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Zero-Emission Vehicle Exposure within U.S. Carsharing Fleets and Impacts on Sentiment Toward Electric-Drive Vehicles

Abstract

Reducing carbon emissions from the United States (U.S.) transportation sector has emerged as a priority action to combat climate change. Carsharing and zero-emission vehicles (ZEVs) could be integral to creating a more sustainable transportation system. This paper presents the results of a study that evaluated the impacts of ZEV exposure on U.S. carsharing users. Surveys were administered to control and experimental groups of carsharing members that used shared PHEVs or EVs. Results showed that users who drove shared PHEVs or EVs more frequently were more likely to exhibit improved ZEV opinions. The population of respondents that used shared EVs and PHEVs were also more likely to recommend that others try driving a ZEV. The results suggest that exposure to PHEVs or EVs through carsharing increased a user's reported likeliness to purchase a ZEV in the future. The experimental group, who employed shared PHEVs or EVs, was more likely to indicate that their next vehicle purchase will be a PHEV or EV than the control group. Collectively, the results suggest that temporary exposure to ZEVs through carsharing improves perceptions that may lead to an expanded ZEV market share.

Keywords

Carsharing; zero-emission vehicles (ZEVs); electric vehicles (EVs); plug-in electric vehicles (PHEVs); purchasing behavior; market barriers

I. Introduction

Zero-emission vehicles (ZEVs) are a growing segment of the automotive market. However, despite falling battery costs and optimistic electric vehicle (EV) market projections, ZEVs currently comprise a small fraction – about 1% – of vehicle purchases in the United States (U.S.). In California, where aggressive ZEV production and use has been incentivized through policy and regulations, ZEVs and gasoline-electric hybrid vehicles comprise about 5% of vehicles owned (Klippenstein, 2017).

In recent years, automakers have announced ambitious targets to produce higher ZEV volumes. Energy science and policy experts credit California as a leader in statewide ZEV adoption due to the California ZEV mandate, adopted in 1990, which was aimed at increasing the sale and dissemination of low-emission vehicles or ZEVs within the California automotive market. The mandate defines the minimum percentage of ZEVs that an automaker must sell. From 2001 to 2018, in an attempt to accelerate the exposure of ZEVs to the general population, additional credits were allotted to automakers in return for placing them into transportation networks, such as carsharing fleets (i.e., short-term vehicle access). Through the ZEV mandate and Executive Order B-48-18, the state aims to deploy five million ZEVs by 2030 and achieve 50% ZEV auto sales by 2035. Executive Order B-48-18 also targets installing 200 hydrogen fueling stations and 250,000 EV chargers statewide by 2025.

At present, the federal government is challenging these measures. Uncertainty in the national landscape emphasizes the need to develop ZEV sale market mechanisms, which can function in the absence of federal legislation (Abuelsamid, 2018). To date, nine states have signed a memorandum of understanding (MOU), the "Multi-State ZEV MOU," demonstrating commitment to collectively having at least 3.3 million ZEVs operating on their roadways by 2025. Individual states are responsible for their respective implementation, but they are following California's lead by requiring automakers to produce ZEVs. The nine states are: California, Connecticut, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont (Center for Climate and Energy Solutions, 2019). In the Multi-State ZEV

Action Plan, action numbers 4 and 5 state goals include ZEVs in public and private vehicle fleets (ZEV Program Implementation Task Force, 2014).

In the 1990s, EVs were a key strategic part of station-based carsharing programs in the U.S. and elsewhere. It was commonly held that EVs were uniquely suited for roundtrip carsharing fleets given their shorter trips and dedicated parking infrastructure. However, high purchase costs of early EVs, compounded by variable reliability and operational costs, led to the closure of many EV carsharing services by the early 2000s (Shaheen et al., 2015). Although EV use in carsharing fleets declined in favor of gasoline-electric hybrid vehicles in the early- to mid-2000s, improved technology and favorable policy has led to an emerging resurgence of EVs in shared mobility services (Shaheen et al., 2012). For example, in the early-2000s, the California Air Resources Board (CARB) recognized the potential for carsharing fleets to act as accelerators for ZEV adoption, creating additional ZEV credits for these vehicles through the California ZEV mandate in 2001. The motivations behind this decision included increasing user exposure to a wide range of alternate fuel vehicles, capitalizing on the short carsharing trip distances that make ZEV use ideal, and linking carsharing to public transit stations (Shaheen et al., 2002). The credits ended in 2018.

On-demand shared ride services, such as transportation network companies (TNCs, also known as ridesourcing and ridehailing), are shifting toward EVs. About one percent of total TNC vehicle miles/kilometers traveled were in EVs by Fall 2017 (George and Zafar, 2018). Although TNCs are taking steps toward reducing their carbon footprint through awareness and educational campaigns (Uber) and carbon offset projects (Lyft), debates exist about the effectiveness of these actions in contrast to shared EV fleets (Jochem, 2018). Furthermore, in 2018, SB 1014 (Clean Miles Standard and Incentive Program) was passed in California. This legislation mandates that CARB establish a baseline metric for relative passenger-mile greenhouse gas (GHG) emissions from vehicles used on TNC platforms by January 1, 2020. The baseline year is 2018. By January 1, 2021, CARB must adopt and the California Public Utilities Commission (CPUC) must implement annual targets and goals starting in 2023 for GHG emission reduction from every TNC company. This legislation also provides credits for bikesharing and scooter sharing trips. TNCs must develop and execute GHG emission reduction plans by January 1, 2022 and every two years after. User exposure to ZEVs through shared mobility vehicle fleets, like carsharing and TNCs, may reduce a number of adoption barriers.

