CAVS – USE, SHARE, OWN? YOUNG DRIVER PERCEPTIONS OF CONNECTED AND AUTOMATED VEHICLES

A Thesis
by
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Abstract

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Connected and Automated Vehicles (CAVs) will eventually change the transportation landscape. However, their success and adoption rate depend in part on public opinions of the technology and willingness to opt into the sharing economy. While CAVs have the potential to improve safety and increase access to mobility, the associated costs and timeline of development and deployment of fully automated vehicles are still uncertain. Understanding the public's opinion on the technology is key in understanding its effects on the future of transportation. This study aims to determine whether young people are willing to give up owning conventional personal vehicles in favor of CAVs and in particular, CAV-based shared mobility. With the potential for widespread CAV deployment in the near term, understanding the perspectives of this age group, which represents the largest age group in the US, is imperative for understanding the impacts of CAVs on the mobility landscape. An online survey was distributed through professional networks across the country in early 2020 to gauge comfort levels in riding in CAVs, relying on shared mobility, and owning a CAV. Univariate and bivariate Chi-Squared tests were then performed to test the correlation between explanatory variables and perceptions of CAVs. The responses revealed ambivalence toward CAVs. Significant relationships indicate that gender identity and urbanicity matter when it comes to willingness to use CAVs and shared mobility. Results also show that young adults may not be as ready for CAVs as some have hypothesized. The results of this study help address gaps in CAV perception research and gauges current attitudes of young adults towards a future of transportation that includes connected and automated vehicles.

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1. Introduction

Connected and Automated Vehicles (CAVs) are electric, driverless vehicles that are some of the biggest technological advancements in transportation history. Theoretically, CAVs will be on a connected network that allows them to communicate with other CAVs and the surrounding infrastructure and environment. They will be fully automated, meaning they will not have a driver, and the passenger will be reliant on the technology to get them to their destination. The vehicles will be fully electric and available for on-demand transportation, with two different pathways of use. Some CAVs would be shared, similar to Uber, Lyft, or a traditional taxi, and hailed from a mobility service. There is also the potential for members of the public to own personal CAVs that would use the public network but be privately owned; owners might also add their CAVs to a shared-mobility pool. There are many uncertainties with CAVs as they are currently being tested across the United States. In principle, CAVs have the potential to offer many benefits such as increased mobility, reduced congestion, a decrease in fossil fuel usage, and improved safety. Currently, it remains an active area of debate whether CAVs will reduce congestion. While CAVs may be individually efficient at providing mobility, as well as freeing people from driving tasks and allowing them to use travel time for other purposes, in the aggregate, widespread use of CAVs may increase congestion and vehicle miles traveled (VMT), because of induced demand and 'deadhead' trips with no passengers.

There are currently six defined levels of automation, ranging from no automation (0) to full automation (5) (Sandt and Owens 2017). As automation increases, driver input decreases (Spurlock et al. 2019). We see level one automation currently on the roads with adaptive cruise control, while the driver is still required to steer. Level two to three automation has come onto the market in the last few years with vehicles that automatically brake, accelerate, and can steer themselves to stay in a lane of traffic. The driver still needs to be paying attention to change lanes and respond to errors. Level four automation is a fully automated vehicle that does not require the driver to pay attention and can conduct most driving tasks in most conditions, allowing them to reclaim time as they devote their attention to things other than driving (Spurlock et al. 2019). Finally, we get to level five automation: CAVs on a connected network. Level five automation will be CAVs as described, either a privately owned or shared vehicle on a connected network, moving freely throughout an area. They can perform all driving tasks under any conditions (Sandt and Owens 2017).

Overall, the uncertainty and complexity of the technology make people hesitant to fully embrace the idea of using CAVs for everyday travel (Cepolina and Farina 2013). The implementation of CAVs will depend largely on the public's perceptions of the technology as they are the most important stakeholders in the future of these vehicles (Bansal and Kockelman 2016). Many factors are shaping the perceptions of CAVs, and as more information becomes available about the implementation, we will have a better idea about how citizens will receive the technology. In principle, CAVs could significantly increase mobility for underserved populations and the elderly by eliminating transportation disparities, the idea being that sharing CAVs may eliminate the need to maintain and purchase a personal vehicle, which can be prohibitively expensive. Currently, there is uncertainty about costs associated with fares and insurance, as well as the technology associated with CAVs. Age, income, and proximity to a city are just some of the factors that can affect someone's views on CAVs. Many studies have looked at attitudes towards CAVs.

Though CAVs have the potential to create a safer transportation experience by eliminating human error, they are still not widely accepted, and the industry still has a substantial amount of work, both improving the technology and people's attitudes, to implement CAVs safely and effectively. The objective of this study is to see if young adults would be willing to give up personal vehicles and use CAVs for their everyday transportation needs.

2. Motivation

The hypothesis that young adults will be ready to rely on CAVs and shared mobility for their transportation needs is not thoroughly explored in the body of current research. This study looks at a group that will potentially see CAV implementation in their lifetime. Millennials (born 1981-1996) and Generation Z (born 1997-2012), here on referred to as 'young adults,' are two generations who grew up with the emergence of the internet, cell phones, and even partial vehicle automation. A survey was conducted to gauge young adults' perceptions and comfort levels with CAVs and shared mobility. With almost 75% of the sample being older Generation Z and young Millennials (age 18-24), 'young adults' best describe the sample.

Young adults are commonly assumed to be willing to adopt and rely on CAV technology due to the perception that they are tech-savvy, having grown up during a period of rapid technological advancement (Bansel and Kockelman 2018; Asgari and Jin 2019). Young adults are currently the largest age group alive and have shown measurable differences in travel behavior and vehicle ownership preferences when compared to their parents' and grandparents' generations (Swan 2019).

