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Exploring “automobility engagement”: A predictor of shared, automated, and electric mobility interest?

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ABSTRACT

Automobility theory investigates the prevalence of the privately-owned car, including technology, infrastructure, and cultural elements. In an application of this theory, we quantitatively explore consumer engagement with aspects of automobility related to car ownership and use. We identify seven potential constructs of “automobility engagement” that might help explain consumer interest in shared, automated, and electric mobility. We develop 40 questionnaire items based on a literature review and analyze survey responses from a representative sample of 3,658 Canadian respondents. First, we conduct exploratory factor analysis and identify seven factors, such as “Car Identity” and “Societal Concern”. We then explore the role of these factors in consumer interest in ride-hailing, carsharing, fully automated vehicles, and electric vehicles through regression analyses. We find that “Societal Concern” predicts interest in all innovations but carsharing, while other factors are more specific. We conclude that quantifying automobility engagement can help to understand consumer interest in innovations.

1. Introduction

Widespread car use has enabled unprecedented mobility but led to significant environmental problems, such as greenhouse gas (GHG) emissions. Research indicates the need to drastically lower GHG emissions from passenger transport globally to stem the worst impacts of climate change (IEA, 2021; Sims et al., 2014). For example, by 2050 the global car fleet must be almost fully electrified to achieve net-zero emissions targets (IEA, 2021).

Various technologies and practices can alter the GHG emissions of passenger transportation. Numerous recent studies focus on the potential of innovations relating to shared, automated, and electric mobility (Greenblatt and Saxena, 2015; Sperling, 2018; Viegas et al., 2016). Shared mobility refers to shared access to travel by vehicles that are not privately owned (Shaheen et al., 2015), automated mobility refers to fully automated vehicles (FAVs) that can drive themselves in most or all conditions without requiring a driver to be paying attention, and electric mobility includes vehicles that can run on electricity. Sperling (2018) terms these innovations as the “Three Revolutions” of transportation, while others use different terms, such as Autonomous, Connected, Electric, and Shared mobility (ACES) (Adler et al., 2019). We simply refer to these as “new mobility innovations” or “innovations” (Axsen and Sovacool, 2019, p. 2), meaning practices, objects, or ideas that individuals perceive as being new.

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Often little attention is paid to how these so-called new mobility innovations relate to systemic patterns in passenger transportation, which may be resistant to change. The prevalence of the privately-owned vehicle as the primary means of transportation in most industrialized countries constitutes what some sociologists refer to as the "automobility system" (Beckmann, 2001; Urry, 2004). It is uncertain how automobility may influence the adoption of new mobility innovations and their consequent impacts to passenger transportation. To begin exploring these interactions, in this paper we explore consumer engagement with aspects of the automobility system as well as consumer response to new mobility innovations. We develop a framework to quantify consumers' "automobility engagement" using survey data and apply it to help explain consumer stated interested in shared, automated, and electric mobility.

Automobility theory analyzes the dominance of the privately-owned vehicle and provides insight into the social structure of car-dependent mobility patterns (e.g., Beckmann, 2001; Böhm et al., 2006; Sheller and Urry, 2000; Schwanen, 2015; Urry, 2004). According to the theory, the automobility system was initially formed in the late 19th century (Motavalli, 2014) and enabled human societies to become mobile to an extent that was unknown before. This system includes cars, car drivers, built infrastructure such as roads and petroleum supplies, and the network of technologies, actors, and institutions that contribute to widespread car use. Urry (2004) describes automobility as a self-reinforcing system, where car use enables urban sprawl and detachment of social practices from place, which further reinforce car use. The system has reached a high level of stability and the fossil-fuel powered car constitutes the dominant form of contemporary mobility (Urry, 2004), with significant contributions to GHG emissions and air pollution (Sims et al., 2014). The industrialized world has thus become "locked into" automobility (Schwanen, 2015, p. 304) – the institution of the system's components (e.g., built-in road infrastructure) makes it difficult to significantly deviate from car ownership and use.

While the system of automobility involves a multitude of actors, such as governmental bodies, transport providers, and automotive manufacturers, among others (Geels, 2012; Hoffmann et al., 2017; Schwanen, 2016), in this study we solely focus on one such actor, namely consumers within an automobility system. There has been relatively little exploration of the automobility system at the individual level of the consumer. As Schwanen (2015, p. 305) argues, macro-level analyses of the systemic nature of automobility are essential but "only one side of the coin", where investigations into micro-level aspects of how cars are experienced and used can provide complementary understandings of automobility from a subjective lens. There are established bodies of literature in transport studies, psychology, and economics (among other fields) focused on consumer perceptions and motives related to car ownership and use (Schwanen, 2015; also see Lucas et al., 2011; Gardner and Abraham, 2008; Ramos et al., 2020; Steg, 2005; Steg et al., 2001) – however, this literature is mostly disconnected from automobility theory. We understand such consumer perspectives to constitute part of the wider system of automobility and, at the same time, to be shaped by system-level components, such as land use patterns, road infrastructure, and cultural representations of the automobile (McLaren and Conley, 2012; Schwanen, 2015).

Here, we explore some of the "micro" aspects of automobility through a conceptual framework of consumer "automobility engagement", focusing on consumer perceptions of and engagement with car ownership and use as components of the automobility system. Car ownership and use represent a core aspect of this system, where automobility theory discusses the automobile as a significant object of private consumption that propagates cultural symbols (e.g., status and "adulthood" symbols) and enables systemic organizations of space and time which are both flexible and coercive (Beckmann, 2001; Böhm et al., 2006; Featherstone, 2004; Urry, 2004). As such, lived experiences, perceptions, and motivations related to owning and using cars form part of how consumers within this system subjectively experience automobility (McLaren and Conley, 2012; Schwanen, 2015). We note that our conceptual framework is not intended as a theoretical contribution to automobility theory; rather, it is a compilation of literature relevant to consumer engagement with aspects of automobility, focusing on car ownership and use. Our intended contribution to the literature is to compile and apply a framework of "automobility engagement" empirically to a survey sample.

We explore "automobility engagement" to empirically investigate the relationship between aspects of automobility and consumer response to shared, automated, and electric mobility. These innovations are seen as novel technologies and services that could lead to significant changes in passenger transportation, if adopted on a large scale (Sperling, 2018). Studies estimate that shared, automated, and electric mobility could, for example, decrease GHG emissions and energy use, increase mobility and accessibility, and transform land use patterns (Milakis et al., 2017; Soteropoulos et al., 2019; Taiebat et al., 2018). However, most studies do not take into consideration how consumers may be locked into aspects of the automobility system when estimating the transformative potential of these innovations. Being deployed within an automobility system, it is logical to expect that consumer engagement with automobility may influence whether and how these innovations are adopted, as well as their consequences for transportation.

The relationship between automobility engagement and consumer response to shared, automated, and electric mobility is relevant in terms of emissions reduction, as the environmental impacts of these innovations will partially depend on whether their adoption reproduces or challenges automobility patterns. Studies indicate that these innovations could reduce transport emissions, especially if deployed as a fleet of FAVs that are shared and electric (Greenblatt and Saxena, 2015; Sperling, 2018; Viegas et al., 2016), where shared electric FAVs under idealized conditions could lead to deep per-kilometre GHG reductions of 87–94% below current conventional vehicles (Greenblatt and Saxena, 2015). However, it is not clear whether consumers may accept and use shared FAVs in lieu of private vehicle use. For example, many studies find higher levels of interest in privately-owned FAVs than in shared forms (Clayton et al., 2020; Haboucha et al., 2017; Kelley et al., 2019; Pakusch et al., 2018; Zmud et al., 2016). FAV adoption that reproduces automobility patterns of car ownership and fossil fuel use could result in up to a doubling of road transport GHG emissions and energy use (Wadud et al., 2016), if emissions are not mitigated by increased vehicle efficiency (Fagnant and Kockelman, 2015; Wadud et al., 2016). Hence, knowledge of how consumer engagement with automobility may impact the markets for shared, automated, and electric mobilities can help elucidate these innovations' potential environmental implications.