To better understand how ZEV exposure in casharing fleets impacts consumer perceptions, we analyze nationwide survey data from members of: 1) car2go; 2) DriveNow (branding at the time of the survey, which changed to ReachNow in Spring 2016); 3) eGo CarShare; and 4) Zipcar. It is important to note that Daimler (car2go) and BMW (ReachNow) merged their carsharing businesses to form one company, Share Now, in mid-2019 (Mooney, 2019). Each of the four carsharing companies had a portion of ZEVs in its shared fleet at the time of the survey. We collaborated with the operators to deploy two member surveys between November 2014 and February 2015. We distributed one survey to a control group, comprised of active carsharing members who did *not* use a plug-in hybrid EV (PHEV) or EV in the carsharing fleet vehicle. The experimental group, defined as members who had used a PHEV or EV through their carsharing provider at least once in the past six months, received the other survey. For each operator, the control group and experimental group had access to the same carsharing fleet. We analyzed a total of 1,920 responses from the experimental group and 1,742 responses from the control group. In the sections that follow, we review previous work focused on ZEV adoption barriers and purchasing behavior. We provide a methodological overview and discuss the data applied to this study, followed by the study results. We conclude with a summary of key findings.

II. Background

There are a number of ZEV adoption barriers. Challenges include increasing consumer awareness of incentives and addressing existing ZEV purchasing biases. In addition to consumers, carsharing operators face logistical and operational challenges to the integration of ZEVs into their shared fleets. In this section, we review: 1) ZEV costs and pricing, 2) range constraints and operations, and 3) demographics and ZEV purchasing behavior.

Costs and Pricing

Soulopoulos (2017) projected that manufacturing battery electric vehicles (BEVs) will cost up to one quarter more than manufacturing internal combustion engines (ICEs) until 2020. According to this analysis, BEVs and ICEs will reach price parity in 2025, at the earliest. However, it has been suggested that carsharing operators that manage their own vehicle fleets could help to spur ZEV demand, increasing the pace of ZEV and ICE price parity through economies of scale (Greene, Park & Liu, 2014). Multiple studies have also addressed concerns over higher upfront BEV purchasing costs, pointing to lower operating costs in the long run (Dijk, Orsato & Kemp, 2013; Greene, Park & Liu, 2014). Diminishing battery costs are also making upfront ZEV prices more competitive, since battery costs have dropped more than 70% per kilowatt hour in six years (Union of Concerned Scientists, 2018). Recent ZEV price analysis shows EV costs dropping below the price of conventional vehicles by 2027, with the lowest range EVs reaching price parity in 2024. Buyers will also experience increased cost competitiveness due to reduced fuel costs, as well as purchasing incentives (Lutsey & Nicholas, 2019).

In the U.S., monetary ZEV consumer purchase incentives take a variety of forms including: purchase rebates, registration tax benefits, or ownership tax benefits. Non-financial incentives include free parking and bus lane use (Kim, Lee & Lee, 2017). However, misconceptions and misinformation about PHEVs and EVs exist among the U.S. population, which hinder the role of purchasing incentives to increase technology adoption rates (Carley et al., 2013). Researchers have explored consumers awareness of purchasing incentives. Carley et al. (2013) found that only 5% of the population in the largest 21 U.S. cities are aware of BEV incentives. Less than 35% of California households are aware of EV purchasing incentives (Jin & Slowik, 2017). While financial incentives and tax rebates encourage EV adoption, low fossil fuel (gasoline and diesel) prices may counteract those mechanisms (Rezvani, Jansson & Bodin, 2015). Rezvani et al. (2015) noted that frequent policy changes can create consumer uncertainty. Finally, recent literature has noted that incentives may be unsustainable at the scale needed to spur ZEV adoption to reach international climate change mitigation goals (Cano et al., 2018).

Range Constraints and Operations

Berkeley et al. (2017) produced a review of non-monetary barriers inhibiting widespread EV adoption. They found that consumers remain concerned about the practicalities of BEV operations, especially with respect to where and how to charge, despite policies that offer reduced rates or free charging. Kim et al. (2017) reviewed recent research on adoption barriers. They found that the relatively insignificant EV market share is partially due to limited driving range. Battery range concerns may be rooted in technology misconceptions about reliability (Berkeley et. al, 2017; Jin & Slowik, 2017). While these barriers inhibit personal ZEV ownership, range constraints and battery limitation perceptions may not drastically affect shorter-distance trips in urban and suburban contexts. For example, many carsharing services are deployed in urban areas where vehicles are driven for shorter distances (Dijk, Orsato & Kemp, 2013). Early carsharing research highlighted the potential for BEV use in shared fleets, as trip distances in and around cities tend to be within BEV range constraints.

Demographics and ZEV Purchasing Behavior

Overall, studies present contradictory findings with respect to demographic factors that correlate with the likelihood to try and/or purchase a ZEV. Egbue and Long (2012) found that attitudes toward EVs differ across gender, income, and educational divides. For example, males were found to be more familiar with EVs and less likely to have safety concerns than females. Carley et al. (2013) surveyed people in late-2011 and found higher educated, younger, and male respondents were more interested in purchasing PHEVs. However, Zoepf (2015) found a weak effect between gender and technology affinity, noting that women were slightly more favorable to the technology. Interestingly, Javid and Nejat (2017) found no distinctions among males and females or among younger and older vehicle buyers. The effect of household income on PHEV adoption has also been debated (Carley et al., 2013; Searle et al., 2016; Javid and Nejat, 2017). Carley et al. (2013) observed that income was not related to PHEV purchasing intent in their survey analysis. However, Searle et al. (2016) found that median income in a city was significantly correlated to increased EV uptake through a multivariate regression analysis. Javid and Nejat (2017) conducted a regression analysis on the 2012 Household Travel Survey dataset and found household income was significantly correlated with plug-in electric vehicle adoption.

Although the first hybrid vehicle models appeared in the market in the late-1990s, lack of vehicle choice (e.g., limited ZEV models) may also impact ZEV consumer purchasing demand (Greene et al., 2014; Kim, Lee & Lee, 2017; Singer, 2016). Interestingly, Singer (2016) found that 48% of survey respondents could name a PHEV make and model in a 2016 National Renewable Energy Laboratory benchmark report of 1,015 consumers. This analysis revealed that 52% and 45% of respondents considered PHEVs and BEVs, respectively, to be just as good or better than traditional ICEs. Further, 24% and 20% of respondents expected to buy or were considering a PHEV or BEV purchase, respectively. Singer (2016) concluded that understanding how ZEVs can reduce environmental impacts and increase fuel savings influenced respondent ZEV opinions. In contrast, Berkeley et al. (2017) questioned whether heightened environmental awareness leads to confidence in BEV emission reduction potential. They suggest that consumers with a high level of awareness could also be skeptical about the cleanliness of the electricity grid. Rezvani et al. (2015) noted debates in the literature regarding how environmental attitudes affect ZEV adoption and cited a gap between an individual's stated values and ultimate purchasing behavior.