I conducted a survey of university-affiliated individuals and probed the respondents' willingness to use and rely on CAVs as their main form of transportation. This looks at these young drivers' attitudes and willingness to adopt automated vehicle technology. It is important to know potential adopters' attitudes towards CAVs to better understand what may make people apprehensive towards adopting the technology. It will also give planners insight on the pace of rollout, aiding in anticipating and planning evolving transportation needs. This may inform measures to better adapt the technology to meet the needs of future CAV the emerging technology.

3. Literature Review

New Transportation Revolution

The world is currently on the verge of three different transportation revolutions that will change the way we travel (Fulton et al. 2017). Electrification and automation of vehicles, as well as the advancement of shared mobility, have the potential to change the transportation landscape; CAVs could be the next wave of mobility (Cohen and Kietzmann 2014; Dowling et al.; 2018 Fulton et al. 2017). When deployed, CAVs have the potential to improve road safety and cut carbon emissions, improve congestion, and boost mobility for underserved and elderly communities (Cohen and Kietzmann 2014; Bajpai 2016; Fulton et al. 2017; Lee and Mirman 2018; Whittle et al. 2019; Charness et al. 2018). Though transportation experts and cities are preparing for the introduction of CAVs into current and future infrastructure, their overall success is partially dependent on public opinions of the technology (Bansal and Kockelman 2016). The public's willingness to adopt and use the new technology will be crucial to the rate at which CAVs can be implemented and their overall effectiveness in society. It is entirely possible that CAVs will not live up to their acclaimed potential. It is still unclear whether CAVs will decrease congestion, emissions, and travel times (Metz 2018). Society will not know whether these issues will be relevant until CAVs are on the roads and integrated into the transportation landscape – although researchers can attempt to get a preview of where things may go with carefully designed data collection. There are still many questions that have yet to be answered. It is important that technology is designed to address users' needs, preferences, and comfort and societal needs for things like congestion, mobility, and emissions reduction. With CAVs offering the opportunity to change the transportation landscape, understanding public perceptions is a critical first step that is currently being overlooked, in the implementation of this technology.

Potential Impacts of CAVs

Anticipated Environmental Benefits

Connected and automated vehicles have the potential to bring many benefits to the environment, the roadways, and the individual user. They may improve sustainability by helping reduce emissions and if they adopt electric vehicle technology (Schluter and Weyer 2019).

How it is Achieved

Establishing the use of electric vehicles (EVs) is one pathway to lower emissions and increased sustainability by decreased consumption of fossil fuels (Schluter and Weyer 2019; Whittle et al. 2019). The enterprises developing and promoting CAVs plan to use EV technology in their construction, with the potential to reduce carbon emissions (Fulton et al. 2017). Along with EV technology, CAVs can reduce emissions, congestion, and improve traffic flow by reducing the number of vehicles on the road (Pakusch et al. 2018). Though reducing emissions and congestion, and improving traffic flow are potential benefits to CAVs, there is also research that suggests that CAVs may not be as beneficial as their champions portray them to be, as discussed below.

Threats

While EVs offer a path to more energy-efficient and environmentally preferable transportation, limited knowledge and uncertainty about the technology are barriers to acceptance (Schluter and Weyer 2019). There is also a need to consider the potential negative impacts of CAVs to avoid reckless optimism in the technology (Axsen & Sovacool 2019). Metz (2018) raised the concern that unoccupied CAVs will 'deadhead' (travel empty) until called for a job, causing increased congestion with unoccupied vehicles. There is also the potential for personally owned CAVs congesting the road when not in use (Metz 2018). Further, there is evidence to suggest that there will be no measured impact on emissions due to the entire vehicle fleet moving to electric; this would cause an increase in energy usage which could potentially cause an uptick in emissions depending on the level of automation (Wadud et al. 2016).

Potential Mobility Improvements

One of the many advantages of CAVs is beneficial mobility options for aging and underserved populations (Charness et al. 2018; Lee and Mirman 2018). For aging adults, CAVs may maintain mobility after their driving skills become impaired, and they are deemed no longer safe to drive. Aging populations face a difficult loss of independence – a mobility challenge CAVs have the potential to address; however, attitudes may impact older drivers' willingness to adopt the new technology (Charness et al. 2018). In addition, CAV technology may improve mobility for underserved populations such as adult non-drivers, those not able to afford a vehicle of their own, and children under the driving age (Lee and Mirman 2018). Lee and Mirman (2018) found in a survey that parents with children under the driving age may be interested in CAV technology because it may be more convenient, and children do not have to be so reliant on their parents for transportation. Age of child and area of residence, as well as the overall public opinion about the technology, were some factors that affected the willingness of parents to use CAV technology (Lee and Mirman 2018).

There is the potential for CAVs to bring more light to shared mobility, which has been increasing in popularity especially in urban areas. With growing populations and urban density, many are choosing to give up personal vehicles in exchange for on-demand ride share services (Cohen and Kietzmann 2014; Asgari et al. 2018; Watkins 2018). Car-sharing, relatively new in the United States, could be crucial to the implementation of CAVs (Cohen and Kietzmann 2014; Alessandrini et al. 2015). An emerging theory in CAV technology is they will be similar to Uber or Lyft in that one would be able to call one and use it to get to the destination, after which the vehicle proceeds to its next job (Dowling et al. 2018). Car-share users are free of the responsibility for maintenance, insurance, and other costs that come with vehicle ownership (Alessandrini et al. 2015). Sharing vehicles could potentially make urban space more efficient and enhance livability in the areas (Fulton et al. 2017). Though this idea has appeal, business models are filled with assumptions and there are many question marks in how the sharing technology will work (Cohen and Kietzmann 2014; Dias et al. 2017). There are many cities internationally that rely on shared transportation, like taxi services, and are incredibly congested (Simoni et al. 2019).

To control congestion, CAVs may need to be controlled and heavily regulated. Dias et al. (2017) suggests that the majority of US ride share, and car-share users tend to be young, well-educated, and of higher income. This may be indicative of attitudes toward CAV adoption among the same demographic as young populations are who are going to experience the CAV revolution and witness the most change. One of the main questions that surround CAVs and their success in the United States is: Can they be regulated to create a smooth, new transportation model?

