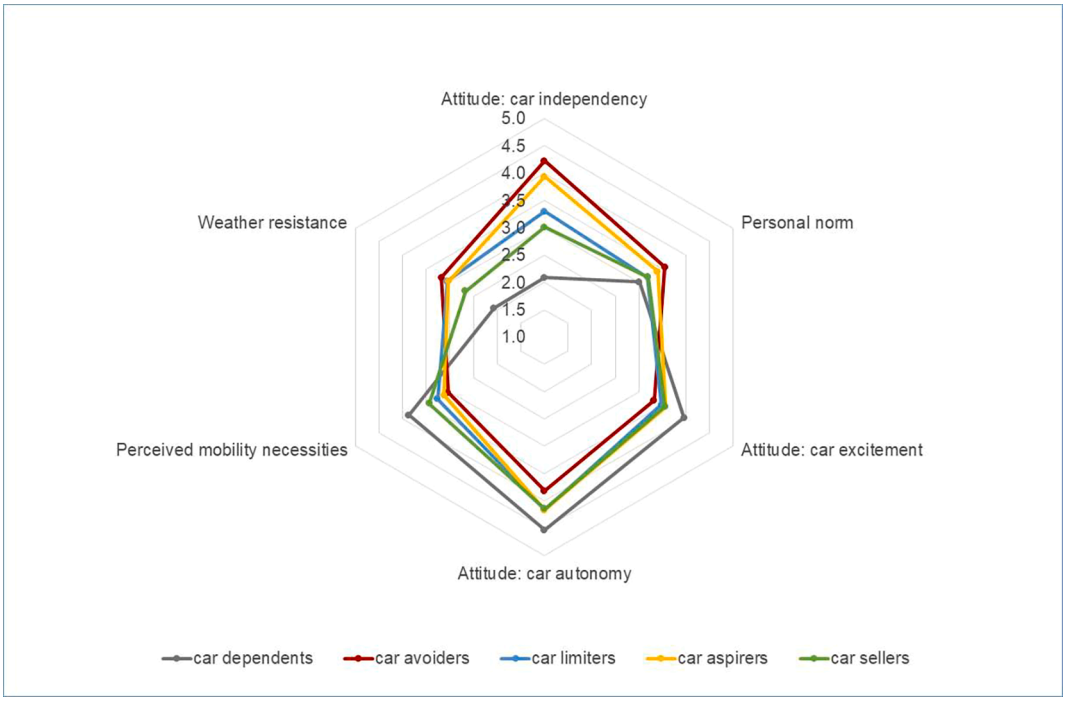

Fig. 1. Attitudinal profiles of FFCS segments.

purpose of the last DriveNow trip, we find that car dependents used the service more for leisure trips, while car avoiders used it mainly for utilitarian trips, in particular for shopping and escorting others. When asked about the transport mode they would have used in case no FFCS service was available for the particular trip, all segments most often would have chosen public transport (46% of last trips). When adding public transport trips in combination with other modes (5%), the percentage is about as high as found in a study from Switzerland, where it was 53% (Becker et al., 2017). With 18%, the replacement of active modes is higher than in Switzerland (12%), which can be explained with the higher cycling share in Copenhagen, which gives more potential for replacement. Car avoiders, aspirers and sellers more often than other segments replaced trips by active modes, while car dependents more often used the service instead of the own car. For car limiters and sellers, the service more often than for other segments replaced taxi trips. Car avoiders have the highest percentage of trips that would not have been conducted without the service. Similar to the results on car use motives, the results indicate that car avoiders mainly use the service when there is no other option, while car dependents use it as a supplement to the private car.

3.1.4. *Changes in mode choice*

Fig. 4 shows on how many days per week a specific mode was used by the different segments when answering the first survey. Car dependents used the car by far most often, followed by car sellers. At the time of being car-free households, car avoiders and car aspirers used the cars the least, while they used active modes and public transport most often.

To examine changes in mode choice, we compared the days by transport modes reported for the previous week in the first survey (as shown in Fig. 4) and last survey and coded whether the days decreased, increased or remained unchanged as individual changes are less visible in average numbers.

Table 5 shows the distribution of the three categories for each transport mode and car sharer segment. We find that car sellers show the