ZEV exposure through shared fleets may elevate consumer awareness and lead to future EV ownership (Jin & Slowik, 2017). In an analysis of Zipcar's ZEV fleets, Zoepf (2015) found that 3.3% of Zipcar survey respondents had driven a Zipcar PHEV, compared with 2.9% who had driven a PHEV outside of carsharing. At the time, 10% of the Zipcar fleet was comprised of PHEV or hybrid vehicles (Zoepf, 2015). Searle et al. (2016) found that outreach was significantly correlated with EV sales in a city. They classified carsharing as one type of outreach approach (Searle, Pavlenko & Lutsey, 2016). Javid and Nejat (2017) found that carsharing membership was significantly correlated with PHEV adoption across California counties, although only 1.1% of the study population were carsharing members. Green et al. (2014) found that ZEV experience can also help consumers acknowledge and reconcile cost barriers. However, Zoepf (2015) noted that carsharing operators control how ZEVs and ICEs are priced, making it more challenging to understand ZEV price sensitivity in shared fleets. This is important, since consumers may lack the basic knowledge needed to calculate total ICE costs and EV payback time (Rezvani, Jansson & Bodin, 2015).

Our study builds upon this literature in several ways. Zoepf (2015) describes carsharing as a low-risk environment with "trainability," meaning that there are multiple opportunities for users to experiment with ZEV technology without making a long-term commitment to it. Similarly, as described above, carsharing memberships have been correlated with ZEV uptake in California. This study builds on prior work through a survey of control and experimental carsharing populations. Our survey was conducted with four carsharing operators (including one-way and roundtrip models) and employed carsharing vehicle activity data to filter ZEV exposure among users.

III. Methodological Overview

To investigate how EV exposure within carsharing fleets impacts consumer EV perceptions, we administered a survey to members of four carsharing companies who deployed PHEVs and/or EVs within their fleets. The surveys were distributed between November 2014 and February 2015 to members of: car2go, DriveNow, eGo CarShare, and Zipcar. Two of the companies – car2go and DriveNow (which became ReachNow in Spring 2016) – operated one-way carsharing fleets. As noted earlier, car2go and ReachNow merged into one carsharing service, Share Now, in mid-2019. Through one-way carsharing, fleet vehicles can be unlocked, driven, and parked anywhere within a defined service area. At the time of the survey, DriveNow deployed a fleet that was exclusively EV-based in the San Francisco Bay Area. Car2go operated a dedicated EV fleet in San Diego and mixed fleets in Portland and Austin, all of which were surveyed. By contrast, Zipcar and eGo CarShare are roundtrip carsharing operators, where members must pick up and drop off a vehicle at the same location. We surveyed Zipcar members in Boston and New York City and eGo CarShare members in Boulder.
Table 1 below provides a summary of the surveyed carsharing operator locations and fleet types.

Table 1. Surveyed Carsharing Operators

Operator	Carsharing Service Type	Cities Surveyed	Fleet Type
Car2go	One-way	San Diego	Full EV
		Portland	Mixed Fleet
		Austin	Mixed Fleet
DriveNow (later called ReachNow)	One-way	San Francisco Bay Area	Full EV
Zipcar	Roundtrip	Boston	Mixed Fleet
		New York City	Mixed Fleet
eGo CarShare	Roundtrip	Boulder	Mixed Fleet

We deployed one control survey and one experimental survey to members across the carsharing companies. Carsharing operators identified which members had driven a PHEV or EV in their carsharing fleet by referencing their activity data. Activity data included user information linked to vehicle reservation information. The operators referenced activity data on user reservations over the 18 months prior to the survey launch. Further, operators analyzed these data to identify which users drove a PHEV or EV more or less frequently than once a month. Both the control and experimental group members had access to PHEVs and EVs through their respective carsharing fleets. Members in the control group had used the carsharing service in the 18 months prior to the survey but had *not* used a shared PHEV or EV in the fleet. The experimental group included members who had used a PHEV or EV through their carsharing program within six months prior to the survey. The survey aimed to capture distinctions in transportation behavior, choice making, and perception as a result of using a shared PHEV or EV. Table 2 below summarizes the control and experimental survey method.

Table 2. Survey Method

	Experimental Survey	Control Survey
Definition of Survey Population	Used a PHEV or EV in the six months before the survey launch date	No PHEV or EV use in the 18 months before the survey launch date
Date Launched	Nov 7, 2014	Dec 4, 2014
Date Closed	Feb 15, 2015	Feb 18, 2015
Total Completions	1,920	1,742
Completion Rate	74%	77%

We administered the control group survey to all operators except eGo CarShare, since they had recently distributed a similar member survey. As an incentive to complete the survey, we placed respondents into a drawing for 25, $50 Amazon gift cards per survey.

The study contained a few limitations that are inherent with this type of survey design. The limitations include self-selection bias and self-reporting. Self-selection bias is a challenge with all surveys in that respondents must consent to being surveyed and provide requested information. Self-reporting is also an inherent bias to this and similar surveys because respondents must self-report their reaction and change in EV perception due to exposure. While these limitations impact the generalizability of the results to the general population, they reflect those common in surveys of focused populations. Survey incentives can help to reduce self-selection bias.

IV. Results

The survey results generally reveal that EV exposure among the experimental population improved respondent perceptions relative to the control population. Of the 1,921 experimental population respondents, a majority (78%) confirmed their EV exposure as either a driver or passenger through a carsharing program. About one quarter (25%) had also been exposed to PHEVs through a carsharing fleet.
Table 3 below shows the percentage of respondents that owned EVs or PHEVs within each survey population.