In this paper, we analyze whether automobility engagement shapes consumer evaluation of shared, automated, and electric mobility. The paper's objectives are to:

i. Develop and explore a conceptual framework of consumer "automobility engagement" by empirically measuring it in a sample of Canadian respondents.
ii. Investigate the relationship between consumer automobility engagement and interest in shared, automated, and electric mobility.

Throughout this paper, we discuss shared services (specifically, ride-hailing and carsharing), fully automated vehicles, and plug-in electric vehicles (PEVs) as new mobility innovations. We define these innovations as follows. Ride-hailing is a service where members book and pay for a ride through a smart phone app (e.g., Uber, Lyft). Carsharing is a self-service where members book, pay for, and use vehicles belonging to a network (e.g., Modo, Evo Car Share). Regarding automated vehicles, the Society of Automotive Engineers defines vehicle automation levels as ranging from Level 0 (no automation) to Level 5 (full automation). FAVs refer to automation Levels 4 and 5, where vehicles can drive themselves in most or all conditions without the need for human input. We investigate both privately-owned and shared FAV modes in this study. PEVs are vehicles that can run on electricity and be plugged in to recharge. This includes battery electric vehicles (BEVs), which can only run on electricity, and plug-in hybrid electric vehicles (PHEVs), which also have an internal combustion engine.

This paper focuses on Canada as a case study – an automobile-dependent country as clearly reflected by several aggregate patterns. The transport sector emitted 30% of Canada's total GHG emissions or 217 Mt $CO_{2\ eq}$ in 2018, with road transportation emitting 154 Mt $CO_{2\ eq}$ (Canada, 2020). In 2017, 85% of Canadian households owned, leased, or used at least one vehicle, while 39% of households owned two or more vehicles (Transport Canada, 2018). Adoption of shared, automated, and electric mobility is generally nascent in Canada but varies by region. For example, ride-hailing has been available in Toronto since 2012 and in Montreal since 2014, while

Table 1
Automobility engagement framework and scale. Survey statements comprise 40 items presented in full.

Construct	Description	Scale items
Car ownership preferences	Preferences for private car ownership and openness to sharing of vehicles	1. Owning a car is important to me. 2. If possible, I'd prefer not to own a car. 3. I am (or would be) comfortable lending my car to a friend. 4. I don't (or wouldn't) want to drive a car that someone else was previously driving.. 5. It is (or would be) important that I keep my car a particular way (seat, mirrors, cleanliness, etc.).
Perceived car dependence	Perceived car needs for daily practices and social relations	6. I need a car to fulfill my everyday obligations. 7. It is easy to plan my day without a car. 8. It is difficult for me to access my friends and family without a car. 9. In my area, every household needs a car. 10. I need a car for my job. 11. Sometimes I feel too dependent on my car.
Residential preferences	Preferences for residential density, diversity, and commute length	12. It is important that I live in a neighbourhood where I can walk to shops and other destinations. 13. It is important for me to live in a place where I can easily access transit. 14. My ideal situation is to live in a private, detached home (not apartment or townhome). 15. It is important for me to own my home. 16. I prefer to live away from urban centers. 17. I don't (or wouldn't) mind having a long commute to work.
Driving emotions	Positive and negative emotions of driving a car	18. I enjoy (or would enjoy) driving. 19. Driving is stressful. 20. The idea of driving makes me tired. 21. I feel (or would feel) in control when I am driving. 22. Driving makes me feel (or would make me feel) free. 23. Being inside a car feels like a safe, protected space.
Car identity	Car ownership association with self-identity, status conveyance, and emotional attachment	24. Owning a car shows (or would show) that I am successful. 25. I want (or would want) my car to represent my personality. 26. You can learn a lot about someone by looking at their car. 27. Buying a car is an important milestone in life. 28. A car is just a way to get around and nothing more. 29. I often feel emotionally connected to cars (or my car).
Social norms	Typical travel behavior in social circles	30. Most of my friends own a car. 31. I know a lot of people that use public transit (bus, subway, etc.). 32. Many of my friends are trying to reduce their car use. 33. Many of my friends commonly walk or bike to get around. 34. I often talk about cars with my friends.
Perceived societal impacts	Perceptions of positive and negative societal impacts of car use	35. Air pollution from cars is a serious problem. 36. Car use is causing climate change. 37. Our transportation system is ineffective for less privileged people (e.g., those with disabilities or lower incomes). 38. Widespread car use is needed to support jobs and the economy. 39. Overall, car use is good for society. 40. Cars, streets and parking take away too much public space.

Vancouver only recently allowed the operation of ride-hailing companies in 2020. In contrast, Vancouver is one of North America's leading cities in terms of carsharing adoption, with a carsharing fleet of around 3,000 vehicles (Vancity, 2018). FAVs are not yet available on the market; however, the federal government has recently launched a program to support jurisdictions in preparing for the emergence of automated vehicles (Transport Canada, 2018). PEV sales in Canada remain low compared to conventional vehicle sales. PEV sales comprised 0.9% of new light-duty vehicle sales in Canada in 2017 and have risen to around 2% in 2018 and 2019 (Klippenstein, 2019), and to 3.5% in 2020 (Government of Canada, 2021).

In Section 1.1, we describe our conceptual framework of automobility engagement. Section 2 provides details on survey design and data collection and explains our methods and data analyses. We then present results, organized by data analysis method (Section 3), discuss our findings (Section 4), and conclude with overall implications, study limitations, and directions for future research (Section 5).

1.1. Conceptual framework: Automobility engagement

The automobility system shapes individual expectations of movement in space and time, generates mobility and car use needs, and propagates symbols and perceptions related to car ownership and use (Beckmann, 2001; Böhm et al., 2006; McLaren and Conley, 2012; Schwanen, 2015; Urry, 2004). Less understood is how consumers perceive and engage with aspects of automobility, and how automobility engagement may influence consumer evaluations of shared, automated, and electric mobility. Guided by literature, we identify relevant constructs to explore consumer "automobility engagement", focusing on consumer perceptions and engagement regarding car ownership and use. We conducted a literature review of research into the automobility system by searching for journal articles and book chapters on the topics of "automobility theory" and "automobility system". Synthesizing the literature, we identify themes (or constructs) that are relevant to the individual level of the consumer. This process was complemented by a literature search of studies on consumer perspectives of car ownership and use, which were mostly related to the fields of consumer research and social psychology.

We synthesize themes from the literature into seven hypothetical constructs of consumer automobility engagement, which thus set up our conceptual framework: "car ownership preferences", "perceived car dependence", "residential preferences", "driving emotions", "car identity", "social norms", and "perceived societal impacts". We do not expect our framework to represent an exhaustive list of automobility engagement constructs, rather a preliminary exploration of this issue. For example, we attempt to minimize inclusion of potential constructs that may be relevant to specific groups and not applicable to the general population, such as constructs applicable only to car owners. Table 1 summarizes the framework and depicts survey items associated with each construct, which compose a survey scale of automobility engagement. This scale is further explained in Section 2.1.

We briefly describe the constructs and relate to the literature. First, car ownership preferences explore whether consumers prefer private vehicle ownership or are open to shared access to vehicles. Private ownership of vehicles is a core aspect of the automobility system. Urry (2004, p. 25) posits that the car is the "quintessential manufactured object" of 20th century capitalism and one of the most significant items of consumption. Shared access to vehicles and other travel modes or "shared mobility", on the other hand, has become a growing sector of the sharing economy, representing a trend towards shared access to services in lieu of private ownership (Shaheen et al., 2015).