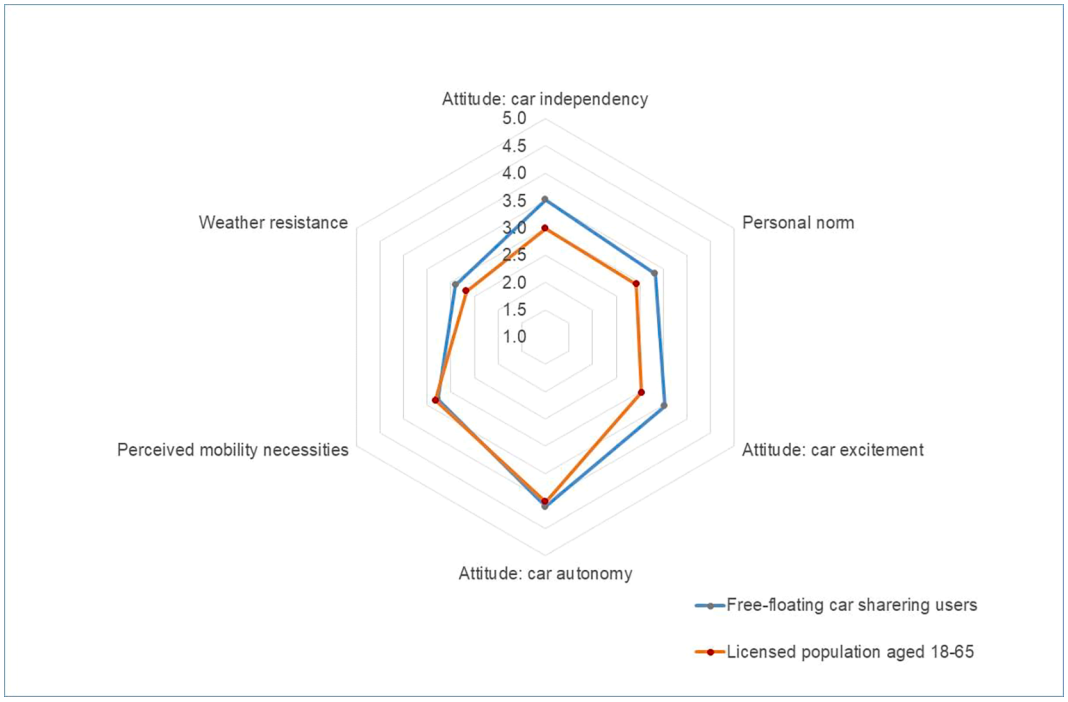

Fig. 2. Attitudinal profiles of FFCS users and potential users in the sample.

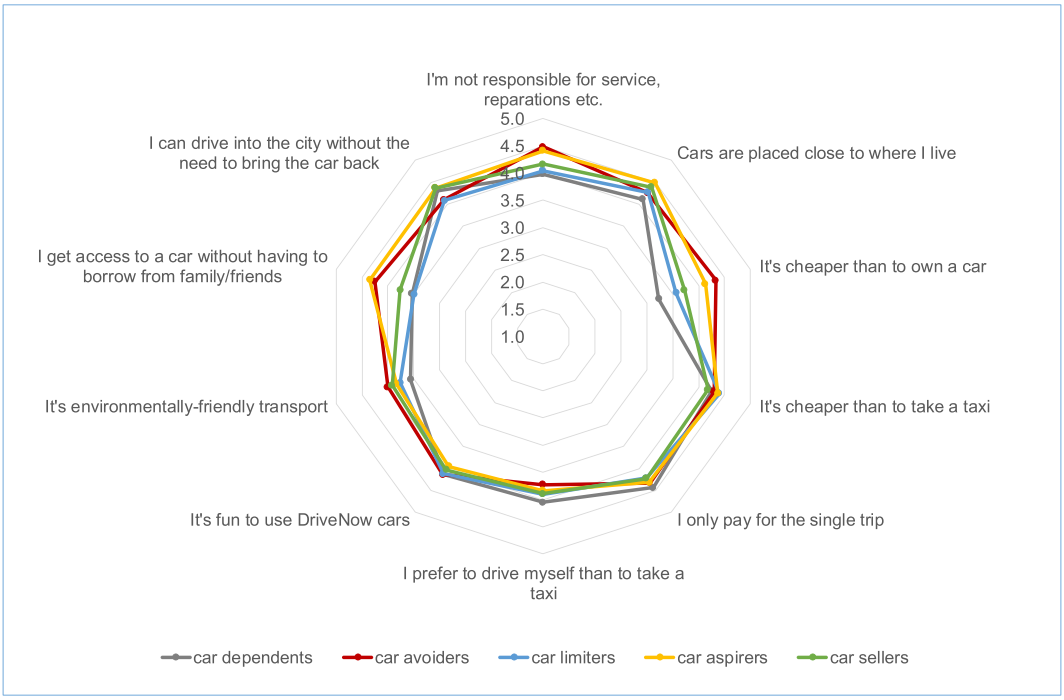

Fig. 3. Motives for membership.

largest changes in transport patterns: more than one third has reduced the number of days on which the car was used. By contrast, a larger share of them increased public transport use, in particular bus use. Car avoiders show the least changes, which is not surprising given that their car ownership did not increase and they only use FFCS when necessary. Car limiters show the largest increases in car use: almost a third have increased their car use. This indicates that they had a high unfulfilled car use need, which could not be fulfilled satisfactory with a single car in the household. For them, FFCS may indeed play a relevant role in avoiding an increase in car ownership. Car aspirers show the greatest reduction in cycling days. For them, the car seems to be more attractive than the bike, while car avoiders rather reduced public transport trips over time.

3.1.5. *Demographic differences between segments*

When comparing segments by demographic variables, we find that car aspirers are younger, more often belong to lower income but higher education groups, are more often women, students and most often live in Copenhagen or Frederiksberg (see Table 6). Car avoiders have a similar

Table 4
Use of FFCS in different segments (data of second survey, percentages within segments).