Table 3. PHEV/EV Ownership Rates Among Respondents

	"Yes" Response (%)		**"No" Response (%)**	
	Experiment (N = 1149)	Control (N = 1171)	Experiment (N = 1147)	Control (N = 1176)
Is at least one of the vehicles you own all-electric (EV)?	4%	2%	96%	98%
Is at least one of the vehicles you own a plug-in hybrid vehicle (PHEV)?	2%	2%	98%	98%

Of the survey respondents that owned a personal vehicle, 96% to 98% did not own a PHEV or EV. The rates of PHEV and EV ownership were almost equally low among the experimental and control respondents. While the low rates of ZEV ownership were not surprising among respondents, they also demonstrate how carsharing fleets could provide exposure and access to PHEVs and EVs to those who would otherwise go without.

As part of the survey, we collected the following respondent demographic attributes: education, ethnicity, income, gender, and age. For education, ethnicity, and income, the distributions of the experimental and control populations were nearly identical. Overall, carsharing members were well educated (i.e., completed a Bachelor's degree at a minimum); 83% of experimental and 85% of control population respondents were working toward or completed an undergraduate or graduate degree. The majority of respondents (77%) were Caucasian. Respondents were middle to higher income; only 12% made less than 25,000 USD annually, and over a quarter in both populations had household incomes over 100,000 USD. The experimental and control population distributions for education, ethnicity, and household income are presented in
Table 4 below.

Table 4. Demographics of Survey Population

Demographic Attributes		Experiment Population (%)*	Control Population (%)	General 2015 U.S. Population (%)
Education	Associate's or less than bachelor's	14	9	70
	Bachelor's (complete/in progress)	50	51	19
	Graduate (complete/in progress)	33	34	11
Ethnicity*	White/Caucasian	75	78	62
	Asian	8	7	5
	Hispanic/Latino	6	7	17
	African American	2	2	12
	American Indian/Alaskan Native	1	0	1
	More than one ethnicity	8	5	3
Household Income	Under 25,000 USD	12	12	23
	25,000 to 49,999 USD	23	23	23
	50,000 to 74,999 USD	17	16	18
	75,000 to 99,999 USD	12	15	12
	100,000 USD and above	28	24	24

**Question format asked respondents to "Select all that apply."*

We also include demographics for the general U.S. population in 2015 in Table 4 for comparison (United States Census Bureau, 2019). As displayed, the survey population underrepresented members with less than a bachelor's degree and overrepresented those with bachelor's or graduate degrees. Our results reflect a more educated population, which may be more aware of transportation's impact on the environment than the general population. This could encourage an increased affinity for ZEVs, if drivers perceive there is a connection between driving ZEVs and lower emissions.

Table 5 below presents the age and gender distribution of the experimental population. Also, in

Table 5 are the gender and age distributions of a May 2013 survey sponsored by the California Air Resources Board (CARB) of PHEV owners. Side-by-side, this compares individuals who used ZEVs in carsharing to PHEV owners.

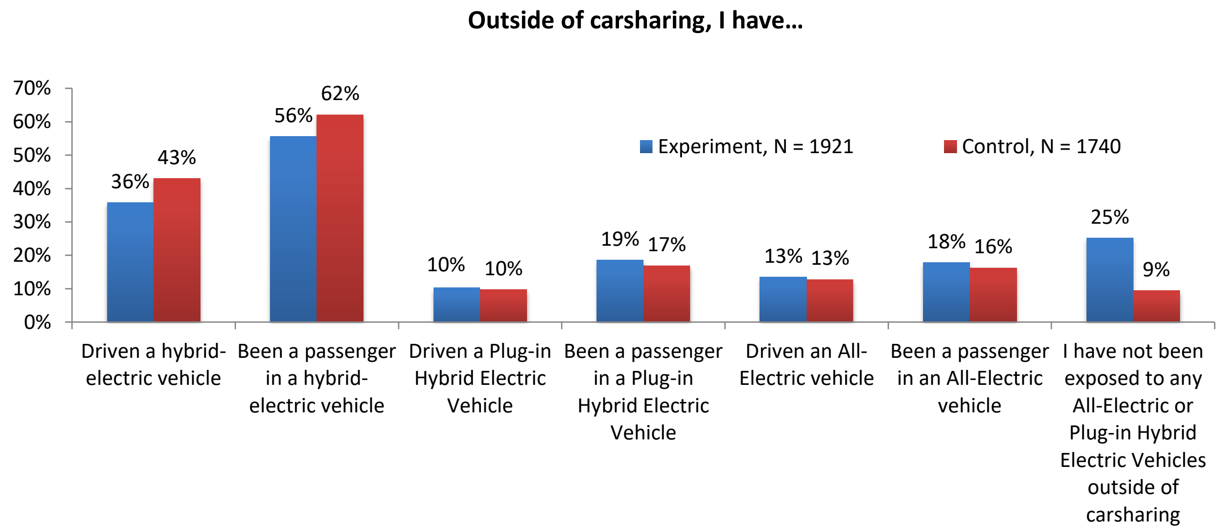
Table 5. Comparison of PHEV/EV Ownership Rates and Carsharing Users

	Respondent Category	CARB 2013 PHEV Owners Survey	2014 to 2015 EV Carsharing Survey Experimental Population
Age	Ages 65 and over	12%	<1%
	Ages 55 to 64	25%	6%
	Ages 45 to 54	34%	12%
	Ages 35 to 44	23%	26%
	Ages 25 to 34	6%	50%
	Ages 18 to 24	<1%	4%
Gender*	Males	79%	59%
Two percent of respondents preferred not to answer	Females	21%	39%

The 2013 CARB survey of PHEV owners found that 79% of respondents were male, and 71% were over the age of 45 (CCSE, 2014). In contrast, the experimental survey of PHEV/EV carsharing users found that only 59% of respondents were male, and 18% were over the age of 45. The experimental respondents exhibited more age and gender diversity in contrast to the PHEV owner population in California. The proportion of females in our experimental survey population was double the proportion of female PHEV owners in California. Members who were exposed to PHEVs and EVs through carsharing were also younger relative to those owning a PHEV. Half of the experimental population (50%) was between the ages of 25 and 34, compared to 6% of the PHEV owner population (CCSE, 2014).