Second, we investigate a subjective measure of car dependence, or perceived car dependence. Car dependence is construed by automobility theory as a structural consequence of the automobility system, where the detachment of social practices and relations from place have constrained people into high mobility and flexibility needs (Beckmann, 2001; Urry, 2004). Multiple structural factors, such as land use patterns, public transit infrastructure and service, car and road infrastructure, and cultural expectations surrounding car use, contribute to a region's level of car dependence (Buehler et al., 2017; Mattioli et al., 2020; McIntosh et al., 2014; Naess, 2006). However, individual decisions – for example, regarding residential location and lifestyle – can also contribute to the level of car dependence that individuals experience (Hopkins and Stephenson, 2016; Lucas, 2009), as explored below.

Third, we explore residential preferences as a construct related to perceived car dependence. Research indicates that individuals may have a degree of agency in accepting or avoiding being car dependent (Hopkins and Stephenson, 2016; Lucas, 2009). Research on residential self-selection explores the ways in which travel preferences influence residential location choices. For example, studies show that some people may choose to live in suburban residential locations because they are willing to accept daily commuting and driving (Humphreys and Ahern, 2019), while others choose walkable neighborhoods in part because they like to walk or cycle more (Cao et al., 2009) – although such preferences can be unrealized due to constraints.

Fourth, we investigate driving emotions as emotions stemming from car use that act as intrinsic motivations for driving (or not driving). Sheller (2004, p. 221) writes about "automobility emotions" in terms of embodied dispositions of car users, including the visceral and other feelings related to car use. Studies indicate that emotions evoked by car driving act as motives for car use (Anable and Gatersleben, 2005; Lois and López-Sáez, 2009; Steg, 2005; Steg et al., 2001). Enjoyment of driving has been conceived as a hedonic vehicle attribute (Schuitema et al., 2013) and found to be a self-reported reason for anticipated increased future driving (Stradling et al., 2000).

Fifth, car identity explores consumer identification with the vehicle as well as with the social status and symbols linked to it. The status symbol attached to private vehicles is thought to be one of the drivers behind the generation and reproduction of automobility (Böhm et al., 2006; Urry, 2004). More generally, symbolic values refer to consumer expression of self-identity, social status, or group membership through possessions (Dittmar, 1992; Steg, 2005). Prior studies find that symbolic motives are associated with car use levels and attractiveness (Steg, 2005; Steg et al., 2001), and that perceptions of electric vehicles' symbolic attributes influence consumer interest (Axsen and Kurani, 2013), adoption (Heffner et al., 2007), and intention to adopt (Schuitema et al., 2013).

Sixth, social norms investigate typical behavior regarding car use and other transport modes in social circles. Automobility is socially constructed (Böhm et al., 2006); however, the social relations that constitute this system are not thoroughly explored in automobility theory (Collin-Lange, 2013). Social norms comprise some of the varied concepts that investigate social influence – influence that others exert over an individual's behavior – and are commonly applied to transportation and energy transitions studies (Axsen and Kurani, 2012a; Li et al., 2017). Here, we focus on descriptive norms, or what travel behaviors are typical and perceived as normal in consumers' social contexts (Cialdini et al., 1990). For example, studies have assessed descriptive norms of travel in terms of whether most people that the respondent knows take a car to work (Ramos et al., 2020), and whether most people that are important to the respondent use a car for most journeys (Gardner and Abraham, 2010).

Finally, we investigate perceived societal impacts of car use. Beckmann (2001) posits that an increasing number of transport users have become aware of the risks associated with automobility – in other words, public perceptions of the automobile are thought to have become increasingly negative over time. Here we examine perceptions of societal impacts of car use, both positive and negative. Societal impacts refer to the direct impacts of a technology to society, such as environmental, energy use, land-use, and economic impacts (Axsen and Kurani, 2012b). Examples from the literature include perceptions about whether car use is environmentally friendly (He and Thøgersen, 2017), as well as broader perceptions of car use as being "disadvantageous for society" or a "societal problem" (Steg and Sievers, 2000, p. 259).

2. Methods

2.1. Survey design

We analyze data from a web-based survey that assesses Canadian citizens' response to new mobility innovations. The survey takes approximately 40 minutes to complete and consists of the following sections: (a) vehicle ownership details; (b) respondent travel patterns; (c) new mobility innovation awareness, familiarity, adoption, and interest; (d) perceptions of ride-hailing, carsharing, fully automated vehicles, and battery electric vehicles; (e) automobility engagement scale and response to new mobility policies; (f) respondent details (e.g., demographics).

In this paper, we analyze (i) an automobility engagement scale and (ii) stated interest in shared, automated, and electric mobility. The automobility engagement scale is a 40-item scale that investigates constructs in consumer perceptions of and engagement with aspects of automobility, following the framework described in Section 1.1 (Table 1). Some scale items are original, while others are adapted from Nazari et al. (2018), Steg (2005), and von Behren et al. (2018). Respondents were asked to indicate their level of agreement with each scale item on a Likert-type scale where response categories ranged from 1 ("strongly disagree") to 5 ("strongly agree") with an option for "I don't know/Not applicable". Because of the context of COVID-19 at the time of survey implementation (June 2020), we asked respondents to answer automobility engagement questions considering their travel patterns and preferences "once social distancing measures are fully removed".

We assessed interest in shared, automated, and electric mobility using Likert-type scales where response categories were presented as follows: 1 ("not at all interested"), 2 ("somewhat interested"), 3 ("moderately interested"), and 4 ("very interested"), with an option for "I don't know". We provided brief descriptions of each innovation to familiarize respondents with innovations before assessing respondent interest. For shared mobility, we assessed interest in using or continuing to use (i) ride-hailing and (ii) carsharing. For automated mobility, we assessed interest in purchasing or leasing (i) a fully automated vehicle (FAV) that can be driven in automated mode or as a conventional vehicle (i.e., with a steering wheel) and (ii) a FAV that can only be driven in automated mode (i.e., without a steering wheel). We further assessed interest in (iii) using a "shared FAV", described as a fully automated Uber/Lyft car with no driver present. For electric mobility, we assessed interest in purchasing or leasing (i) a battery electric vehicle (BEV) and (ii) a plug-in hybrid electric vehicle (PHEV).

We further assessed "car use frequency", which is included as a control variable in our regression analyses (see Section 2.3). For this variable, we asked respondents how frequently they used their household vehicle in a typical week (including weekends) in February 2020, before social distancing measures were set. The response categories were 1 ("never"), 2 ("about once a month"), 3 ("about once a week"), 4 ("2–3 times a week"), 5 ("4–5 times a week"), and 6 ("once a day or more"). For the regression analyses, we coded car use frequency as a dummy variable with two categories – "about once a month or less" and "about once a week or more".

2.2. Data collection

The survey was implemented in June 2020 to a sample of Canadians at least 19 years old or older, with oversamples of Metro Vancouver, Greater Toronto Area, and Montreal Metro Area to allow for regional comparisons (which are not the focus here). Within each metro region, respondents were equally sampled from four levels of urbanization, which are characterized by their population density as well as the primary mode for commuting to work: active cores, transit suburbs, near auto suburbs, and far auto suburbs regions (following Gordon and Janzen, 2013). Active cores are areas where a higher proportion of residents use active transport (walking or cycling) to commute to work. Transit suburbs are areas where a higher proportion of residents commute by transit. Auto suburbs comprise areas in which most residents commute by car, where population densities of at least 150 people/km2 or more are classified as near auto suburbs, and lower population density regions are defined as far auto suburbs.

For descriptive analyses, we apply three levels of corrective weights to mitigate any biases introduced by the urbanization level sampling, the metro area oversamples, and any residual regional oversamples. We calculate weights by comparing population proportions from each urbanization level, metro area, and region to respective survey proportions. We use corrective weights to examine descriptive statistics for interest in new mobility innovations and agreement with automobility engagement scale items, presented in Sections 3.2 and 3.3. We performed all other analyses without the use of corrective weights.