		Car dependents	Car avoiders	Car limiters	Car aspirers	Car sellers	Total
Frequency of private DriveNow use	At least weekly	10.0	20.7	12.8	13.9	22.2	16.2
	1–3 time per month	30.0	36.9	29.1	35.2	36.5	33.8
	Less than once a month	60.0	42.3	58.2	50.9	41.3	50.0
Frequency of work-related DriveNow use	At least weekly	1.0	3.2	4.2	4.7	6.4	3.6
	1–3 time per month	10.0	6.3	9.9	8.3	11.1	8.5
	Less than once a month	89.0	90.5	85.8	87.0	82.5	87.9
Trip purpose (last trip)	Home	22.9	20.5	21.9	26.4	15.3	21.7
	Work, education	8.3	9.3	10.9	11.3	8.5	9.8
	Bringing/picking up others	3.1	11.2	8.6	1.9	3.4	7.0
	Shopping	1.0	11.2	1.6	1.9	1.7	5.0
	Errands	7.3	11.2	6.3	12.3	11.9	9.8
	Leisure	42.7	28.4	33.6	33.0	37.3	33.4
	Business	8.3	1.4	9.4	3.8	11.9	5.6
	Other	6.3	7.0	7.8	9.4	10.2	7.8
Replaced mode (last trip)	Active modes (bike, walking)	10.4	21.9	14.1	21.7	20.3	18.2
	Car (driver, passenger)	24.0	7.9	14.8	9.4	15.3	12.9
	Taxi	14.6	8.4	19.5	8.5	20.3	12.9
	Public transport	42.7	46.0	46.1	54.7	39.0	46.4
	Public transport in combination with other modes (car, bike)	5.2	7.4	2.3	3.8	3.4	5.0
	Other modes	0.0	1.9	0.8	1.9	1.7	1.3
	Would not have made the trip	3.1	6.5	2.3	0.0	0.0	3.3

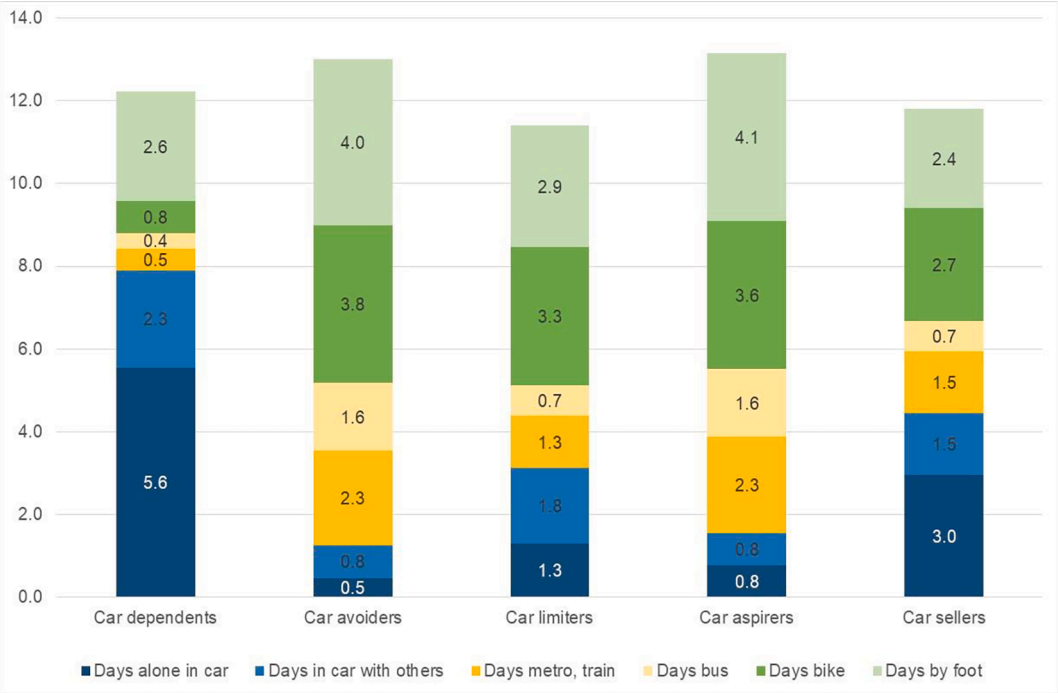

Fig. 4. Mode choice at the time of the first survey (days specific mode was used in the previous week).

profile and least often have access to a private parking space. Car limiters and car sellers are more often in the older age groups and less often live alone, however, a higher percentage of car limiters have a high level of education. The lowest percentage of people with higher education can be found among car dependents. They most often live outside Copenhagen or Frederiksberg and almost half of them have a private parking space (compared to less than 10% of car-free segments). The greater access to parking can be explained by lower prices of parking space within smaller municipalities and a greater need for parking space due to higher structural car dependency. When looking at the large differences in residential location of car dependents and car avoiders and their contrasting psychological profiles (see Fig. 1), residential self-selection is likely to play a role in the group differences as well. Within the group of car aspirers, the percentage of people who experienced a change in their living situation before their last survey participation is greatest, which might have contributed to their car acquisition (or related intention).