Twenty-five percent of the experimental population had *not* been exposed to PHEVs or EVs outside of carsharing, suggesting that their first and only exposure to those vehicle types was through carsharing. While 75% of the experimental respondents had in some way been exposed to such vehicles, Figure 1 below shows that outside of carsharing use, respondents were more likely to be passengers in these vehicles (e.g., traveling in a friend's car) rather than drivers.

Figure 1. Exposure to PHEVs and EVs Outside of Carsharing



Among the experimental population, only 13% and 10% of respondents had driven an EV or PHEV, respectively, outside of carsharing. A considerably larger share (36%) of experimental respondents had driven a hybrid-electric vehicle.

The control population was defined as respondents who had not recently used PHEVs/EVs in a carsharing fleet despite having access. Our survey sought to inform why this group did not use PHEVs/EVs, even though those vehicle types were available for use in carsharing fleets. This understanding can provide insights into what might inhibit carsharing members from experimenting with shared PHEVs and/or EVs. Figure 2 below provides the breakdown of the reported reasons why respondents in the control population did not use a shared PHEV/EV.

Figure 2. Reasons for Not Using a PHEV or EV

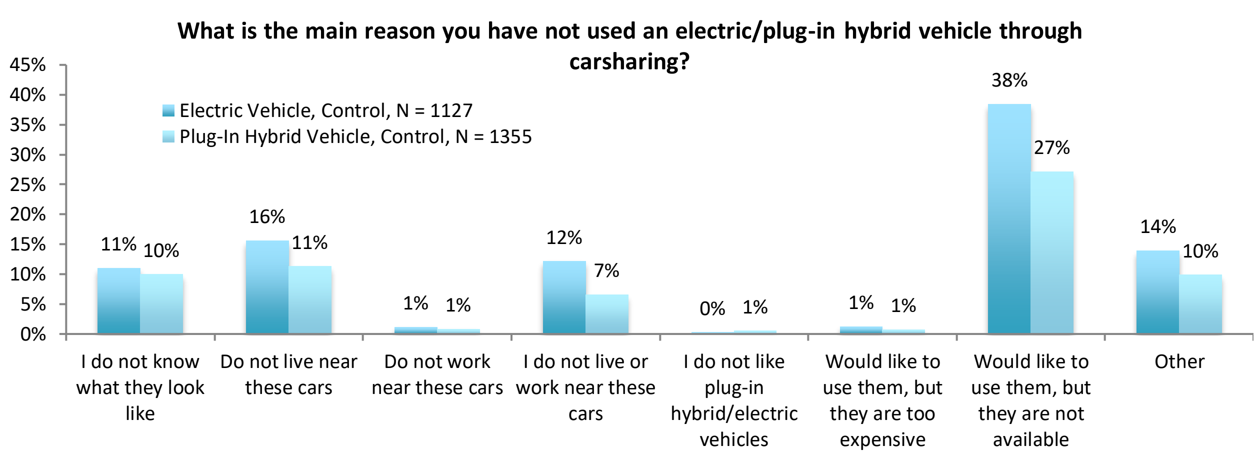


Figure 2 reveals limited availability of PHEVs/EVs accounted for at least 65% of respondents failing to use one of these vehicle types. Vehicle location was also important in enabling PHEV/EV access. Depending on vehicle type, between 7% and 16% of control population respondents reported that their home and work locations were not near PHEV/EV carsharing vehicles.

About one third (33%) of the control population stated that they were unaware that PHEVs were in the fleet. Ten percent did not know what the PHEV vehicles looked like. Four percent had not used EVs because they were unfamiliar with the charging process. One percent noted the battery range was insufficient for their travel needs. Only about 1% of respondents stated that they did not like PHEVs, and none indicated that they did not like EVs.

Additional questions explored whether exposure to PHEVs and EVs in carsharing fleets influenced their future vehicle purchasing behavior. Figure 3 below shows the distribution of responses to a question about the impact of EV exposure on purchasing behavior. This question was only asked of experimental survey respondents, and it evaluates the direction of change in desire to own an EV or PHEV and the cause of that change as a result of carsharing exposure. The activity data revealed that all respondents had some EV exposure, but it was not known whether experimental respondents were also exposed to PHEVs. For this reason, we asked respondents whether they had driven a PHEV through carsharing and the impact of that exposure. This additional filter resulted in different sample sizes for EVs and PHEVs in Figure 3.