A market research company recruited the sample. Respondents who completed the full survey received an incentive of CAD $4.50. We received 3,762 complete responses and removed 94 due to low quality. The realized sample was of 3,658 respondents, of which: 993 from Metro Vancouver, 794 from the Greater Toronto Area, 819 from the Montreal Metropolitan Area, and 1052 from the rest of Canada. We compare sociodemographic data for the total sample (weighted) with 2016 Canadian Census data (Table 2). The weighted sample is representative of the Canadian population in age, gender, and provincial distribution. Compared to the Canadian population, the weighted sample has higher education levels and slightly higher household income levels.

2.3. Data analysis

We performed all data analyses using IBM SPSS statistical software (Versions 25 and 27). We first conduct an exploratory factor analysis of the automobility engagement scale items. Factor analysis is a method that reduces observable variables to a smaller number of latent variables (factors) which share a common variance and can represent the larger number of observable variables (Yong and Pearce, 2013). Here, we analyze whether the observable variables (scale items) can be reduced to the hypothesized automobility engagement constructs (shown in Table 1). We used principal axis factoring as the extraction method and direct oblimin (oblique) rotation. We use oblique rotation to explore correlations between the resulting factors (Rummel, 1967), as we did not expect the factors to necessarily be mutually exclusive. We selected the factor solution aiming to (i) maximize factor interpretability, (ii) maximize factor loading strength, and (iii) reduce the number of items that cross-load, show consistently low factor loadings, and have low correlation coefficients (Costello and Osborne, 2005).

Second, we examine descriptive statistics for interest in ride-hailing, carsharing, FAVs with and without a steering wheel, shared FAVs, BEVs, and PHEVs. We then proceed to explore descriptive statistics for the automobility engagement scale items, organized according to the factor analysis solution. In these analyses we apply the corrective weights described in Section 2.2.

Third, we perform multivariable ordinal logistic regressions. More specifically, we use the proportional odds model, which is the default method for ordinal regression analysis in SPSS. This model estimates the probability of being at or below a particular level of a dependent variable and assumes that the effect of each independent variable is the same across the categories of the ordinal dependent variable (Liu and Koirala, 2012).

We begin by investigating the association between the resulting factors (independent variables) and one of the scale items as a

Table 2
Demographic characteristics of survey sample (weighted) and Canadian Census (2016).

	Canada sample (total, weighted)	Canada population (2016 Census)
Size (n)	3,658	27,711,720 (aged 19 +)
Age		
19–24	9%	10%
25–34	17%	17%
35–44	17%	16%
45–54	18%	18%
55–64	18%	18%
65+	22%	21%
Education		
High school education or less	18%	41%
Apprenticeship, trades certificate or diploma	5%	10%
College, CEGEP or other non-university diploma	22%	21%
University below bachelor level	7%	3%
Bachelor's degree	27%	16%
Graduate or professional degree	22%	8%
Income (pre-tax)		
<$40,000	19%	26%
$40,000-$59,999	16%	16%
$60,000-$89,999	23%	20%
$90,000-$124,999	22%	16%
$125,000+	21%	22%
Gender		
Male	48%	49%
Female	51%	51%
Provincial distribution		
British Columbia	14%	13%
Alberta	12%	12%
Prairies (Manitoba and Saskatchewan)	7%	7%
Ontario	38%	38%
Quebec	23%	23%
Maritimes	7%	7%
Territories	0.3%	0.3%

2016 Canadian Census data available from: https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang = E.

dependent variable, specifically "Owning a car is important to me" (item 1 from Table 1). We use this item as an indicator of consumer engagement with automobility. As car ownership represents one of the core aspects of automobility, exploring whether automobility engagement factors predict car ownership importance can indicate whether the resulting factors are indeed assessing automobility engagement. This also serves as a "conventional mobility" baseline before applying the factors to the more novel cases of interest in shared, automated, and electric mobility. We then use ordinal logistic regressions to examine the potential of the resulting factors to explain interest in shared, automated, and electric mobility.

We control the ordinal logistic regressions for the following variables:

1. Sociodemographic characteristics, where age and income are treated as continuous variables. Education and gender are treated as dummy variables.
2. Urbanization levels (i.e., active core, transit suburbs, and near and far auto suburbs), treated as dummy variables, where respondents that were not sampled from the metro regions (i.e., "rest of Canada") form the base.
3. Travel patterns, which we measure in terms of "car use frequency". Car use frequency refers to how frequently the respondent uses their household vehicle in a typical week, as described in Section 2.1. This variable is treated as a dummy variable with two categories – "about once a month or less" and "about once a week or more".

3. Results

3.1. Identifying automobility engagement factors with factor analysis

We conducted exploratory factor analysis of the automobility engagement scale described in Section 2.1. Kaiser-Meyer-Olkin measure of sampling adequacy (0.88) and Bartlett's Test of Sphericity ($p < 0.01$) indicated that the data is suitable for factor analysis (Kaiser, 1974; Tabachnick, 2013). As noted in Section 2.3, we removed one of the scale items (item 1 from Table 1) from the factor analysis and used it as a dependent variable. We then proceeded to analyze multiple factor solutions to remove items consistently loading below 0.32 and/or showing communalities below 0.2 (Costello and Osborne, 2005; Tabachnick, 2013; Yong and Pearce, 2013). Initial factor analyses showed that four scale items did not load well onto any factors; these items were removed from the analysis (items 3, 4, 5, and 37 from Table 1). We then proceeded to perform factor analyses iteratively and remove problematic items one by one. Through this process, we further removed items 2, 17, 30, and 38 (Table 1), which showed low factor loadings or led to less interpretable solutions.

After removing these items, we found that a 7-factor solution was the most interpretable. Table 3 depicts the 7-factor solution. Two of the included items are reverse coded. We highlight the highest factor score for each item, indicating the factor that item most strongly loads onto. We display factor eigenvalues for the rotated solution. We also indicate Cronbach's alpha values as a measure of factor internal consistency. We calculated Cronbach's alpha values according to the scale items that are highlighted in Table 3 (i.e., based on the highest factor score for each scale item). Items that load negatively onto the factors were reverse coded for the purposes of calculating Cronbach's alpha.

We summarize the resulting factors (capitalized):

- Factor 1 represents "Perceived Car Dependence", or perceptions of car needs for daily and social practices.
- Factor 2 represents "Car Identity"– i.e., that car ownership is associated with one's self-identity, status image, and emotions.
- Factor 3 represents "Driving Aversion" – items that indicate a negative feeling towards driving load positively onto this factor, while items that indicate a positive feeling towards driving load negatively.
- Factor 4 indicates a "Societal Concern" for car use impacts, such as air pollution.
- Factor 5 indicates "Non-Car Travel Norms" in social circles, referring to active travel, transit use, and car use reduction behaviors being typical in one's social circle.
- Factor 6 represents a "House Ownership Preference" and preference for suburban living.
- Factor 7 indicates an "Accessibility Preference", meaning a preference for residential areas that are walkable and provide access to public transit.

Table 4 shows the bivariate Pearson Correlations for the resulting factors. Factor analysis and Pearson Correlations results indicate that there are significant correlations between factors, corroborating the use of oblique rotation. The highest positive correlation is that between Perceived Car Dependence and House Ownership Preference (0.546), which may suggest a shared link with suburban living. The highest negative correlation is that between Car Identity and Driving Aversion (-0.308), suggesting that Car Identity may be associated with positive driving emotions.

3.2. Response to shared, automated, and electric mobility

We describe responses regarding interest in shared, automated, and electric mobility. Fig. 1 shows the percentage of Canadians that reported being moderately or very interested in each innovation. For shared mobility, interest in ride-hailing (26%) is higher than interest in carsharing (13%). For automated mobility, interest in FAVs *with* a steering wheel (34%) is higher than interest in FAVs *without* a steering wheel (20%) as well as shared FAVs (19%). For electric mobility, interest in BEVs (32%) is not significantly different than interest in PHEVs (32%) at a 95% confidence interval.