Threats

Whether CAVs actually increase mobility remains an open question. There is the potential for some congestion relief to be achieved through fewer crashes and smaller headways, but vehicle miles traveled (VMT) may increase (Simoni et al. 2019). Congestion surge pricing already appears with ride-share services today, with ride prices rising during peak travel times. With the potential for VMT to increase and the demand and size of a CAV fleet still in question, congestion surge pricing may disproportionately burden lower-income commuters (Charness et al. 2018; Simoni et. al 2019).

Impacts of CAVs

Connected and Vehicles have the opportunity to change not only the urban transportation landscape but the transportation landscape as a whole (Wang et. al 2018; Wu et al. 2020). Instant access to transportation gives users high flexibility and better connectivity (Cepolina and Farnia 2013). Ride-sourcing, also known as the on-demand transportation models that CAVs may have or what companies like Uber currently use, are disruptive mobility services and are gaining popularity in the industry (Dias et al. 2017). With disruptive mobility gaining popularity, especially with the younger generation, CAVs are looking like they might be very desirable to young adults in the future (Dias et al. 2017). Pakusch et al. (2020) conducted a study in which they interviewed thirty-four Millennial age people (born 1981-1996) and asked if they would be willing to ride in driverless taxis. The study found that driverless taxis are potentially ideal for Millennials as having a human driver is a low priority and the potential for lower fares is a high priority (Pakusch et al.

2020). Automation will change the way we use time spent in traffic. The ability to work while traveling to and from employment sites will allow some occupants to use their time more efficiently, even if they are potentially spending time in traffic. (Fulton et al. 2017). The flexibility and convenience of the on-demand shared CAV model has the potential to make private AV (autonomous vehicle) ownership less appealing (Nazari et al. 2018). It is still extremely unclear whether potential users will want to own versus share a CAV due to the lack of certainty and trust in the industry (Nazari et. al 2018; Merfeld et al. 2019; Pettigrew et al. 2019).

There is the potential for CAVs to provide high flexibility and relatively quick access to transportation, with optimal wait times in urban areas potentially being as low as five to ten minutes (Krueger et al. 2016). This type of transportation presents the challenge of uneven distributions of vehicles, reduction in traditional transportation jobs, and the potential end of public transportation as we know it today (Cepolina and Farnia 2014; Fulton et al 2018; Currie 2018). Cepolina and Farina (2013) suggest that because of the potential differences in demand across the city, some stations could end up with more cars and others with none. Therefore, a relocation scheme would be necessary to ensure that vehicles are periodically redistributed across their specific area. Traditional transportation jobs are also in jeopardy with the potential CAV revolution (Fulton et al. 2017; Pakusch et al. 2020). There is limited research on how many jobs will be lost due to automation and the introduction of CAVs, but the general consensus is that it will affect driving as a career (Pakusch et al. 2020). With the potential disruption of driving a vehicle as a job, there will also be a disruption of public transit as we know it today (Currie 2018). Though some believe that public transit will become obsolete when CAVs are widely accepted, there is no way to completely know the timeline or to ‘categorically assert’ that public transit is potentially a dying branch of mobility (Currie 2018).

Attitudes Towards CAVs

There are many benefits and impacts, both good and bad, that CAVs will bring to the transportation world. Many of the impacts are highly dependent on the public’s acceptance of the technology (Krueger et al. 2016; Panagiotopoulos and Dimitrakopoulos 2018; Watkins 2018; Merfield et. al 2019; Liu et al. 2019; Raue et al. 2019). Currently, there is more automation on the market than one may think, and many major automakers are integrating some level of automation into current vehicles (Hardman et al. 2019). From adaptive cruise controls to full automation, those who are currently using this technology are classified as early adopters of CAV technology (Hardman et al. 2019; Berliner et al. 2019). Hardman et al. (2019) conducted a study on those who had already purchased plug-in electric vehicles (PEVs) as a base for people who have already bought into an aspect of CAV technology. They found that respondents had a generally positive perception of the technology and were aware that the technology would be more expensive. They also found that those who would be willing to adopt the technology come from higher socio-economic status and would be willing to purchase a CAV for personal use (Hardman et al. 2019). Other studies have found that young men of higher education and higher income who already purchase higher priced vehicles are most likely to buy into the technology first (Berliner et al. 2019). Berliner et al. (2019) had similar findings to Hardman et al. (2019) in that many respondents in their study are interested in purchasing and using CAVs, but they only have average knowledge of the technology. Charness et al. (2018) also state that men are less concerned with the technology and potentially more likely to adopt than women.

There is also a safety concern when it comes to CAVs. Though CAVs have the potential for improved safety, there is no way they can eliminate all crashes (Liu et al. 2019). Trust can directly or indirectly affect acceptance of the technology through the public's perceived risks and benefits (Liu et al. 2018). Liu et al. (2019) found that people tended to perceive traffic crashes involving CAVs as more severe than crashes involving human driven vehicles, regardless of severity or cause of the crash. This shows that people may already have a prior negative attitude towards CAVs which could lead to lower acceptability (Liu et al. 2019). We are told that CAVs are safe and will improve safety; it is jarring when there is a crash that is associated with a technology that has claimed to be safe. Similarly, to Liu et al. (2019), Brell et al. (2018) found that perceived risks associated with conventional driving were lower as compared to CAV driving. Conventional driving is factually riskier in terms of accident hazards, but people perceived it as less risky (Brell et al. 2018). This could be because people are familiar with conventional driving technologies and associate the familiarity with less of a perceived risk (Brell et al. 2018).