3.2. Multivariate car sharing impact analysis

To examine the effect of FFCS membership on car ownership, separate regression analysis were calculated for people who owned a car when participating in the first survey (Table 7) and people in a car-free household (Table 8). For both groups, first a regression analysis was

Table 5
Changes in use of transport modes (based on comparisons of the first and last survey data, percentages within segments).

Mode use in previous week	Car dependents	Car avoiders	Car limiters	Car aspirers	Car sellers	Chi²-test, p <
Days by car						.001
Reduced	27.1	5.6	3.5	8.0	34.9	
Unchanged	62.6	85.8	63.9	63.4	55.6	
Increased	10.3	8.6	32.6	28.6	9.5	
Days by bike						.01
Reduced	8.4	22.7	29.2	34.8	17.7	
Unchanged	72.0	56.7	55.6	46.4	62.9	
Increased	19.6	20.6	15.3	18.8	19.4	
Days by metro/ train						.001
Reduced	6.7	20.3	16.2	31.5	11.5	
Unchanged	86.7	63.6	73.2	52.3	72.1	
Increased	6.7	16.0	10.6	16.2	16.4	
Days by bus						.001
Reduced	4.8	18.2	9.8	27.0	1.6	
Unchanged	92.4	70.6	81.8	62.2	82.0	
Increased	2.9	11.3	8.4	10.8	16.4	

calculated that did not control for the intention to change car ownership (referred to as Model 1) and then a second model that controlled for the change intention (Model 2). For car-owning households, we find in Model 1 that joining car sharing increases the likelihood to decrease the number of car ownership ($p < .05$). However, this effect is no longer significant when controlling for the intention to change car ownership. Variables that we find negatively related to a decrease in car ownership in both models are having one (and not more) cars is a household and having access to one's own parking space, while a decrease in the number of persons in the household is positively related to a decrease in car ownership. The change in household composition is the strongest predictor after the intention to decrease car ownership. Surprisingly, the intention to increase car ownership also has a (though smaller) positive effect on reducing car ownership. This may either indicate that some people mixed up the answer options or that people who consider changes in car ownership, are in a less stable life situation (e.g. in terms of their job or family conditions), which may results in different changes than intended.

When considering which factors are related to an *increase* in the number of cars in the household, car sharing membership does not play a significant role but the number of days people use a bus. However, its significant effect disappears when controlling for change intention in Model 2. In both models, people who only have one car in the household, who have a private parking pace and who perceive high mobility necessities are more likely to increase car ownership. In Model 2, the

Table 6
Differences in socio-demographic variables and related changes (percentages within segment).

	Car dependents	Car avoiders	Car limiters	Car aspirers	Car sellers	Total	Chi²-test, p <
Age							.001
18-30	12.7	25.9	6.4	34.9	12.7	19.7	
31-40	25.5	26.8	23.4	42.2	15.9	27.4	
41-60	54.9	40.9	58.9	22.0	60.3	45.8	
61+	6.9	6.4	11.3	0.9	11.1	7.1	
Gender							.001
Women	13.7	28.6	14.2	32.7	11.3	22.0	
Men	86.3	71.4	85.8	67.3	88.7	78.0	
Income (yearly family income before taxes)							.001
Below median[b]	41.5	61.0	38.5	59.2	38.5	47.7	
Above median[c]	58.5	39.0	61.5	40.8	61.5	52.3	
Higher education							.001
No	43.5	32.4	33.9	29.6	40.4	36.2	
Yes	56.5	67.6	66.1	70.4	59.6	63.8	
Student							.001
No	96.1	86.4	97.2	81.8	95.2	90.4	
Yes	3.9	13.6	2.8	18.2	4.8	9.6	
Single-person-house							.001
No	84.3	61.4	89.4	62.7	90.5	74.4	
Yes	15.7	38.6	10.6	37.3	9.5	25.6	
Kids in Household							.001
No	52.9	75.5	50.4	73.6	52.5	63.7	
Yes	47.1	24.5	49.6	26.4	47.5	36.3	
Number of cars in household (survey 1)							.001
0	0.0	100.0	0.0	100.0	12.7[a]	53.6	
1	62.6	0.0	100.0	0.0	50.8	36.9	
2 or more	37.4	0.0	0.0	0.0	36.5	9.6	
Region							.001
Copenhagen/Frederiksberg	49.5	80.3	69.4	85.7	65.6	72.4	
Other area in Capital Region	50.5	19.7	30.6	14.3	34.4	27.6	
One's own parking place							.001
No	52.5	93.5	62.4	91.8	74.6	77.8	
Yes	47.5	6.5	37.6	8.2	25.4	22.2	
Changed job, household composition or residential location							=.05
No	20.8	19.3	33.8	13.2	26.7	22.0	
Yes	79.2	80.7	66.2	86.8	73.3	78.0	

[a]abolished a car up to 12 month before (and did not buy a new car); [b]up to 699,999 DKK; [c]700,000 DKK (ca. 94,000 EUR) and above

Table 7
Multinomial logistic regression explaining whether car-owning people increased or decreased the number of cars in the household between first and last survey participation (as compared to no change in car ownership).