Table 3
Exploratory factor analysis of automobility engagement scale (only shows factor loadings above 0.32, scale items abbreviated, n = 3,658). Column headings present resulting factors. Reverse coded items indicated as (reversed).

Survey items	Perceived Car Dependence	Car Identity	Driving Aversion	Societal Concern	Non-Car Travel Norms	House Ownership Preference	Accessibility Preference
I need a car to fulfill my everyday obligations.	0.797						
I need a car for my job.	0.625						
It is easy to plan my day without a car. (reversed)	0.498						
Sometimes I feel too dependent on my car.	0.490						
In my area, every household needs a car.	0.486						
It is difficult for me to access my friends and family without a car.	0.474						
I want my car to represent my personality.		0.777					
Owning a car shows that I am successful.		0.673					
I often feel emotionally connected to cars.		0.657					
You can learn a lot about someone by looking at their car.		0.582					
A car is just a way to get around and nothing more. (reversed)		0.487					
Buying a car is an important milestone in life.		0.431					
I often talk about cars with my friends.		0.411					
I enjoy driving.			−0.817				
The idea of driving makes me tired.			0.720				
I feel in control when I am driving.			−0.681				
Driving is stressful.			0.628				
Driving makes me feel free.			−0.627				
Being inside a car feels like a safe, protected space.			−0.430				
Car use is causing climate change.				0.835			
Air pollution from cars is a serious problem.				0.833			
Cars, streets and parking take away too much public space.				0.463			
Overall, car use is good for society.				−0.383			
Many of my friends commonly walk or bike to get around.					0.636		
Many of my friends are trying to reduce their car use.					0.603		
I know a lot of people that use public transit.					0.415		0.360
My ideal situation is to live in a private, detached home.						0.705	
It is important for me to own my home.						0.498	
I prefer to live away from urban centers.						0.467	−0.327
It is important for me to live in a place where I can easily access transit.							0.670
It is important that I live in a neighbourhood where I can walk to destinations.							0.592
Factor number	1	2	3	4	5	6	7
Eigenvalue	3.482	3.432	3.690	2.690	2.131	2.305	2.365
Cronbach's alpha	0.792	0.802	0.826	0.726	0.710	0.593	0.723

Table 4
Bivariate Pearson Correlations between factors derived from factor analysis. Correlation significance (2-tailed) is indicated as **p < 0.01, *p < 0.05.

	Perceived Car Dependence	Car Identity	Driving Aversion	Societal Concern	Non-Car Travel Norms	House Ownership Preference	Accessibility Preference
Perceived Car Dependence	1	0.374**	−0.217**	−0.167**	−0.186**	0.546**	−0.291**
Car Identity	0.374**	1	−0.308**	−0.155**	0.061**	0.369**	0.074**
Driving Aversion	−0.217**	−0.308**	1	0.284**	0.277**	−0.224**	0.202**
Societal Concern	−0.167**	−0.155**	0.284**	1	0.340**	−0.094**	0.419**
Non-Car Travel Norms	−0.186**	0.061**	0.277**	0.340**	1	−0.130**	0.469**
House Ownership Preference	0.546**	0.369**	−0.224**	−0.094**	−0.130**	1	−0.168**
Accessibility Preference	−0.291**	0.074**	0.202**	0.419**	0.469**	−0.168**	1

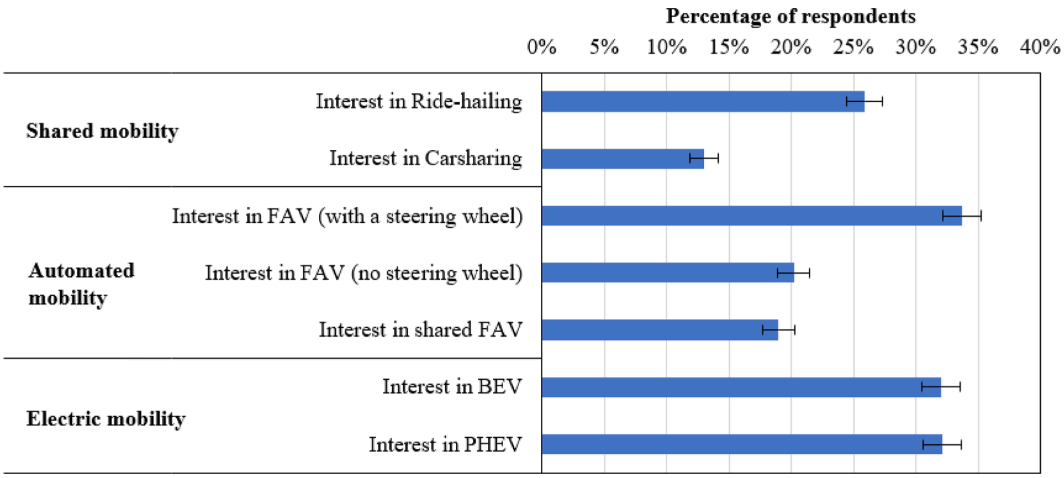

Fig. 1. Percentage of respondents that are "moderately interested" or "very interested" in innovations (full sample, n = 3,658, weighted). Error bars represent 95% confidence intervals.

3.3. Response to automobility engagement scale items

We now describe responses to automobility engagement scale items (Fig. 2). "Agreement" with scale items refers to "somewhat agree" and "strongly agree" responses to the items. We organize responses by resulting factors.

1. Perceived Car Dependence: most Canadians show that they are dependent on a car for aspects of their daily lives, with 60% agreeing that "I need a car to fulfil my everyday obligations". Canadians seem particularly dependent on cars for socialization, as 68% agree that "It is difficult for me to access my friends and family without a car".
2. Car Identity: only 28% agree that "Owning a car shows that I am successful". It could be that the image of success is linked to owning a certain type of car and not to owning a car in general (Gatersleben, 2011). However, 61% of Canadians agree that "Buying a car is an important milestone in life", suggesting that the car may continue to carry meaningful symbols – for example, Böhm et al. (2006) discuss the car as a symbol of entering adulthood.
3. Driving Aversion: most Canadians show positive feelings towards driving, as indicated by a 70% agreement with "I enjoy driving". At the same time, 40% agree that "Driving is stressful".
4. Societal Concern: most Canadians indicate a concern about negative societal impacts of car use – 76% agree that "Air pollution from cars is a serious problem" and 67% agree that "Car use is causing climate change".
5. Non-Car Travel Norms: walking, biking, and car use reduction do not seem to be common travel behaviors in most Canadians' social circles, although public transit seems more commonly used (53% agreement). This may suggest that most Canadians are part of car-centered social circles.
6. House Ownership Preference: results indicate a strong preference for house and property ownership in general – 67% agree with "My ideal situation is to live in a private, detached home", and 73% with "It is important for me to own my home".
7. Accessibility Preference: most Canadians prefer to live in a walkable neighborhood (62% agreement).