Perceptions are dynamic and change as more information becomes available and in today's digital age, more exposure can lead to more acceptance (Talebian and Mishra 2018). The more people who are exposed to advertisements for CAVs and the more their personal social circle accept the technology, the more likely it is that an individual person will feel comfortable in CAVs (Talebian and Mishra 2018). Advertisements for CAVs are potentially a way to show an impact on adoption, though this is not known yet (Talebian and Mishra 2018). Factors that shape people's perceptions and level of acceptance of CAVs remain unclear (Raue et al. 2019). Often, personal experience and knowledge of a product shape perceptions. The general public has limited to no exposure to CAVs and have limited knowledge on the technology, making it difficult to form a concrete opinion (Raue et al. 2019; Berliner et al. 2019). Until the technology is demonstrated, and people can see its full potential, it is unlikely that we will gain insight into if and when the public will accept CAVs.

Acceptance also depends on the willingness of users to pay for CAVs (Krueger et al. 2016; Talebian and Mishra 2018; Gkartzonikas and Gkritza 2019; Asgari and Jin 2019). With the potential for different levels of automation, it is important to know whether and how much people are willing to pay for the technology. Bansal and Kockelman (2016) conducted a survey in Texas and found that people were willing to pay around $7,000 or more for level 5 full automation and around $3,300 for level 4 partial automation. Socioeconomic status is a large contributing factor when it comes to a willingness to pay and those who already use cruise control were more likely to show willingness to pay for AV technology (Gkartzonikas and Gkritza 2019; Asgari and Jin 2019). Willingness to pay also depends on one's acceptance of shared AVs; some are inclined to pay more if they own a personal CAV (Krueger et al. 2016). Willingness to pay for AV technology will change as more information becomes available (Talebian and Mishra 2018). CAVs have the opportunity to hold a significant market share as long as people accept and use the technology (Gkartzonikas and Gkritza 2019). Today, it is not a question of whether CAVs are coming; rather, it is when are CAVs coming.

Research Gaps

The literature surrounding CAVs has increased in the last few years and will continue to increase as more information becomes available. Many studies have been done about the technology of CAVs but there is a significant gap when it comes to attitudes and perceptions of CAVs. Studies have varied in certainty when it comes to willingness to adopt, pay for, and use CAVs (Lee and Mirman 2018; Berliner et al. 2019; Brell et al. 2019; Gkartzonikas and Gkritza 2019; Hardman et al. 2019; Rahimi et al. 2020). Other factors such as gender, age, and prior knowledge of CAVs contribute to willingness to adopt but have not been explored to their fullest extent (Charness et al. 2018). This study aims to contribute to the existing knowledge and contribute new information about willingness to adopt CAVs using age, gender, urbanicity, and others.

4. Methods

Grounded in the review of the literature, this study uses data from an online survey to test the assumption that young adults will express interest in adopting CAV technology and give up personal vehicles.

The survey aims to understand respondents' personal attitudes towards the potential integration of CAVs into their daily lives and their willingness to use one. The survey, distributed in January 2020 to college and university students through a professional network of faculty at multiple universities across the country, captured respondents' attitudes towards the technology. The survey, conducted through a Qualtrics interface, kept respondents anonymous, while collecting demographic data including sex, age, marital status, age, and name of college or university.

Objectives

The goal of this research was to test the assumption, cited in popular press and sometimes in discussions in transportation- and technology-related professions, that young adults would be willing to use CAVs for their daily transportation needs. The study probes whether young adults are comfortable with the potential implementation of CAVs and are willing to use them as a mobility service in lieu of personal vehicle ownership. Findings from this study will contribute to the base of CAV knowledge revealing information about attitudes towards implementation and comfort levels of potential future users.

Research Questions

- How comfortable are young adults with riding in CAVs?
- How inclined are young adults to give up personal vehicle ownership in favor of shared CAVs?
- How does sociodemographic status and other personal factors contribute to the levels of comfort with CAVs?

Survey Questions

The survey began by briefly explaining what CAVs are and how they will likely operate. It then asked respondents three questions meant to gauge the likelihood of using a CAV and their desire to potentially own one in the future. Those questions included:

1. How comfortable would you feel riding in a driverless car in mixed traffic (i.e., with other driverless vehicles, human-operated vehicles, pedestrians & bicyclists, buses, etc.) for everyday travel?
2. How comfortable would you feel relying on shared or hailed driverless vehicles INSTEAD of owning/renting a personal motor vehicle?
3. Would you like to own a driverless vehicle?

The ordinal data came from responses to the three major question on four-point Likert scales: extremely comfortable, somewhat comfortable, somewhat uncomfortable, and extremely uncomfortable (or, for the future CAV ownership question: Definitely yes, probably yes, probably no, and definitely no). Two questions asked about the respondent's access to vehicles and the final four questions were basic socio-demographic questions. See the survey instrument in Appendix A.

Data Preparation

Once the survey closed, the data was cleaned to remove any inconsistencies in the answers. Responses that were deleted included incomplete and blank answers and those who did not complete the survey. Subsequently, answers were filtered by age to produce a data set containing respondents who fell into the Millennial (born 1981-1996) and Generation Z (born 1997-2012) age group. Other variables were created based on information provided by the respondents including urbanicity, university type, and university size (if respondents responded with their university name). Cross-tabulations revealed relationships within and between the age groups.

Data

A total of 510 responses were submitted. After a preliminary scan of the data, 508 responses were viable for analysis. Following additional cleaning and filtering of the data, 463 response met the criteria for analysis of our hypothesis. The reasons for excluding 45 responses included insufficient answers, incompletion of the survey, and being above the "millennial age range" (18-44, respectively) we set for the study. Excluded ages included those in the 45-64 and 64+ age range, to focus on the responses of Millennials and Generation Z. Of the 463 viable responses, 346 of them fell into the 18-24 age range, 105 in the 25-34 age range, and 12 in the 35-44 age range. Other descriptive factors were developed to add depth to the responses. New descriptions included university size (small, medium, large), university setting (urban, suburban, rural), and university type (public or private).