Figure 3. Impact of Exposure on Desire to Own EVs/PHEVs

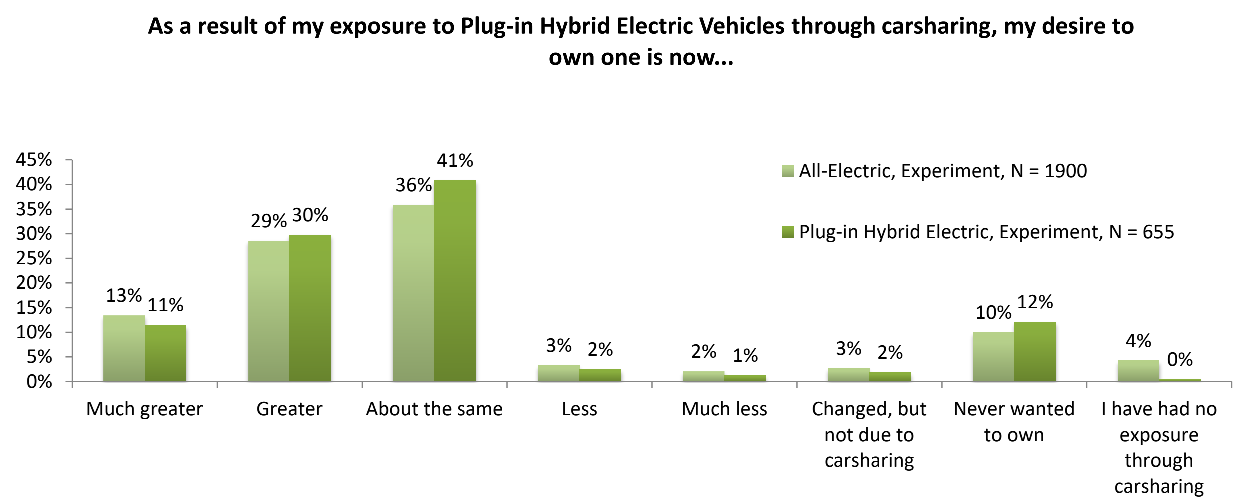
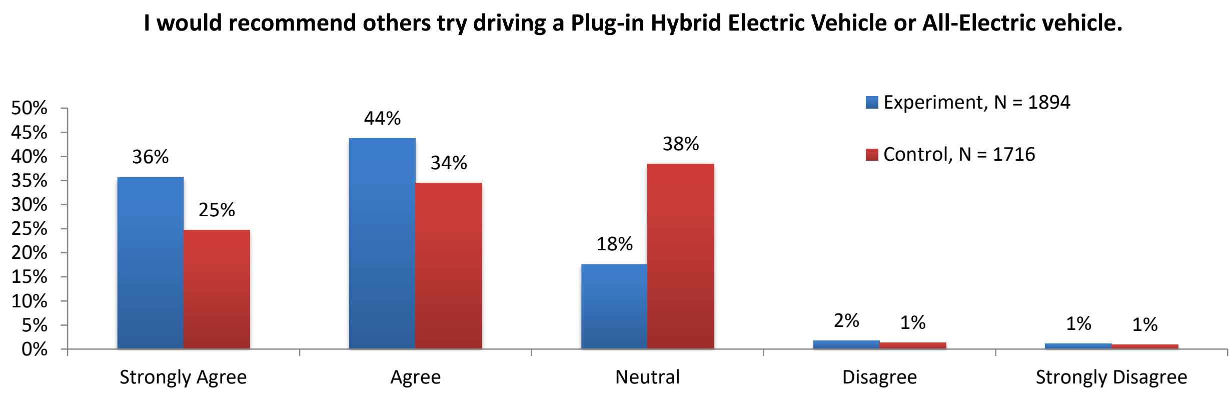


Figure 3 indicates that EV and PHEV exposure *through carsharing* correlates with greater desires to own these vehicle types. For the subset of the experimental population who were exposed to PHEVs through carsharing, 41% exhibited a "greater" or "much greater" desire to own a PHEV in the future. Of the respondents who drove an all-electric vehicle (or EV) through carsharing, 21% stated a "greater" or "much greater" desire to own an EV in the future. An additional question explored the reasons for this change. Responses varied primarily across the following categories: greater driving enjoyment due to vehicle performance, appreciation of emission benefits, and understanding of vehicle range.

About 5% of experimental respondents felt "less" or "much less" inclined to own all-electric vehicles after carsharing use. The two most common reasons cited were concerns regarding vehicle range and not enjoying the experience of driving the vehicle.

We asked additional questions to evaluate the impact of EV exposure on sentiments of the experimental and control populations. Relative to the control survey, the experimental population was more likely to recommend that others try driving an EV/PHEV than the control population. Figure 4 below shows the distribution of responses to this question across both survey populations.

Figure 4. Recommend Driving an EV/PHEV to Others



While small proportions of the experimental and control populations would not recommend trying these vehicle types (3% and 2%, respectively), those who had experienced using them through carsharing fleets were less likely to feel neutral about them. A majority of respondents in both survey populations stated that they would recommend driving a PHEV/EV to others. The key distinction shown in Figure 4 is the greater skew of positive responses to the question in the experimental population relative to the control. This is one comparative piece of evidence that suggests PHEV/EV exposure through carsharing fleets increases positive sentiment toward these vehicle types.

Figure 5 below provides the comparison of responses across the experimental and control population for a similar question probing recommendations for purchasing a PHEV/EV. It shows that 56% of the experimental population would recommend buying a PHEV/EV compared to 47% of the control. As with Figure 4, a majority of respondents in both surveys suggested that they would recommend the purchase of a PHEV/EV to others. But as in the Figure 4, the inclination to make this recommendation is more common among respondents who were exposed to PHEVs/EVs, as indicated in the experimental survey.

Figure 5. Recommend Purchasing an EV/PHEV

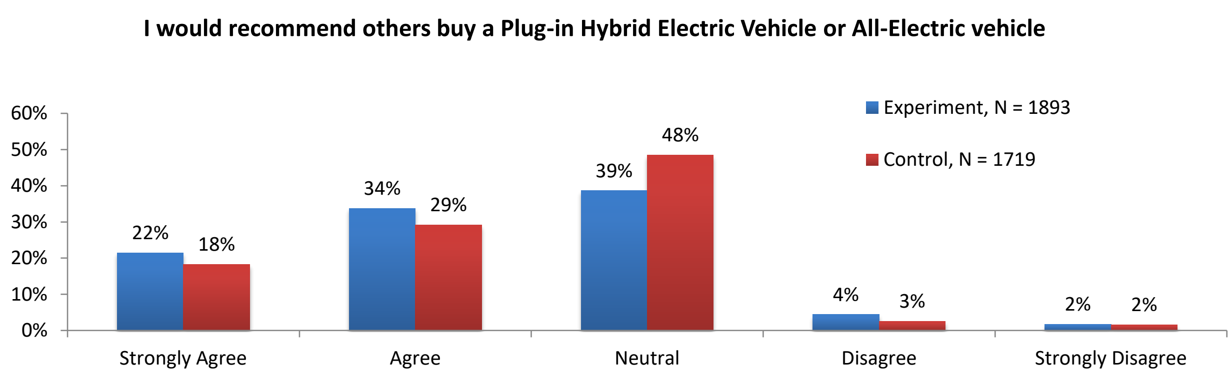


Figure 5 also shows that similar percentages of the control and experimental populations would *not* recommend buying an EV/PHEV. Since 66% of the control population had either driven an EV, PHEV, or other hybrid-electric vehicle outside of a carsharing fleet, these results suggest that few carsharing members had experiences through or outside of carsharing that would *prevent* them from recommending an EV/PHEV purchase to others.