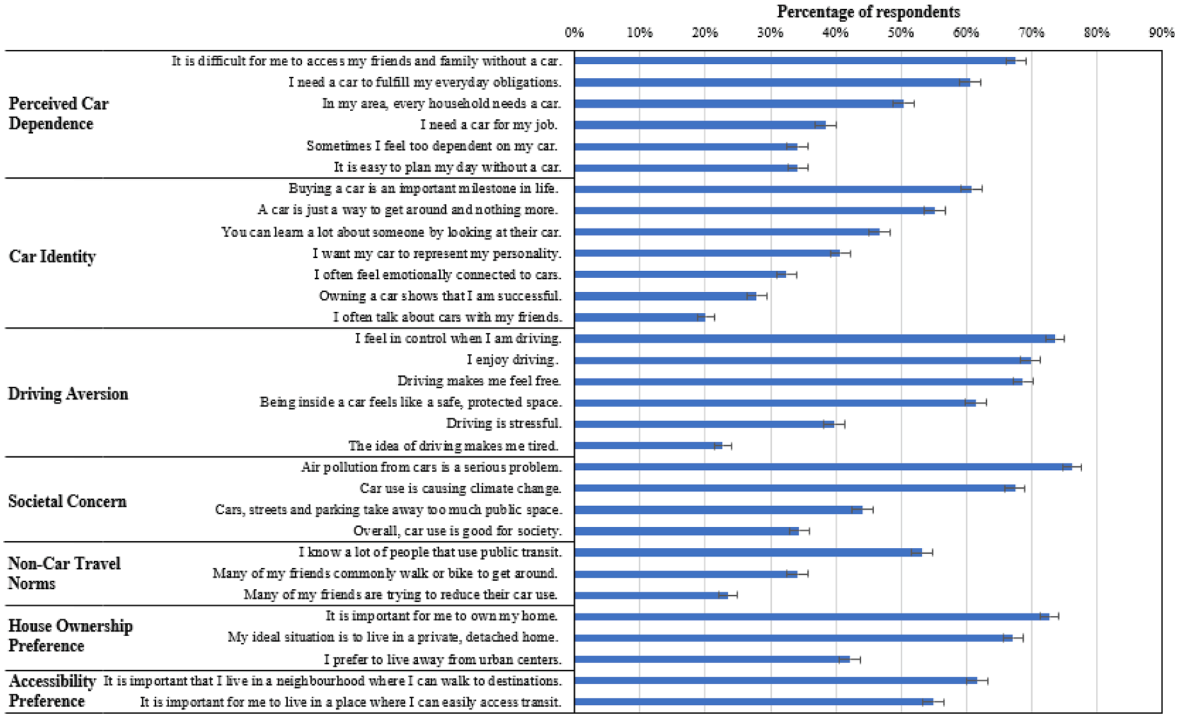

Fig. 2. Percentage of respondents that "somewhat agree" or "strongly agree" with scale items corresponding to automobility engagement factors. Scale items are shown in abbreviated version (full sample, n = 3,658, weighted). No items are reversed. Error bars represent 95% confidence intervals.

3.4. Predicting car ownership importance and interest in shared, automated, and electric mobility

We then used ordinal logistic regressions to investigate the potential of resulting factors to predict (i) a dependent variable which we name "car ownership importance" (scale item 1 from Table 1) and (ii) interest in shared, automated, and electric mobility. As independent variables, we include sociodemographic characteristics, urbanization levels, travel patterns, and automobility engagement factors (where factor scores were saved as variables). Pearson Correlation coefficients between independent variables (<0.8), Variance Inflation Factor (<5), and Condition Index (<15) values showed no indication of multicollinearity in the model (Shrestha, 2020).

We find that the final models significantly predict the dependent variables above the intercept-only models (p = <0.001). Pearson and Deviance Chi-Square indices test the null hypothesis that the observed data is consistent with the fitted model. Deviance values suggest a good model fit for all final models, whereas Pearson values suggest a poor model fit for the models predicting car ownership importance and interest in FAVs without a steering wheel (Table 5). We also report Nagelkerke's Pseudo R Square index (Table 5), which has been found to most closely approximate ordinary least-squares regression estimates of R Square (Smith and McKenna, 2012).

Table 5 presents unstandardized coefficients (*B*) and odds ratio (OR) for the independent variables. Unstandardized coefficients represent an expected change in log odds of the dependent variable for a one unit increase in a continuous independent variable, or for a change between response categories for categorical independent variables. The OR indicates the change in odds of the dependent variable outcome being above each response category cut point (i.e., from "not at all interested" to "somewhat interested") per unit increase in a continuous independent variable, or per change in response category for categorical independent variables (e.g., dummy variables) (Szumilas, 2010).

In this text summary, we highlight the coefficients that are significant at a 95% confidence level or higher, placing special focus on stronger predictors in terms of the magnitude of coefficients. We begin by describing results pertaining to automobility engagement factors, which is followed by a description of control variable results. We find a Pseudo R Square (Nagelkerke) value of 0.500 for the final model predicting car ownership importance. Perceived Car Dependence and Driving Aversion are the strongest predictors of car ownership importance, among automobility engagement factors. Perceived Car Dependence, Car Identity, and House Ownership Preference are positively associated with car ownership importance. Driving Aversion, Societal Concern, and Non-Car Travel Norms are negatively associated with car ownership importance.

Pseudo R Square (Nagelkerke) values for interest in new mobility innovations range from 0.133 to 0.200. Perceived Car Dependence significantly predicts interest in all innovations but carsharing and PHEVs. Car Identity significantly predicts interest in ride-hailing as well as privately-owned and shared FAVs. Driving Aversion is positively associated with interest in privately-owned

Table 5
Predicting car ownership importance and interest in shared, automated, and electric mobility by using multivariable ordinal logistic regressions (n = 3,658). Column headings depict the dependent variables. We present unstandardized coefficients (*B*, **p < 0.01, *p < 0.05) and odds ratio (OR) for the independent variables.

	Car ownership importance		Ride-hailing interest		Carsharing interest		FAV interest (with steering wheel)		FAV interest (no steering wheel)		Shared FAV interest		BEV interest		PHEV interest	
	B	**OR**	***B***	**OR**	***B***	**OR**	***B***	**OR**	***B***	**OR**	***B***	**OR**	***B***	**OR**	***B***	**OR**
Sociodemographics																
Education *(Dummy, 1 = Bachelor's diploma or above)*	−0.033	0.967	0.194**	1.214	0.343**	1.410	0.172**	1.187	0.198**	1.219	0.321**	1.378	0.206**	1.229	0.176**	1.192
Age *(continuous)*	0.009**	1.009	−0.035**	0.965	−0.028**	0.972	−0.031**	0.970	−0.027**	0.973	−0.039**	0.962	−0.033**	0.968	−0.029**	0.972
Income *(continuous)*	−0.002	0.998	0.006**	1.006	0.000	1.000	0.006**	1.006	0.003**	1.003	0.004**	1.004	0.004**	1.004	0.003**	1.003
Gender *(Dummy, 1 = female)*	0.469**	1.599	−0.040	0.960	−0.352**	0.703	−0.406**	0.666	−0.516**	0.597	−0.546**	0.579	−0.531**	0.588	−0.231**	0.794
Urbanization levels *(Dummy, base = rest of Canada)*																
Active core	0.171	1.186	0.318**	1.374	0.713**	2.040	0.190	1.209	0.147	1.158	0.285*	1.330	0.231*	1.260	0.245*	1.278
Transit suburb	0.026	1.026	0.152	1.165	0.354**	1.425	0.139	1.149	0.161	1.175	0.178	1.194	0.440**	1.553	0.329**	1.390
Near auto suburb	−0.099	0.906	0.087	1.091	0.260*	1.297	0.143	1.153	0.240*	1.271	0.098	1.103	0.375**	1.455	0.302**	1.353
Far auto suburb	−0.255*	0.775	0.160	1.173	0.081	1.085	0.057	1.058	0.140	1.150	−0.038	0.962	0.357**	1.429	0.262**	1.299
Travel patterns																
Car use frequency *(Dummy, 1= "once a week or more")*	1.005**	2.732	−0.180*	0.835	−0.068	0.934	0.238**	1.269	0.105	1.111	0.037	1.038	0.410**	1.506	0.584**	1.792
Automobility engagement *(continuous, 1–5)*																
Perceived Car Dependence	0.763**	2.145	0.113*	1.119	0.033	1.033	0.127**	1.135	0.156**	1.168	0.239**	1.270	0.168**	1.183	0.088	1.092
Car Identity	0.381**	1.463	0.237**	1.268	0.010	1.010	0.226**	1.254	0.220**	1.246	0.299**	1.349	0.003	1.003	−0.001	0.999
Driving Aversion	−0.838**	0.433	−0.018	0.982	0.010	1.010	−0.049	0.952	0.190**	1.209	0.185**	1.203	−0.083*	0.920	−0.093*	0.911
Societal Concern	−0.161**	0.851	−0.085*	0.918	0.082	1.085	0.254**	1.289	0.172**	1.188	0.162**	1.176	0.455**	1.577	0.338**	1.402
Non-Car Travel Norms	−0.475**	0.622	0.208**	1.231	0.563**	1.756	0.034	1.034	0.175**	1.192	0.224**	1.251	0.209**	1.233	0.218**	1.243
House Ownership Preference	0.385**	1.470	−0.180**	0.835	−0.181**	0.834	0.118*	1.126	0.081	1.084	−0.061	0.941	0.171**	1.187	0.203**	1.225
Accessibility Preference	−0.028	0.973	0.293**	1.341	0.178**	1.195	0.057	1.059	0.036	1.037	0.045	1.046	−0.064	0.938	−0.056	0.946
Model summary																
Nagelkerke R^2	0.500		0.179		0.200		0.154		0.133		0.189		0.184		0.141	
−2 Log Likelihood	$p = 0.000$		$p = <0.001$		$p = <0.001$		$p = <0.001$		$p = <0.001$		$p = <0.001$		$p = <0.001$		$p = <0.001$	
Pearson	$p = <0.001$		$p = 0.599$		$p = 0.891$		$p = 0.483$		$p = 0.005$		$p = 0.279$		$p = 0.334$		$p = 0.200$	
Deviance	$p = 1.000$		$p = 1.000$		$p = 1.000$		$p = 1.000$		$p = 1.000$		$p = 1.000$		$p = 1.000$		$p = 1.000$	