Change in car ownership survey 1-survey2	Independent variables	Model 1 (not including intention to change car ownership)		Model 2 (including intention to change car ownership)	
		B	Odds ratio	B	Odds ratio
Decreased	Intercept	−0.36		−0.54	
	Month between first and last survey participation	0.01	1.01	0.00	1.00
	New FFCS members (reference group: non-members)	0.92*	2.50	0.54	1.71
	Existing FFCS members (reference group: non-members)	0.78	2.17	0.77	2.15
	Days by car (alone)	0.07	1.08	0.08	1.08
	Days by car (with others)	−0.08	0.92	−0.10	0.90
	Days by metro, train	0.11	1.12	0.08	1.09
	Days by bus	−0.21	0.81	−0.19	0.83
	Days by bike	0.14	1.15	0.09	1.10
	Days by foot	0.03	1.03	0.02	1.02
	One car in the household (reference: > 1 car)	−2.49***	0.08	−2.48***	0.08
	Intention to decrease car ownership (reference: no change intention)			2.25***	9.51
	Intention to increase car ownership (reference: no change intention)			1.175*	3.24
	Living in Copenhagen or Frederiksberg	0.43	1.54	0.27	1.32
	One's own parking space	−1.09**	0.34	−1.075**	0.34
	Male gender	−0.64	0.53	−0.55	0.58
	Age:18–35 (reference: 60+)	0.48	1.62	0.73	2.07
	Age:36–59 (reference: 60+)	0.09	1.10	0.23	1.26
	Student	−0.54	0.58	−0.76	0.47
	Higher education	−0.24	0.79	−0.31	0.73
	Single-person household	0.15	1.16	0.26	1.30
	Children in the household	−0.17	0.84	−0.25	0.78
	Attitude: car independency	0.20	1.22	0.13	1.13
	Personal norm	0.08	1.08	0.12	1.13
	Attitude: car excitement	−0.05	0.95	−0.04	0.96
	Attitude: car autonomy	−0.40	0.67	−0.37	0.69
	Perceived mobility necessities	0.06	1.07	0.00	1.00
	Weather resistance	−0.10	0.90	−0.01	0.99
		1.72***	13.58	1.82***	6.18
	Numbers of persons in household decreased (reference: unchanged)				
	Numbers of persons in household increased (reference: unchanged)	0.24	5.36	0.40	1.49
Increased	Intercept	−5.26**		−4.94**	
	Month between first and last survey participation	−0.02	0.98	−0.01	0.99
	New FFCS members (reference group: non-members)	0.33	1.39	0.42	1.52
	Existing FFCS members (reference group: non-members)	0.25	1.28	0.14	1.15
	Days by car (alone)	0.05	1.05	0.06	1.06
	Days by car (with others)	−0.12	0.89	−0.13	0.88
	Days by metro, train	−0.17	0.84	−0.11	0.90
	Days by bus	0.30*	1.35	0.25	1.29
	Days by bike	−0.10	0.91	−0.10	0.90
	Days by foot	0.00	1.00	−0.01	0.99
	One car in the household (reference: >1 car)	0.93*	2.52	0.92*	2.52
	Intention to decrease car ownership (reference: no change intention)			0.20	1.22
	Intention to increase car ownership (reference: no change intention)			1.68***	5.38
	Living in Copenhagen or Frederiksberg	0.05	1.05	−0.02	0.98
	One's own parking space	0.74*	2.09	0.70*	2.01
	Male gender	−0.38	0.68	−0.44	0.64
	Age:18–35 (reference: 60+)	0.83	2.30	0.70	2.01
	Age:36–59 (reference: 60+)	0.17	1.18	0.08	1.08
	Student	0.81	2.25	0.89	2.44
	Higher education	−0.16	0.85	−0.15	0.86
	Single-person household	−0.31	0.73	−0.19	0.83
	Children in the household	0.09	1.09	0.01	1.01
	Attitude: car independency	−0.02	0.98	−0.07	0.93
	Personal norm	−0.14	0.87	−0.13	0.87

(continued on next page)

Table 7 (*continued*)

Change in car ownership survey 1-survey2	Independent variables	Model 1 (not including intention to change car ownership) B	Model 1 Odds ratio	Model 2 (including intention to change car ownership) B	Model 2 Odds ratio
	Attitude: car excitement	−0.04	0.96	−0.05	0.95
	Attitude: car autonomy	0.17	1.18	0.15	1.16
	Perceived mobility necessities	0.41*	1.50	0.35*	1.42
	Weather resistance	0.12	1.13	0.10	1.11
	Numbers of persons in household decreased (reference: unchanged)	0.14	1.16	0.38	1.47
	Numbers of persons in household increased (reference: unchanged)	0.56	1.75	0.68	1.97
Nagelkerke's R^2		0.240		0.305	

Notes. Due to a large number of participants not wanting to disclose information regarding their income, the variable was not included in the final analysis. Changes in postal code from survey 1 to survey 2 (indicating a move) and in occupation were not included due to missing values in the first or last response and only few observed changes. Separate analyses including income, a shift in postal code and occupation showed no significant effect for any of these added variables, so they were neither included in the final models in Table 7 nor in Table 8. *p < .05; **p < .01; ***p < .001.

intention to increase car ownership is the most important predictor of increased car ownership.

