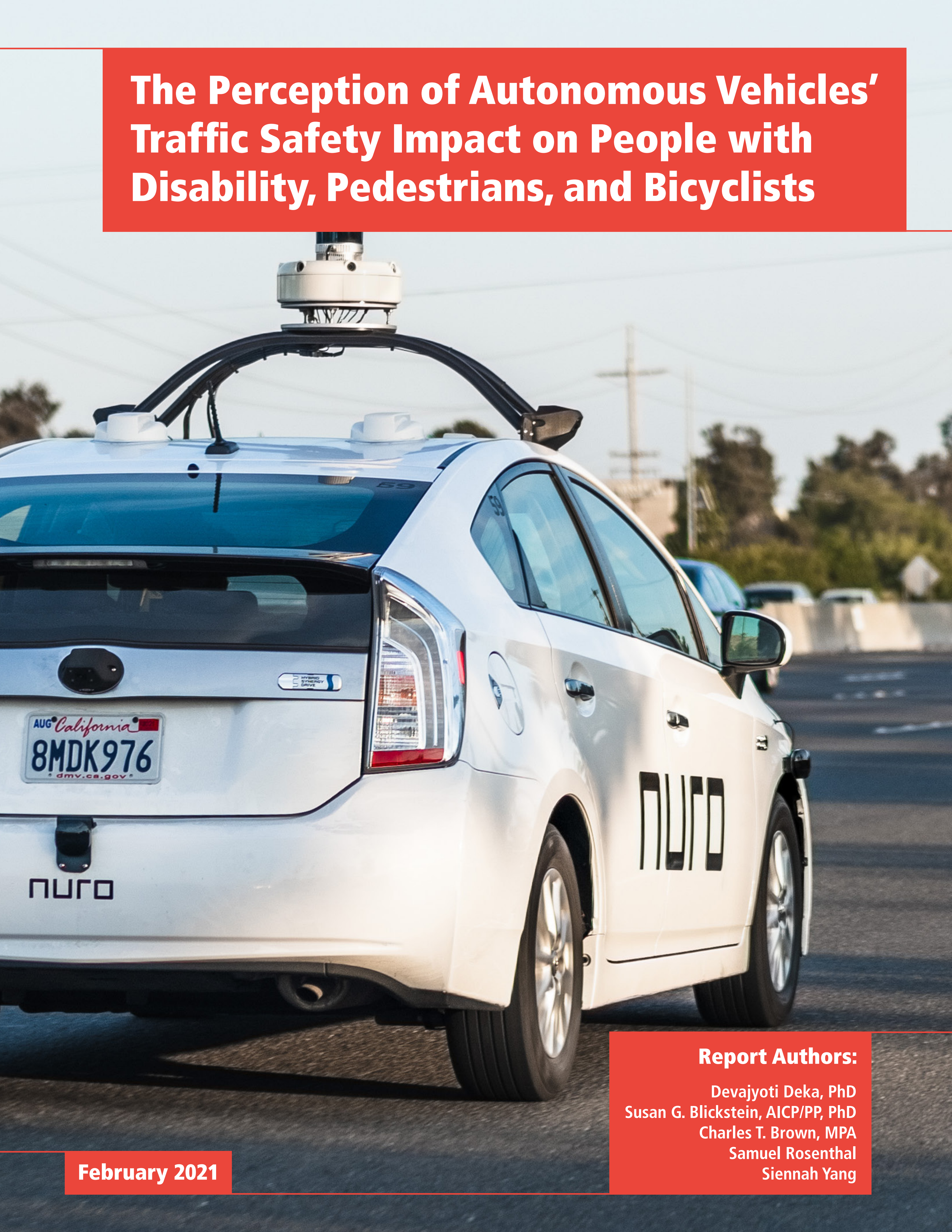
The Perception of Autonomous Vehicles' Traffic Safety Impact on People with Disability, Pedestrians, and Bicyclists



Report Authors:

Devajyoti Deka, PhD
Susan G. Blickstein, AICP/PP, PhD
Charles T. Brown, MPA
Samuel Rosenthal
Siennah Yang

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Prepared by:

Alan M. Voorhees Transportation Center
New Jersey Bicycle and Pedestrian Resource Center
Susan G. Blickstein, LLC

About

The Alan M. Voorhees Transportation Center (VTC) is a national leader in the research and development of innovative transportation policy. Located within the Edward J. Bloustein School of Planning and Public Policy at Rutgers University, VTC has the full array of resources from a major research university on transportation issues of regional and national significance.

The New Jersey Bicycle and Pedestrian Resource Center (BPRC) assists public officials, transportation and health professionals, and the public in creating a safer and more accessible walking and bicycling environment through primary research, education, and dissemination of information about best practices in policy and design. The Center is supported by the New Jersey Department of Transportation through funds provided by the Federal Highway Administration.