FAVs without a steering wheel (i.e., that can only drive in automated mode) and shared FAVs, but not in FAVs with a steering wheel. Societal Concern is positively associated with interest in FAVs (privately-owned and shared), BEVs, and PHEVs, and negatively associated with interest in ride-hailing. Societal Concern most strongly predicts interest in BEVs. Non-Car Travel Norms significantly predict interest in all innovations but FAVs with a steering wheel and are most strongly associated with interest in carsharing. House Ownership Preference is positively associated with interest in privately-owned FAVs with a steering wheel, BEVs, and PHEVs and negatively associated with interest in ride-hailing and carsharing. Accessibility Preference significantly predicts interest in ride-hailing and carsharing only.

We now discuss the results pertaining to our control variables. For sociodemographic characteristics, we find that having a Bachelor's diploma or higher is associated with an increase in the odds of being interested in all studied innovations. Conversely, an increase in age (expressed in years) is associated with a decrease in the odds of being interested in all innovations. An increase in income (expressed in thousands of dollars) is linked to increased odds of being interested in all innovations but carsharing, where the association was not significant at a 95% confidence level. Female gender is associated with a lower odd of being interested in the innovations relative to male gender, where all associations were significant at a 95% confidence level except for ride-hailing interest.

Regarding urbanization levels, living in an active core significantly predicts interest in all innovations but privately-owned FAVs. Living in an active core is a particularly strong predictor of interest in carsharing. The results indicate that interest in BEVs and PHEVs is associated with living in different types of suburbs.

Using a household vehicle once a week or more (i.e., car use frequency) is associated with an increased odd of perceiving car ownership as important and of being interested in privately-owned FAVs with a steering wheel, BEVs, and PHEVs. This level of car use frequency is further linked to a decreased odd of being interested in ride-hailing.

4. Discussion

Shared, automated, and electric mobility could significantly reduce GHG emissions from passenger transportation, if deployed as a shared fleet of electric FAVs (Greenblatt and Saxena, 2015; Sperling, 2018; Viegas et al., 2016; Wadud et al., 2016). However, studies indicate that positive impacts of full automation are partially contingent on diverging from current patterns related to private car ownership and fossil fuel use (Fagnant and Kockelman, 2015; Wadud et al., 2016), which may be resistant to change. These patterns are characteristic of the incumbent system of "automobility", where the privately-owned car prevails as the main transport mode in industrialized societies (Beckmann, 2001; Urry, 2004). We develop a conceptual framework that explores consumer perceptions of and engagement with aspects of automobility, which we term "automobility engagement". We identify seven potential constructs of consumer automobility engagement drawing on a literature search of sociological studies on automobility theory and consumer perspectives of car ownership and use. Based on this framework, we construct a 40-item "automobility engagement" scale, which was implemented in June 2020. We analyze data from a survey of 3,658 Canadian respondents to explore automobility engagement and its relationship with consumer interest in shared, automated, and electric mobility.

First, we find that five of our literature-informed constructs of automobility engagement can be identified through exploratory factor analysis, resulting in five automobility engagement factors (capitalized). Factor 1, Perceived Car Dependence, is identical to our conceptualized construct and items, referring to a subjective measure of car dependence (Beckmann, 2001; Mattioli et al., 2020; Urry, 2004). Factor 2, Car Identity, is also identical to the proposed construct in meaning, referring to self-identity and status expression through car ownership (Dittmar, 1992; Steg, 2005; Urry, 2004), but includes one additional item (item 34 from Table 1). Factor 3, Driving Aversion, includes all items related to driving emotions (Sheller, 2004; Steg, 2005), where items describing positive emotions load negatively onto the factor. Factor 4, Societal Concern, refers to perceived negative impacts of car use, indicating an overall perception that car use is socially harmful. Factor 5, Non-Car Travel Norms, is mostly similar to the proposed social norms construct, referring to descriptive norms of travel behavior in social circles (Cialdini et al., 1990; Gardner and Abraham, 2010). Items depicting active travel, transit use, and car use reduction behaviors loaded onto the factor, while items depicting car-based norms did not – hence, we name this factor "Non-Car" Travel Norms.

The remaining two factors represent subconstructs within the proposed residential preferences construct. Factors 6, House Ownership Preference, and 7, Accessibility Preference, indicate that residential preferences for house ownership are not necessarily associated with residential preferences for living in a neighborhood that provides access to transit and destinations – although both factors are to some degree associated with a general preference for or against urban living. Literature on residential preferences confirms that housing preferences and accessibility preferences comprise distinct components of residential preferences and motives for residential location choice (Cao, 2008; Ge and Hokao, 2006; Luckey et al., 2018; Yan, 2020; Zondag and Pieters, 2005). We could not identify our proposed car ownership preferences construct through factor analysis – results suggested that items regarding a preference for car ownership and items depicting openness to sharing cars are not correlated with each other. We removed these items from the factor analysis (items 1 to 5 from Table 1).

Second, we conduct ordinal logistic regressions to analyze the predictive power of automobility engagement factors to explain perceptions of "car ownership importance", which we use as an indicator of consumer engagement with automobility. We generally find that our resulting factors are predictive of car ownership importance. Perceived Car Dependence is especially strongly associated with car ownership importance, which supports claims of a structural dependence on automobiles prompting the prevalence of car ownership in industrialized societies (Urry, 2004; Beckmann, 2001; Böhm et al., 2006). Car Identity is predictive of car ownership importance, indicating that the use of cars to express self-identity and status relates to the perception of car ownership as important. Driving Aversion is strongly negatively associated with car ownership importance, suggesting that driving emotions are related to the perceived importance of car ownership, in addition to constituting motives for car use (Steg, 2005) and predictors of car use intention

(Stradling et al., 2000). Therefore, there seems to be a relevant emotional component to how consumers engage with automobility. Further, we find that Non-Car Travel Norms are negatively associated with car ownership importance. Thus, this study indicates that being situated in social circles where travel behaviors deviate from car use could lead to lower perceived importance of car ownership. In a similar vein, Haustein et al. (2009) find that socialization significantly affects car use norms and habit.