Table 8 shows the results of the logistic regression explaining an increase of car ownership for people who had no car in the first survey. While FFCS membership does not play a role, we find that two car-related attitudes are related to acquiring a car: people with a high score in car autonomy and a low score in car independency are more likely to increase car ownership. However, this effect disappears when controlling for the intention to increase car ownership. This is not surprising as these attitudes may contribute to forming the intention to get a car. In both models, an increase of household members is related to an increase in car ownership. Similar as for car-owning households, the strongest factor in Model 2 is the intention to increase car ownership.

When interpreting the results of all models, we find that the intention to change car ownership is the most relevant factor for actual changes in car ownership. A change in the number of household members is particularly relevant for the shift from a car-free to a car-owning household and vice versa but less relevant for a shift from one to more cars in the household. Similar, reducing a car in the household is less likely when only having one car than when having more than one car, while it is more likely to increase car ownership when not already having more than one car. For people who already have a car, access to a privately owned parking place both plays a significant role in increasing car ownership as well as in preventing car ownership reduction.

Attitudinal factors only play a role in increasing car ownership levels: For people who already own a car, perceived mobility necessities increase the likelihood to buy yet another car. People who do not own a car yet, are more likely to get one, if they find it difficult to handle their everyday life without a car (low car independency) and appreciate the freedom and flexibility of a car (high car autonomy).

Table 8
Logistic regression explaining whether people in car-free households increased the number of cars in the household or not between first and last survey participation.

Independent variables	Model 1 (not including intention to change car ownership) B	Model 1 Odds ratio	Model 2 (including intention to change car ownership) B	Model 2 Odds ratio
Intercept	−3.15*		−4.01**	
Month between first and last survey participation	0.08**	1.08	0.09**	1.09
New FFCS members (reference group: non-members)	−0.80	0.45	−0.88	0.41
Existing FFCS members (reference group: non-members)	−0.05	0.95	−0.11	0.90
Days by car (alone)	−0.06	0.94	−0.08	0.92
Days by car (with others)	0.14	1.15	0.14	1.15
Days by metro, train	0.14	1.15	0.12	1.13
Days by bus	−0.15	0.86	−0.16	0.86
Days by bike	−0.07	0.93	−0.06	0.94
Days by foot	0.10	1.11	0.12*	1.13
Intention to increase car ownership (reference: no change intention)			1.76***	5.82
Living in Copenhagen or Frederiksberg	−0.25	0.78	−0.19	0.83
One's own parking space	0.51	1.66	0.69	2.00
Male gender	0.13	1.14	0.02	1.02
Age:18–35 (reference: 60+)	0.36	1.43	0.26	1.30
Age:36–59 (reference: 60+)	0.07	1.07	−0.04	0.96
Student	0.56	1.75	0.74	2.09
Higher education	0.27	1.31	0.18	1.20
Single-person household	−0.46	0.63	−0.44	0.65
Children in the household	0.21	1.23	0.05	1.05
Attitude: car independency	−0.39*	0.68	−0.18	0.84
Personal norm	−0.17	0.84	−0.19	0.83
Attitude: car excitement	0.00	1.00	−0.09	0.92
Attitude: car autonomy	0.38*	1.46	0.31	1.36
Perceived mobility necessities	−0.12	0.88	−0.03	0.97
Weather resistance	0.19	1.21	0.12	1.13
Numbers of persons in household decreased (reference: unchanged)	−0.20	0.82	−0.20	0.82
Numbers of persons in household increased (reference: unchanged)	1.34**	3.82	1.37**	3.94
Nagelkerke's R^2	0.205		0.276	

Notes. *p < .05; **p < .01; ***p < .001.

4. Discussion and conclusions

This study is based on longitudinal survey data including people who joined FFCS in Copenhagen and people who did not, who were followed over a period of up to 2.5 years. While we found a significant effect of joining FFCS on car ownership reduction, this effect disappeared when controlling for the intention to reduce car ownership. Thus, that FFCS members were more likely to reduce car ownership can be explained by a higher intention to reduce car ownership when joining the service. For people who intended to reduce car ownership, FFCS membership did not make it more or less likely that this intention turned into action. However, it is possible that the awareness of a FFCS service contributed to developing an intention to decrease car ownership. For car-free households, FFCS membership neither made it more likely that people remained car-free nor that they increased car ownership – possibly both effects evened out.

Besides the intention to change car ownership, actual changes in household composition between the first and second survey was an important factor for changed car ownership. This result is in line with findings about the relevance of changing numbers of adults in a household (Clark et al., 2016; Prillwitz et al., 2006; Yamamoto, 2008), relationship dissolution (Oakil et al., 2018), and childbirth for changes

in car ownership (e.g. Guo et al., 2020; Lanzendorf, 2010; Oakil et al., 2014). Results of the present study stress that changes in household composition are more important for changes in car ownership than demographic characteristics per se: In contrast to Jochem et al. (2020) and Le Vine and Polak (2019), we found no significant effects of demographic variables, such as household size, children in the household, age or education. For car-owning households, access to a private parking space decreased the likelihood of abolishing a car and increased the likelihood of getting another car.