As shown in Table 1, approximately 51 percent of the respondents identified as female, 46.4 percent identified as male, and 2.6 percent identified as non-binary, self-described, or prefer not to answer, here on collectively referred to as 'other.' Approximately 74.7 percent of respondents were in the 18-24 age group, 22.7 percent were in the 25-34 age group, and 2.6 percent were in the 35-44 age group. Approximately 87.6 percent of respondents have some level of a college degree (associates, bachelors, masters/professional degree, or doctorate), 0.7 percent have a GED or High School diploma, and 12% did not answer.

Table 1: Age and Gender

Age	Female	Male	Non-Binary/3rd Gender/ Prefer to self-describe	Grand Total
18 - 24	39.3%	33.9%	1.5%	74.7%
25 - 34	10.1%	11.4%	1.1%	22.6%
35 - 44	1.5%	1.1%	0%	2.6%
Grand Total	**51%**	**46.4%**	**2.6%**	**100%**

5. Results and Discussion

The survey consisted of a small set of sociodemographic measures, and three substantive questions used to determine the respondents' attitude towards CAVs expressed as willingness to use, share, and purchase CAVs. Analysis of the data was primarily cross tabulations of variables to reveal correlations. I performed Chi-Squared tests on variables of interest to evaluate whether differences shown in crosstabs were statistically significant. The results also suggest which dependent variables would potentially be strong predictors of whether or not a particular group would be more willing to adopt CAV technology.

Question One: "How comfortable would you feel riding in a driverless car (i.e., with other driverless vehicles, human-operated vehicles, pedestrians & bicyclists, buses, etc.) for everyday travel?"

"How comfortable would you feel riding in a driverless car (i.e., with other driverless vehicles, human-operated vehicles, pedestrians & bicyclists, buses, etc.) for everyday travel?" A plurality (40.5 percent) are somewhat uncomfortable with riding in a driverless car, followed by 34.9 percent of respondents feeling somewhat comfortable. As for the same question but with gender as our independent variable, we can see a similar trend of ambivalence to CAVs. For females, the most common response category falls on the somewhat uncomfortable category with 47.5 percent and 30 percent in the somewhat comfortable category. As for males, the most common response was (40.7 percent) falling into the somewhat comfortable category with the next largest being 33.6 percent (Table 2). The final variable that was looked at in depth was urbanicity and comfort with riding in CAVs. Using the universities that the respondents provided, I determined whether the university setting was urban, suburban, or rural based on descriptions provided by College Board. For rural settings, a plurality (43.6 percent) of respondents said they would be somewhat uncomfortable with riding in CAVs. For suburban, a plurality was also somewhat uncomfortable (41.2 percent). For urban, again, a plurality was somewhat uncomfortable (42.1 percent) (Table 2).

Table 2: Question One: "How comfortable would you feel riding in a driverless car (i.e., with other driverless vehicles, human-operated vehicles, pedestrians & bicyclists, buses, etc.) for everyday travel?"

Responses, %	Extremely comfortable	Somewhat comfortable	Somewhat uncomfortable	Extremely uncomfortable	Total # (%)
All respondents	9.5%	34.9%	40.5%	15.2%	463/100%
By gender					
Male	32 (15%)	87 (40.7%)	72 (33.6%)	23 (10.7%)	214(100%)
Female	10 (4.2%)	70 (30%)	112 (47.5%)	44 (18.6%)	236(100%)
Other/no response	2 (16.7%)	4 (33.3%)	3 (25%)	3 (25%)	12 (100%)
By age					
18-24	30 (8.7%)	119 (34.5%)	148 (42.9%)	48 (13.9%)	345(100%)
25-34	12 (11.4%)	37 (35.2%)	35 (33.3%)	21 (20%)	105(100%)
35 and older	2 (16.7%)	5 (41.7%)	4 (33.3%)	1 (8.3%)	12 (100%)
Urbanicity					
Rural	15 (7.4%)	67 (33.2%)	88 (43.6%)	32 (15.8%)	202(100%)
Suburban	5 (9.8%)	18 (35.3%)	21 (41.2%)	7 (13.7%)	51 (100%)
Urban	12 (9.9%)	43 (35.5%)	51 (42.1%)	15 (12.4%)	121(100%)
No Response	12 (13.6%)	23 (26.1%)	27 (30.7%)	16 (18.2%)	88 (100%)

Next, a univariate Chi-Squared test was performed to test whether there is a difference between the expected frequency and the observed frequency. The univariate test for question one using all four categories, found it to be significant at $p < 0.05$. When the middle rows (somewhat comfortable and somewhat uncomfortable) are combined, we find that it is still significant.

Then, with three explanatory variables, a bivariate Chi-Squared test was preformed to see the level of statistical significance between comfort with riding in CAVs and another dependent variable. The first Chi-Squared test, comparing level of comfort and age, found that age was not a significant predictor for level of comfort. The next Chi-Squared test, performed between comfort and gender, found a significant correlation between level of comfort riding in a CAV and gender, making it a significant predictor of level of comfort in riding in a CAV ($\alpha = 0.05$). No significant correlation between comfort in riding and urbanicity, so it is not a significant predictor.

The same bivariate Chi-Squared test, was performed, with the middle two columns (somewhat comfortable and somewhat uncomfortable) collapsed into one column to see if there was significant correlation now that those on the fence were in one group. For age and comfort level, the p-value was lower than with the four categories, however it was still not a significant predictor. For comfort level and gender, just like with four categories, the Chi Square test with the three categories was statistically significant like before. For comfort level and urbanicity, the result was not significant, similar to the previous test.

Question Two: How comfortable would you feel relying on shared or hailed driverless vehicles INSTEAD of owning/renting a personal motor vehicle?"