Third, we discuss ordinal regression results for predicting consumer interest in shared, automated, and electric mobility. Perceived Car Dependence significantly predicts interest in all innovations but carsharing and PHEVs, suggesting that consumers who perceive themselves as being car dependent are more likely to be interested in ride-hailing, FAVs, and BEVs. Interestingly, this applies also to some forms of shared mobility, such as ride-hailing and shared FAVs. These results suggest that adoption of ride-hailing and shared FAVs may complement or reproduce car-dependent engagement with automobility.

Results suggest that consumers with higher levels of Car Identity are more likely to be interested in FAVs. Thus, privately-owned as well as shared FAVs may appeal to consumers that entertain the car as a status symbol and a means for identity expression. Early research into symbolic perceptions of FAVs suggests that this innovation may be associated with status symbols (Acheampong and Cugurullo, 2019) and with expressing a "hi-tech" image (Pettersson and Karlsson, 2015, p. 696). Sovacool and Axsen (2018) similarly analyze that FAVs could maintain or even strengthen certain frames of automobility.

Driving Aversion is positively associated with interest in FAVs without a steering wheel and shared FAVs, indicating that there may be an untapped market for driverless vehicles stemming from consumers that hold negative feelings towards driving. This hints that also these consumers hold positive views of mobility by cars. An implication of these results is that FAVs could indeed help expand car use to consumer segments that cannot or prefer not to drive, as suggested by various studies (Fagnant and Kockelman, 2015; Harper et al., 2016; Milakis, 2019; Milakis et al., 2017; Wadud et al., 2016).

Our study suggests that consumers who have a Societal Concern for car use impacts are more likely to be interested in FAVs (privately-owned and shared), BEVs, and PHEVs – this indicates that the potential for these innovations to lower impacts relative to conventional vehicles may be one of the reasons behind consumer interest (Axsen and Sovacool, 2019; Axsen et al., 2012; Berliner et al., 2019; Spurlock et al., 2019). Overall, these results suggest that consumers may perceive privately-owned automated and electric mobility as an opportunity to reform automobility into a lower impact system, albeit one that may still be based on car ownership and use – as Kester et al. (2020, p. 4) describe it, an opportunity to provoke a transformation *within* but not *of* automobility.

Our results further point to a significant role of Non-Car Travel Norms in consumer interest in new mobility – Non-Car Travel Norms are associated with interest in all innovations but FAVs with a steering wheel. Hence, being situated in social circles where travel behaviors generally deviate from private car use (e.g., active travel and transit use) may be linked to a greater openness to shared, automated, and electric mobility. We conclude that descriptive norms of travel potentially affect new mobility perceptions and that more research is needed to investigate the nature of this relationship. The extent to which descriptive norms of travel influence new mobility perceptions may depend on the specific innovation. For example, our results indicate that Non-Car Travel Norms are most strongly associated with interest in carsharing, which echoes Burghard and Dütschke's (2019) finding that social norms significantly predict attitudes towards carsharing.

We note that House Ownership Preference is positively associated with interest in most studied forms of *private* mobility and negatively associated with forms of *shared* mobility (i.e., ride-hailing and carsharing interest). We thus consider that a latent preference for private ownership may underlie our results – however, more data would be needed to substantiate this claim. In addition to being associated with House Ownership Preference, we find that interest in BEVs and PHEVs is also linked to living in suburban regions. Hence, interest in electric mobility seems to be currently tied to a pattern of suburban living.

For shared mobility in specific, we find that interest in ride-hailing and carsharing is linked to living in active core regions and to an Accessibility Preference, or preference for neighborhoods that are walkable and provide access to transit and destinations. These findings indicate that the consumer market for shared mobility may choose to live in active core regions to engage in active travel and transit use – in other words, that residential self-selection may mediate the link between active core regions and shared mobility interest.

Results pertaining to socioeconomic and demographic variables are consistent with literature reviews indicating that higher education, younger age, higher income, and male gender are generally associated with interest in new mobility innovations (Axsen and Sovacool, 2019; Becker and Axhausen, 2017; Li et al., 2017; Nordhoff et al., 2019). The automobility system and its self-reinforced patterns of car dependence have unequal social impacts, where lower-income households and the elderly comprise some of the population segments that can suffer from accessibility challenges, such as lower access to car ownership and use and peripheral residential locations (Mattioli, 2014). The fact that these population segments are less likely to be interested in new mobility innovations raises questions about these innovations' potential accessibility benefits (Milakis and van Wee, 2020).

5. Conclusions

We conclude that an increased understanding of consumer engagement with automobility can help to explain consumer response to various new mobility innovations. Overall, results indicate that consumer interest in carsharing is less associated with ingrained patterns of private car dependence and urban sprawl, relative to consumer interest in privately-owned fully automated vehicles and electric vehicles. Similarly, Kent and Dowling (2013) explore carsharing as a potentially automobility-challenging practice. Results regarding other forms of shared mobility, more specifically ride-hailing and shared FAVs, are less conclusive and suggest that consumers interested in these innovations may be dependent upon and symbolically invested in private cars.

Our study provides only limited evidence of consumer engagement with aspects of automobility – still, our findings suggest that a certain degree of caution may be warranted when estimating the climate mitigation potential of shared, automated, and electric mobility. More specifically, our results suggest that consumer interest in privately-owned as well as shared FAV modes may be linked to consumer patterns of dependence on private cars and perceptions of the car as a status and identity symbol (Beckmann, 2001; Steg, 2005; Urry, 2004). Thus, studies based on assumptions that shared FAVs replace private car use may overestimate this innovation's potential to mitigate GHG emissions.

We also highlight potential implications related to Non-Car Travel Norms. In our study, these social norms of active travel, transit use, and car use reduction both decrease the odds of perceiving car ownership as important as well as increase the odds of interest in shared, automated, and electric mobility. Thus, we conclude that transport policies that promote increased uptake of active travel and public transit may be associated with such co-benefits – for example, of challenging perceptions of automobility and encouraging consumer openness to various new mobility innovations.

We acknowledge that the context of the global COVID −19 pandemic constitutes a limitation for our study and may have had an influence on results. Shamshiripour et al. (2020)'s survey of Chicago metropolitan area respondents finds that perceived risk of traveling during the COVID-19 pandemic is significantly higher for ride-hailing and other shared mobility services (e.g., pooled ride-hailing, bike-sharing) relative to using a personal vehicle. Similarly, the pandemic and associated health risks of shared travel could have affected responses to automobility engagement factors that include items on transit use and access, such as Non-Car Travel Norms and Accessibility Preference. Conversely, Perceived Car Dependence may have increased for segments of the population that have access to a personal vehicle and are concerned about shared modes of travel.

It is important to note that this study does not examine the potential for shared, automated, and electric mobility to be adopted in conjunction, which may enhance their societal benefits and lead to different relationships with automobility engagement (Sperling, 2018). This is a theme that requires more exploration in future studies. Future research would also benefit from qualitative studies, which would provide respondents with the opportunity to indicate additional constructs that may be significant in their engagement with automobility but have not been explored in the literature so far. Further, this study did not explore constructs specific to car drivers in their automobility engagement, where studies targeting car drivers could explore constructs such as car use habits (Schwanen et al., 2012) and the car-driver hybrid (Sheller, 2007; Urry, 2004).

CRediT authorship contribution statement

Viviane H. Gauer: Conceptualization, Data curation, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Jonn Axsen:** Conceptualization, Supervision, Funding acquisition, Methodology, Formal analysis, Writing – review & editing. **Elisabeth Dütschke:** Supervision, Methodology, Writing – review & editing. **Zoe Long:** Data curation, Funding acquisition, Project administration, Writing – review & editing.

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.

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Glossary

ACES: Autonomous, Connected, Electric, and Shared mobility
BEV: Battery electric vehicle
FAV: Fully automated vehicle
GHG: Greenhouse gas
PEV: Plug-in electric vehicle
PHEV: Plug-in hybrid electric vehicle
OR: Odds ratio