Based on the findings of Jain et al. (2020), five segments of car sharers were defined, which show similar attitudinal profiles as the segments identified in the Australian study, although attitudes were not used to create the segments. In the present study, the largest segment among car sharers were car avoiders, while non-sharers were dominated by car dependents. Car limiters were well-represented in both groups, while segments that changed car ownership (car sellers, car aspirers) were overrepresented in the group of car sharers. Car aspirers, mainly young people living in central areas, were the group who most often experienced changes in their living situation. Based on the regression results their increased car ownership most likely resulted from increased household size (e.g. moving together with a partner or childbirth).

As is the case in major cities in other countries, young men were also overrepresented among FFCS members in Copenhagen. In addition, there were more car-free households among car sharing members than among non-members. The characteristics of members have changed a bit towards inclusion of more older drivers and women over time, indicating a growing acceptance in the general population.

When signing up for FFCS, people showed slightly different motivations depending on current car ownership. Motives for car-free households were associated with easy and cheap access to a car and cars were mainly used for utilitarian purposes, while car dependents used the service more frequently for leisure trips. These results reflect findings from Garrett et al. (2021) on differences in usage between car-owning and car-free segments. However, they are in conflict with the results of Jain et al. (2020) who found that car dependents used car sharing mainly when being in need for a specific type of vehicle (e.g. for moving furniture). This difference can be explained by the different car sharing systems under examination. In the largest period of the study, DriveNow only offered one car model in Copenhagen, the electric BMW i3. That car dependents used the service, was therefore more likely motivated by affective motives (driving a fast accelerating electric car) and by avoiding the use of one's own car in certain situations (when not going back by car).

Decisions on car ownership and use are influenced by socio-demographic and psychological factors, spatial context and accessibility, and can be changed by key events in a person's life course as addressed in the mobility biography approach (e.g. Müggenburg et al., 2015). While psychological factors gained increasing attention in explaining mode choice, they have so far hardly been considered in quantitative studies on FFCS. One exception is a recent study by Mattia et al. (2019) who applied the Theory of Planned Behaviour (Ajzen, 1991) to explain car sharers' re-use intention, and a few studies that included single (and thus less reliable) attitudinal variables to explain user motivation (Becker et al., 2017, 2018; Garrett et al., 2021). We measured mobility-related attitudes and norms based on reliable scales derived from attitude theory. In this way, we could quantify the qualitative findings by Jain et al. (2020) on car dependency and perceived mobility necessities and could additionally show differences in symbolic-affective car motives and personal norm for the classified segments.

The differences we found between users and non-users are smaller than those found for station-based car sharing (e.g. Burkhardt and Millard-Ball, 2006). However, within the group of car sharers, there are large differences in single attitudinal factors, but mostly for segments that differed in their car ownership and use at the beginning of the study. Based on results from Jain et al. (2020) a larger difference between car avoiders and car aspirers was expected as most car aspirers were described as car enthusiasts in their study. Yet, that one of the two segments later changed car ownership was hardly visible from their profile at the beginning, which supports the assumption that external factors and changes in the household composition played a larger role in that process. It may also question the commonly assumed direction of influence by which attitudes affect behaviour and suggests that attitudes also change as a consequence of changed car ownership as supported by recent research (e.g. Kroesen et al., 2017; Moody and Zhao, 2020; van Wee et al., 2019). Yet, the multivariate analysis revealed that attitudinal factors had an effect on car ownership change, though not a major one. For people in car-owning households, perceived mobility necessities (Haustein and Hunecke, 2007) played a role in their decision to buy another car. For people in car-free households, appreciating the autonomy a private car offers and finding it difficult to handle everyday life without a private car most likely played a role in forming an intention to buy a car as these factors (car autonomy, car independency) were not significant any longer when car purchase intention was added to the model. The analysis additionally stresses the central role of intention for behaviour (Ajzen, 1991; Bamberg, 2013). Supplementary qualitative interviews at different project stages could have shed more light on the process of behavioural change (e.g. Clark et al., 2016), in particular, how often car use reduction is the result of a voluntary, deliberate process of behaviour change or the consequence of changed living circumstances that require behavioural adaption.

By the inclusion of attitudinal factors in the definition of segments, we could have created segments more similar to the segments described by Jain et al. (2020). However, our main interests was to see how segments differ in demographic and attitudinal variables, when only using objective criteria of behaviour change. As a result, the differences between the segments' attitudinal profiles are more quantitative than qualitative with the largest differences between car dependents who evaluate the car positive in all aspects, care less about the environment and perceive high mobility necessities, and car avoiders who seem more driven by environmental norms and a more instrumental relation to the car. The other segments lie within this spectrum but they do not show more distinct profiles. For many purposes, a simple distinction between car-owning and car-free segments of FFCS might thus be sufficient. When aiming for more distinct profiles, the inclusion of attitudinal factors in the process of segmentation is recommended.