The second question in the survey was "How comfortable would you feel relying on shared or hailed driverless vehicles INSTEAD of owning/renting a personal motor vehicle?" The most common response (38.4 percent) were somewhat uncomfortable and 30.2 percent were somewhat comfortable (Table 3). These responses were similar to the responses for the previous question in that there is still an overall ambivalence, this time in relying on shared mobility. With gender as the predictive variable for relying on shared mobility, the most common response for females were somewhat uncomfortable (41.9 percent), and 30.9 percent were somewhat comfortable. The common response for males were somewhat uncomfortable (35.8 percent), and 30.7 percent somewhat comfortable (Table 3). For the final variable of urbanicity and the comfort in relying on shared mobility, a plurality (39.9 percent) of rural residents were somewhat uncomfortable with the next largest category being extremely uncomfortable (28.6 percent). A plurality (35.3 percent) of suburban residents were somewhat uncomfortable and 31.4 percent were somewhat comfortable. A plurality (38 percent) of urban residents were somewhat uncomfortable and 30.7 percent were somewhat comfortable (Table 3).

Table 3: Question Two: "How comfortable would you feel relying on shared or hailed driverless vehicles INSTEAD of owning/renting a personal motor vehicle?"

Responses, %	Extremely comfortable	Somewhat comfortable	Somewhat uncomfortable	Extremely uncomfortable	Total #/%
All respondents	10.6%	30.2%	38.4%	20.7%	463/100%
By gender					
Male	30 (14%)	66 (30.7%)	77 (35.8%)	42 (19.5%)	215(100%)
Female	14 (5.9%)	73 (30.9%)	99 (41.9%)	50 (21.2%)	236(100%)
Other/no response	5 (41.7%)	1 (8.3%)	2 (16.7%)	4 (33.3%)	12 (100%)
By age					
18-24	28 (8.1%)	103 (29.8%)	140 (40.5%)	75 (21.7%)	346(100%)
25-34	20 (19%)	31 (29.5%)	35 (33.3%)	19 (18.1%)	105(100%)
35 and older	1 (8.3%)	6 (50%)	3 (25%)	2 (16.7%)	12 (100%)
Urbanicity					
Rural	11 (5.4%)	53 (26.1%)	81 (39.9%)	58 (28.6%)	203(100%)
Suburban	8 (15.7%)	16 (31.4%)	18 (35.3%)	9 (17.6%)	51 (100%)
Urban	20 (16.5%)	44 (36.4%)	46 (38%)	11 (9.1%)	121(100%)
No Response	10 (11.4%)	27 (30.7%)	33 (37.5%)	18 (20.4%)	88 (100%)

Next, a univariate Chi-Squared test was performed to test if there is a difference between the expected frequency and the observed frequency for Question Two. The univariate test for Question Two using all four categories, we find that it is significant with $p < 0.05$. When the middle rows (somewhat comfortable and somewhat uncomfortable) were combined, it is still significant.

Then, with three explanatory variables, a bivariate Chi-Squared test was performed to identify the level of statistical significance between relying on shared mobility and one of the explanatory variables. The first Chi-Squared test, comparing comfort in relying on shared mobility and age, found that there was significance between the two. The next found a significant correlation between gender and comfort in relying on shared mobility and it is a significant predictor in level of comfort in relying on shared mobility ($\alpha = 0.05$). The final test between comfort in relying on shared mobility and urbanicity found significant correlation between the two variables and it is a significant predictor.

Another bivariate Chi-Squared test was performed using the same explanatory variables with the middle two columns (somewhat comfortable and somewhat uncomfortable) collapsed into one column. The first test, performed between comfort in relying on shared mobility and age, found that it was significant with the same p-value as with four categories. The next test between comfort in relying on shared mobility and gender found it was significant. The final test, between comfort in relying on shared mobility and urbanicity, found that this was significant

Question Three: Would you like to own a driverless car?

The third question in the survey asked, “Would you like to own a driverless car?” A plurality (35.2 percent) of respondents reported they probably would not want to own a driverless car; and the next largest group (34.1 percent) answered ‘probably yes,’ they would want to own a driverless car (Table 4). This question, like the previous questions, shows answers clustering in the two middle categories with few strong opinions. On the desire to own a driverless car and gender identity, a plurality (43.2 percent) of females reported probably not and the next largest group (32.6 percent) said probably yes. A plurality (35.8 percent) of males reported probably yes and the next largest group (26.5 percent) said probably not (Table 4). The other variable looked at was again, urbanicity and likelihood of owning a driverless car. A plurality (35.5 percent) of rural residents said probably yes, with the next largest group (34 percent) saying probably not. A plurality (35.3 percent) of suburban residents reported probably no, and 31.4 percent said probably yes. A plurality (39.6 percent) of urban residents say probably not, with 33.1 percent saying probably yes (Table 4).

Table 4: Question Three: "Would you like to own a driverless car?"

Responses, %	Definitely Yes	Probably Yes	Probably no	Definitely No	Total #/%
All respondents	14%	34.1%	35.2%	16.6%	463/100
By gender					
Male	49 (22.8%)	77 (35.8%)	57 (26.5%)	32 (18.9%)	215(100%)
Female	16 (6.8%)	77 (32.6%)	102 (43.2%)	41 (17.4%)	236(100%)
Other/no response	0 (0%)	4 (33.3%)	4 (33.3%)	4 (33.3%)	12 (100%)
By age					
18-24	51 (14.7%)	123 (35.5%)	116 (33.5%)	56 (16.2%)	346(100%)
25-34	13 (12.4%)	32 (30.5%)	40 (38.1%)	20 (19%)	105(100%)
35 and older	1 (8.3%)	3 (25%)	7 (58.3%)	1 (8.3%)	12 (100%)
Urbanicity					
Rural	26 (12.8%)	72 (35.5%)	69 (34%)	36 (17.7%)	203(100%)
Suburban	9 (17.6%)	16 (31.4%)	18 (35.3%)	8 (15.7%)	51 (100%)
Urban	12 (9.9%)	40 (33.1%)	48 (39.6%)	21 (17.4%)	121(100%)
No Response	18 (20.5%)	30 (34.1%)	28 (31.8%)	12 (13.6%)	88 (100%)

Next, a univariate Chi-Squared test was performed to test if there is a difference between the expected frequency and the observed frequency. The univariate test for Question Three using all four categories, was found to be significant. When the middle rows (probably yes and probably no) are combined, it is still significant.