It is important to note that the control population appeared to view PHEVs/EVs favorably even though they had not used these vehicles in carsharing. Indeed, 91% of the control respondents had been exposed to PHEVs/EVs outside of carsharing (e.g., riding in a vehicle with a friend). This result may also be due to the growing acceptance of PHEVs/EVs, especially among individuals who choose to join carsharing programs and may be more open to alternatives to traditional vehicle ownership.

Table 6 and Table 7 show the degree to which carsharing members who used shared EVs/PHEVs at different frequencies changed their opinion about these vehicle types. In the tables below, responses are organized by how frequently respondents indicated using a shared EV/PHEV. Column titles denote the directionality (i.e., improved or worsened) and magnitude of the shifts (e.g., "greatly improved" versus "improved") in respondent opinions.

Table 6. Cross-Tabulation of ZEV Use Frequency with Change in ZEV Opinions

How has your exposure to PHEV/EVs through carsharing changed your opinion of them?								
Type of ZEV	***N***	***Frequency of ZEV use***	***It has greatly improved***	***It has improved***	***My opinion has not changed***	***It has gotten worse***	***It has gotten much worse***	***Not applicable***
PHEV	395	Once a month or less	10%	45%	38%	3%	1%	4%
	87	More than once a month	28%	44%	24%	2%	1%	1%
EV	926	Once a month or less	14%	43%	33%	7%	2%	1%
	568	More than once a month	24%	50%	21%	3%	1%	1%

Table 7. Cross-Tabulation of ZEV Use Frequency with Change in Desire to Own a ZEV

			As a result of my exposure to PHEV/EVs through carsharing, my desire to own a PHEV/EV in the future is now …							
Type of ZEV	*N*	*Frequency of ZEV use*	*Much greater*	*Greater*	*About the same*	*Less*	*Much less*	*Desire has changed, not due to carsharing*	*Did not want to own before or now*	*Have not been exposed through carsharing*
PHEV	282	Once a month or less	10%	29%	42%	2%	1%	3%	11%	1%
	73	More than once a month	18%	40%	29%	3%	0%	1%	10%	0%
EV	924	Once a month or less	12%	29%	36%	5%	3%	4%	10%	1%
	570	More than once a month	20%	35%	31%	2%	1%	2%	9%	1%

Table 6 and Table 7 show that those respondents using PHEVs and EVs more frequently also had an improved opinion of ZEVs, as well as a greater desire to own ZEVs. In Table 6, there is a net positive difference of 16% and 17% toward an improved or greatly improved opinion of PHEVs and EVs, respectively, between lower and higher frequency users. Similarly, Table 7 shows a 19% and 14% increase in those with a greater or much greater desire to own PHEVs and EVs, respectively, between lower and higher frequency users.

As shown in Table 6, of members exposed to PHEVs through carsharing, about the same proportion of respondents who used PHEVs infrequently (45%) and frequently (44%) reported that their vehicle opinions had improved. By contrast, 43% of infrequent EV users stated that their EV opinions had improved, compared to 50% of frequent EV users. EVs thus may be more unfamiliar to users than PHEVs, such that more frequent exposure to them tangibly improves user opinion.

Using shared EVs/PHEVs more frequently was also found to correlate with greater magnitudes of change (i.e., "it has *greatly* improved" versus "it has improved" and "*much* greater" versus "greater") in member opinions and desires to own these vehicle types. When compared to respondents who used PHEVs/EVs once a month or less, more of the respondents who used shared EVs/PHEVs more frequently reported a "much greater" desire to own an EV/PHEV in the future. In Table 7 above, 10% and 12% of the less frequent respondents stated that they had a "much greater" desire to own a PHEV or EV, respectively, compared to 18% and 20% of the more frequent users.

Figure 6 and Figure 7 below indicate that PHEV/EV carsharing exposure also had an impact on vehicle purchasing decisions. Since a carsharing user cannot be identified until they have started a membership through a provider, we asked respondents to retroactively recall their thoughts on their next vehicle purchase before they joined carsharing. We then compared this with their expected next vehicle purchase decision at the time of the survey. Figure 6 shows the type of car that respondents expected to buy *before the survey*, while Figure 7 shows the type of vehicle that respondents next expected to buy *at the time of the survey*.