4.1. Policy implications

According to Jain et al. (2020) a reduction in car ownership is often initiated by changes in one's life situation, where car sharing only plays a contributing role in the decision to sell a car. Therefore, they recommended developing campaigns aimed at people close to specific key life events, such as retirement or having one's last child leaving home. Our findings about the car reducing effect of decreasing household size support this conclusion. Additionally, the results show the relevance of increasing household size for buying a car.

In our study, it is in particular car aspirers who experience changes in their living conditions. To prevent that car avoiders (the car-free households that do not buy or intend to buy a car) become car aspirers, in particular when the household size increases due to partnership or childbirth, additional measures may be required that make it easier for them to remain car-free because FFCS alone may not meet all their car-related mobility needs in the long run (Garrett et al., 2021). This includes better opportunities to use FFCS in combination with other car services, such as car rental, station-based and peer-to-peer car sharing, as well as a general better connection of different modes of transport via MaaS solutions, so that more irregular car needs (e.g. weekend trips) can be covered more easily without owning a car. However, new smart mobility options are also subject to social exclusion as they require access to a smartphone, which not everyone has, and require the installation of apps that may be in conflict with the wish to

protect one's privacy (Groth, 2019; Hunecke et al., 2021). Such digital barriers should be overcome by offering solutions that improve accessibility for all.

Our results also show that the potential for reducing car ownership is linked to the place of residence and in particular the availability of a private parking space, which is probably partly a result of residential self-selection (e.g. De Vos and Witlox, 2016; van Wee et al., 2019). Municipalities that aim for a reduction of the number of cars in a city, could either increase the price of private parking spaces or reduce the number of these and at the same time increase the number of parking spaces for car sharing cars. To motivate people who already own a parking place to abolish a car, municipalities could offer payment in form of free minutes for car sharing and/or a reduced price for public transport for renting out the parking space. To be successful and publicly accepted, parking management strategies should be accompanied by measures to reduce car dependence (Mattioli and Colleoni, 2016). As the city-specific results of Jochem et al. (2020) indicate, the availability of other sharing systems and city characteristics that facilitate car-free living make it more likely that FFCS users reduce car ownership.

A target group that so far did not get much attention when it comes to the promotion of FFCS are older people. FFCS is clearly targeted at a young and mobile urban population. However, new cohorts of older people are much more active than previous cohorts and more often wish to retain their driver's license until high age (Haustein and Siren, 2015; Siren and Haustein, 2013). Already in 2015, 91% of Danes aged 55–64 years had a smartphone (Statista, 2015) and thereby potentially had access to FFCS when living in the operating area of such services. Most importantly, and in line with results from Jochem et al. (2020), older people were overrepresented among car sellers. Although there is a clear tendency to reduce car use and mileage as a result of retirement, older people also increase car use for leisure purposes (Siren and Haustein, 2016), and leisure trips are the main trip purpose by FFCS. The overall lower car demand of retired people may be easier to meet with FFCS than car commuting. In particular, when older couples separate or one partner dies, car ownership reduction may be considered and FFCS membership could be a way to prevent older people's mobility loss.

While older people who already use FFCS do not consider the use of the system as more complicated than younger users (Haustein and Nielsen, 2018), it is very likely that existing users are more technology-oriented than the general older population. Thus, easy access and some extra support or encouragement seem relevant for the adoption of the service by older people.

4.2. Limitations and future research perspectives

Most studies that attempt to estimate the effect of car sharing are based on cross-sectional data that compare car ownership before and after membership based on retrospective data. To overcome limitations related to retrospective data, such as memory and hindsight bias, this study is based on longitudinal data. While longitudinal studies have many advantages, there are also disadvantages, especially in terms of representativeness and dropout. We have attempted to address this problem by increasing the incentives for participation in the later survey waves but the study may still be subject to self-selection bias.

Another group of studies compares car ownership and use between car sharing users and non-users. A limitation is that both groups differ from the start, which has also been shown in our study and has been addressed in effect modelling in more recent studies (e.g. Mishra et al., 2015, 2019). In this study, a large number of control variables was used to account for this problem in the effect assessment. A random assignment of people to the group of users and non-users would be the ideal solution to this problem but in case of FFCS membership, a random assignment would be very difficult to realise with study participants most likely differing from typical members, which would restrict the transferability of results. While it would probably allow for better conclusions with regard to achievable effects, it would not allow for comparison of the distribution of FFCS segments with the distribution of similar segments in the general population, as was done in this study.

Instead of creating segments entirely based on actual car use and ownership and observed changes over time, an interesting alternative approach would be to segment people based on their characteristics (e.g. attitudinal factors or transport patterns) when joining car sharing and to examine whether they change group membership as a consequence of car sharing. This could be studied by applying latent transition analysis (e.g. Kroesen, 2014; De Haas et al., 2018) and is subject to future research.

Availability of data and material

Access to the data is not povided as it is customer data of DriveNow users and study participants were not asked if they agree to making their data public.

Code availability

Not applicable.

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Sonja Haustein: Conceptualization, Methodology, Formal analysis, Writing - original draft.

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