As with the previous sections, a bivariate Chi-Squared test was performed to identify the level of statistical significance between the likelihood of owing a CAV and three explanatory variables. The first test, looking at likelihood of owing a driverless car and age, found that there was no significant correlation between the two. The second test, looking at likelihood of owing a driverless car and gender, found a significant correlation between two, and shows that gender is a significant predictor. As for the likelihood of owing a CAV and urbanicity, there is no significant correlation between the two and it is not a significant predictor.

Another bivariate Chi-Squared test was performed using the same explanatory variables with the middle two columns (probably yes and probably no) collapsed into one column. The first test, between the likelihood of owning a driverless car and age, found no significant correlation between the two. The next test, between the likelihood of owing a driverless car and gender, found that there was a significant correlation between the two, similar to the result with four categories. The final test, between likelihood of owing a driverless car and urbanicity, found no correlation significant

Notable Trends

The results of our study indicate that there is a level of ambivalence with young drivers and CAVs. The responses of young adults' to the three main questions revealed no strong opinion on the adoption of CAVs and shared mobility. A plurality of respondents fell in the middle, showing some level of ambivalence in their opinions. However, Chi-Squared tests revealed that there are some traits that matter when it comes to the level of comfort riding in CAVs, willingness to rely on shared mobility, and desire to own a driverless car.

Looking first at Question One (level of comfort for riding in CAVs) only gender is a significant predictor for level of comfort for the explanatory variables tested. The results suggest that more females are somewhat uncomfortable and extremely uncomfortable than in the predicted chi-squared values. Fewer are somewhat comfortable and extremely comfortable than in the predicted chi-squared values. As for the males, more reported being either somewhat or extremely comfortable with riding in a CAV than somewhat or extremely uncomfortable. This is the opposite of the expected values in the chi-squared test, showing that, based on our sample, males are potentially more comfortable with riding in CAVs than females. When the middle two rows (somewhat comfortable and somewhat uncomfortable) were collapsed, there is no change in what explanatory variables are significant. Gender is still the only significant variable.

As for Question Two, willingness to rely on shared mobility, all the explanatory variables tested with the four categories were significant. Age, and gender, and urbanicity were significant predictors. Looking at age, the expected values were very similar to observed values. Looking at gender, being male again matters. Males are more comfortable with relying on shared mobility than females in this sample. When it comes to urbanicity and willingness to rely on shared mobility, those in rural settings are less likely to be comfortable than those in urban settings. This could be due to ride-share services being more prevalent in urban areas while those in rural areas tend to rely on personal vehicles as their primary mode of transportation. When the middle two rows are collapsed, all three of the explanatories stay significant.

Looking at Question Three, desire to own a driverless car, and the three explanatory variables, only gender is a significant predictor When the middle two rows (probably yes and probably no) are collapsed, gender is still the only significant predictor. We find that more males would like to own driverless cars as opposed than females This is consistent with the literature presented by Berliner et al. (2019) and Charness et al. (2018) in that males will be more likely to feel more comfortable with and adopt the technology.

Limitations

There are some limitations that this study presents. The data was gathered through university affiliated individuals and personal networks, limiting the number of people reached and introducing possible selection bias. Because it was distributed through a university, there is a large population who will be affected by CAVs that were not included in the conversation, specifically the general public.

6. Conclusion

This study aimed to test the hypothesis that young adults, specifically Millennial and Generation Z aged people, would be willing use CAVs and shared mobility for their transportation needs in the future. The assumption that young travelers are likely to adopt CAV technologies and give up personal vehicles in favor of shared mobility is common in public and professional discourse about CAVs, but has scant empirical evidence. The study helped fill gaps in the knowledge base investigating whether young drivers will be willing to forgo personal vehicle ownership and opt into shared mobility with the use of CAVs. The data were collected through an online survey distributed to university affiliated individuals across the country.

The findings show that being male matters and urbanicity matters in the likelihood of adopting CAVs. This shows that certain populations are already more comfortable with the technology than others, even before its widespread implementation. There is a lack of research done on perceptions of CAVs specifically, and this research contributes to the ongoing conversation on CAVs and their implementation.

The findings of this study contribute to existing research by providing evidence that young adults may not be ready to implement CAV technologies into their everyday lives just yet. Looking at age, gender, and urbanicity are only a few indicators of willingness to adopt. Future analysis should look at other factors that may affect a respondent's willingness to adopt CAV technology and shared mobility such as average travel time, prior knowledge of the technology, and preferred mode of transportation. More research should also be done on how to make other, more hesitant groups more comfortable with CAVs to prepare the population for their eventual breakthrough into the transportation landscape.

The results offer meaningful insights into young adults and their willingness to adopt new technology as they stand on the cusp of multiple new transportation revolutions. Understanding young driver attitudes toward CAVs and shared mobility will help better prepare for the eventual implementation of this technology. The more that is known about the attitudes toward the technology, the more we can prepare for a smooth and effective implementation.