Figure 6. Vehicle Purchasing Expectations Before Carsharing

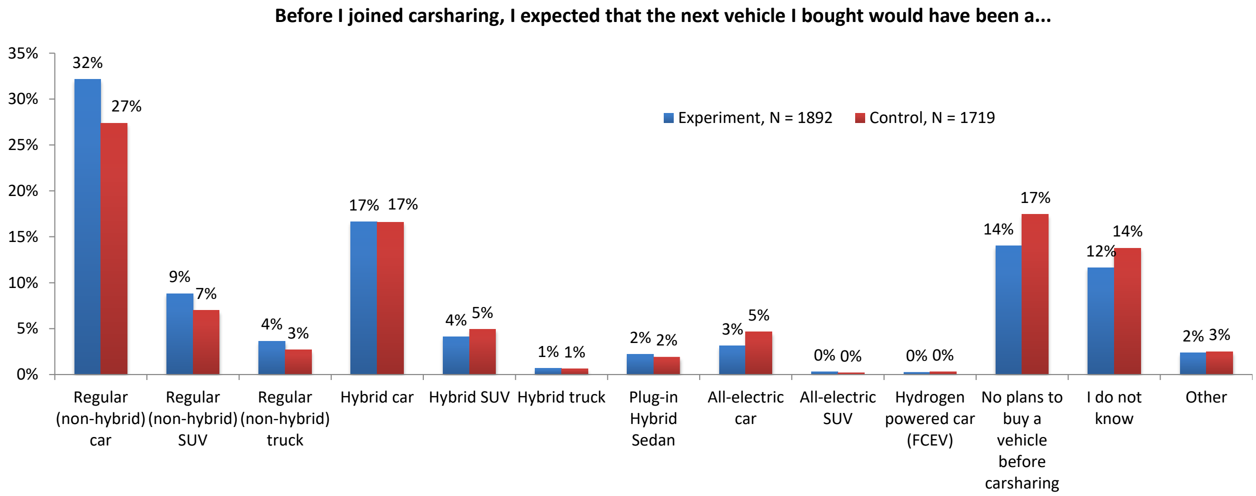


Figure 7. Vehicle Purchasing Expectations After Carsharing

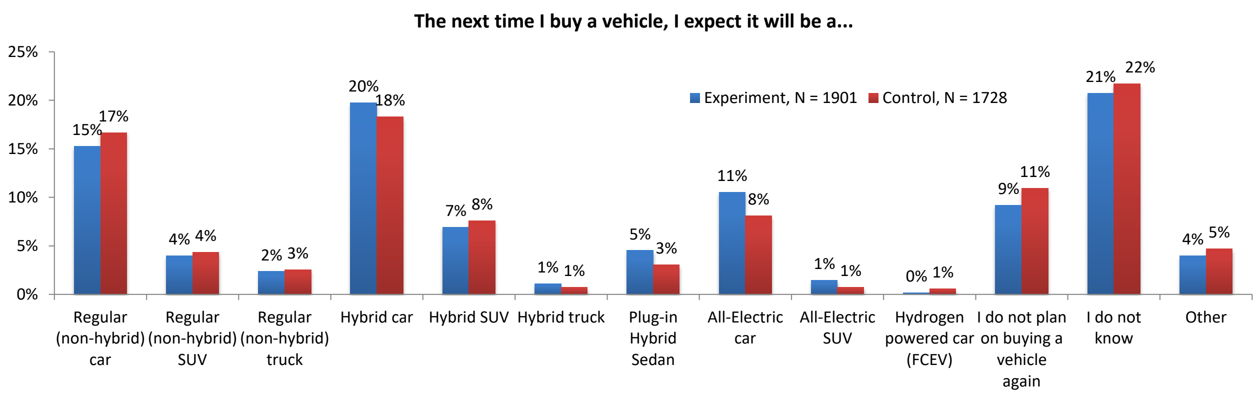


Figure 6 indicates that 5% of the experimental population and 7% of the control expected to buy a PHEV (plug-in hybrid sedan) or EV (all-electric car) before joining carsharing. Figure 7 shows that 17% of the experimental population and 12% of the control expected to buy a PHEV or EV as their next purchase. Thus, the share of the experimental population interested in these vehicles increased by 12 percentage points, while the share of the control only increased by 5 percentage points. Some of this movement in both groups is the result of time, as the market for these vehicles has grown, and ZEV costs have declined. But Figure 6 andFigure 7 show that the experimental population had a slightly lower share of respondents interested in these vehicles before carsharing as compared to the control and a modestly higher share after carsharing exposure. Exposure to PHEVs/EVs in carsharing correlates with a shift toward these vehicle types with respect to planned vehicle purchasing behavior.

V. Conclusion

This study sought to evaluate the degree to which PHEV/ EV exposure through carsharing fleets influenced respondent sentiments toward these vehicle types. In this study, we implemented an experimental and a control survey across multiple carsharing operators and cities. We gave the experimental survey to those members who had used PHEVs or EVs through carsharing within six months prior to our survey implementation, based on their activity data. We gave the control survey to those members who had not recently used (i.e., within 18 months before our survey) these vehicles in a carsharing program, even though they were available in the shared fleets they accessed.

Twenty-five percent of the experimental population had *not* been exposed to PHEVs or EVs outside of carsharing, suggesting that their first and only exposure to those vehicle types was through carsharing. The majority of the control population (65%) indicated that they had not used a PHEV or EV because they were unavailable. This suggests that some members of the control population were interested in using ZEVs, if they were more readily available in shared fleets.

Overall, the results suggest that ZEV exposure through carsharing fleets improves the general sentiment toward these vehicle types. This was demonstrated through questions directly probing this impact among carsharing members in the experimental population and by comparisons of questions answered by the control population. While both groups exhibited neutral to positive attitudes toward ZEVs, the sentiments of the experimental population were generally more positive. Respondents who used ZEVs more frequently (more than once per month) were more likely to indicate that their ZEV opinions *greatly* improved. Greater shares of the experimental population also agreed that they would recommend driving or purchasing ZEVs to others. In contrast, the control group reported neutral responses to these questions.

The comparisons also showed that a greater percentage of respondents exposed to PHEVs/EVs reported that they expected their next expected vehicle purchase to be a ZEV relative to the control population. This comparison suggests that exposure to PHEVs/EVs is influencing the purchasing behavior of some respondents. The survey results also found that increased EV use was correlated with improvements in a desire to own PHEVs/EVs. Those using ZEV vehicles more than once a month (based on carsharing activity data) were more likely to directly attribute an increased desire to own similar vehicles due to their carsharing exposure.

However, as previously mentioned, responses may reflect a self-selection bias. Recent positive experiences may result in impressions that respondents want to convey to researchers, particularly if using an EV or PHEV aligns with their consumer values. Respondents who had positive experiences with these vehicle types may be more likely to predict future desires, despite not knowing their upcoming purchasing decisions with certainty. Our analysis also did not consider respondent price sensitivity and whether this differed across the control and experimental groups.

The study findings suggest that ZEV exposure through carsharing can influence the attitudes of users in favor of these vehicles. These findings suggest that policies that encourage the proliferation of technology and infrastructure in support of ZEVs in shared mobility will have a secondary effect of increasing ZEV acceptance within the vehicle purchasing market. As ZEVs continue to exhibit improved technical performance, consumers exposed to this technology through shared fleets may respond well to these experiences. Given the generally positive results, a key finding of this study is that carsharing can serve as a conduit to increase ZEV exposure, improving sentiment toward these vehicles and potentially accelerating growth in market share.

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