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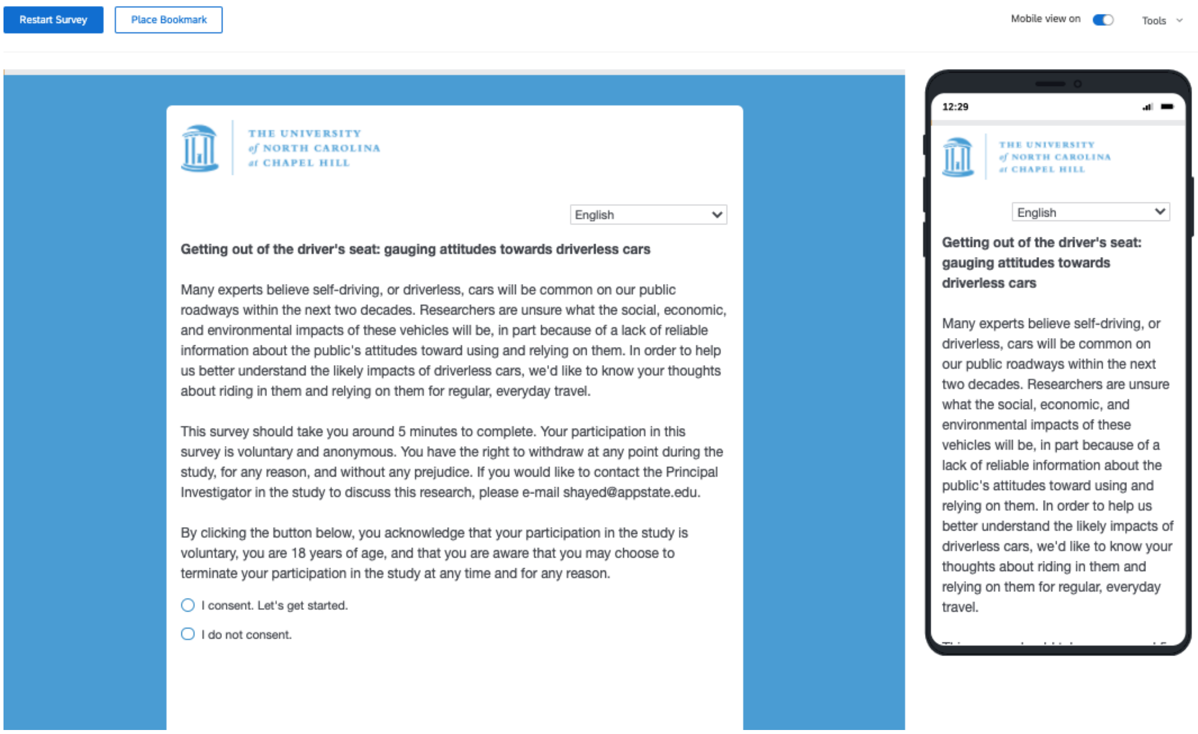
Appendix A: Survey Instrument

CAVs and young drivers



Getting out of the driver's seat: gauging attitudes towards driverless cars
Many experts believe self-driving, or driverless, cars will be common on our public roadways within the next two decades. Researchers are unsure what the social, economic, and environmental impacts of these vehicles will be, in part because of a lack of reliable information about the public's attitudes toward using and relying on them. In order to help us better understand the likely impacts of driverless cars, we'd like to know your thoughts about riding in them and relying on them for regular, everyday travel.

This survey should take you around 5 minutes to complete. Your participation in this survey is voluntary and anonymous. You have the right to withdraw at any point during the study, for any reason, and without any prejudice. If you would like to contact the Principal Investigator in the study to discuss this research, please e-mail shayed@appstate.edu.

By clicking the button below, you acknowledge that your participation in the study is voluntary, you are 18 years of age, and that you are aware that you may choose to terminate your participation in the study at any time and for any reason.

- o I consent. Let's get started
- o I do not consent

**

1. How comfortable would you feel riding in a driverless car in mixed traffic (i.e., with other driverless vehicles, human-operated vehicles, pedestrians & bicyclists, buses, etc) for everyday travel?

Extremely comfortable	Somewhat comfortable	Somewhat uncomfortable	Extremely uncomfortable

2. How comfortable would you feel relying on shared or hailed driverless vehicles INSTEAD of owning/renting a personal motor vehicle?

Extremely comfortable	Somewhat comfortable	Somewhat uncomfortable	Extremely uncomfortable

3. Would you like to own a driverless vehicle?

Definitely yes	Probably yes	Probably not	Definitely not

4. In the past year, about how often did you use ride-hailing services (e.g., Uber, Lyft, conventional taxis) in the city or town in which you live?

Very often (at least 3 days/week)	Somewhat often (once or twice a week)	Not very often (once or twice a month)	Rarely (less than once per month)	Never

5. At the present, do you own, rent, or otherwise have unrestricted use of an operable motor vehicle?

Yes	Yes, but I do not regularly use it	No

6. What is your age in years?
- 18 - 24
- 25 - 34
- 35 - 44
- 45 - 64
- 65 or older

7. With what gender do you identify?
- Female
- Male
- Non-binary/3rd gender
- Prefer not to answer
- Pref to self-describe

8. Which best describes your current family situation?
- Single, no dependents
- Single, with dependents
- Married/in a relationship, no dependents
- Married/in a relationship, with dependents
- Prefer not to answer
- Other

9. Which best describes your employment status? (check all that apply)
- o Employed full time
- o Employed part time
- o Unemployed looking for work
- o Unemployed not looking for work
- o Retired
- o Student
- o Disabled
- o Other

10. In which state do you currently live? (if you're a student, please list the state in which you attend school).
[text box]

Vita

Hannah Lynn Bagli was born and raised in Chattanooga, Tennessee. Her parents, Deris and Sue Bagli, instilled a love for the mountains and outdoors in her from a young age. After graduating from Chattanooga School for the Arts and Sciences in May of 2016, Hannah moved to Boone, North Carolina, to attend Appalachian State University.

As an undergraduate, Hannah was on the executive boards for the Residence Hall Association, the National Residence Hall Honorary, the Club Equestrian Team, and was a member of Club Council and the Presbyterian Episcopal Campus Ministry. As a junior, Hannah was able to participate in transportation research with Dr. Elizabeth Shay through the Planning Studio class. This opportunity inspired her to pursue a master's degree in Geography through the Accelerated Admissions Program and continue transportation and Connected and Automated Vehicle (CAV) research. Hannah graduated Cum Laude with a Bachelor of Science in Community and Regional Planning with a GIS Certificate in May 2020.

As a member of the Accelerated Admissions Program, Hannah began her second year of graduate school at Appalachian in August 2020. She was able to continue transportation and CAV research under the direction of Dr. Elizabeth Shay, which turned into her thesis. Upon graduating with a Master of Arts in Geography in May 2021, Hannah plans on moving to Asheville, North Carolina, to begin her career as a transportation planner.