Alan M. Voorhees Transportation Center
Edward J. Bloustein School of Planning and Public Policy
Rutgers, The State University of New Jersey
33 Livingston Avenue, Fourth Floor
New Brunswick, New Jersey 08901

Susan G. Blickstein, LLC is a planning, policy, and public engagement firm that specializes in sustainable land use and transportation planning in the State of New York and New Jersey. It provides urban planning and strategic planning services to municipal entities, MPOs, state agencies, and the private sector. Susan G. Blickstein, LLC is a certified DBE (Disadvantaged Business Enterprise) in New York and New Jersey.

For questions, please contact Charles T. Brown, MPA, Principal Investigator: charles.brown@ejb.rutgers.edu.

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Cover photo: Nuro Autonomous Vehicle Driving on the Freeway in Silicon Valley, July 25, 2020 (cropped)
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Executive Summary

Autonomous vehicles (AVs), commonly referred to as self-driving cars or driverless cars, have seen tremendous investment and technological advancement over the past decade, and their deployment will almost certainly result in radical changes to the built environment, transportation infrastructure investments, and the ways we travel. As these technologies continue to be developed, planners, policymakers, and the general public have become increasingly aware of AVs and have begun to think about their potential impacts. There is hope that AVs could bring about promising environmental and safety benefits, but there remain valid concerns regarding AVs' effect on road design and congestion, and some fear that AVs may, in fact, have a negative impact on road safety, particularly for vulnerable road users. These concerns are significant because the ability of AVs to deliver any benefits will depend not only on how the technology is integrated and employed, but also on how all roadway users perceive and respond to sharing roads with AVs and on how AVs' impacts on people and communities play out.

In an effort to better understand the public's comprehension of and concerns regarding AVs–and ultimately plan for safe and effective AV integration–this report examines the perceptions of AVs' safety impacts on vulnerable road users, specifically pedestrians, bicyclists, and those with disability. Part I of the report includes a literature review that covers existing research regarding pedestrians' and bicyclists' perceptions of AVs and helps to identify where further research is needed. The literature review informs the design of the survey and focus groups that follow.

Part II of the report discusses findings from a statewide survey of 1,001 New Jersey adults about the perception of the potential impact of autonomous vehicles on pedestrians, bicyclists, and people with disability. Statistical modeling of survey results shows that the two variables that consistently affect the perception of AVs' safety impacts are familiarity and gender, and that people with ambulatory disability are highly concerned about a negative safety impact of autonomous vehicles on people with disability.

Part III of the report discusses findings from three focus groups conducted to provide supplemental qualitative information regarding how pedestrians, bicyclists, and people with disability presently view autonomous vehicles and their potential impacts on safety for those three groups. Focus group findings were consistent with survey results in that those with disability expressed heightened concern over autonomous vehicles' safety impacts, both generally and for people with disability in particular. At the same time, focus group participants were both less familiar with AVs and less optimistic about AVs' ability to improve safety than survey respondents. While many participants believed that AVs could reduce the frequency and severity of vehicle-to-vehicle collisions, they were more skeptical about their ability to improve safety for more vulnerable road users.

The insights gained through this research provide a deeper understanding of the public's perceptions and concerns regarding AVs' safety impacts on vulnerable road users and should be considered by planners and policymakers when determining safe and effective methods of AV integration into existing transportation systems. This research is also particularly relevant to New Jersey, due in part to the state's high number of crashes involving pedestrians and bicyclists. Between 2014 and 2018, there were 1,034 serious injuries and 934 fatalities for bicyclists and pedestrians in the state, and the FHWA has identified New Jersey as a bicyclist and pedestrian focus state (NJDOT, 2020). A better understanding of AVs' perceived safety impacts on vulnerable road users will be crucial to reducing fatalities and serious injuries for these groups. Furthermore, New Jersey's ubiquitous and complicated highway system, range of land uses, and varied community types (urban, suburban, and rural) will pose unique challenges for the deployment of autonomous vehicles. As a result, this research is especially pertinent to the state as it looks toward the future of AV integration.

Introduction

Autonomous vehicles (AVs), commonly referred to as self-driving cars or driverless cars, have seen tremendous investment and technological advancement over the past decade. While there is still uncertainty regarding the timeline for widespread deployment of AVs, autonomous features of Advanced Driver Assistance Systems (ADAS), such as automatic emergency braking and lane departure warning, are already being implemented in cars currently on the market and have hinted at what the future of fully autonomous vehicles might look like (USDOT, 2020). Certainly, the integration of AVs will result in radical changes to the built environment, transportation infrastructure investments, and the ways we travel.

As these technologies continue to be developed, planners, policymakers, and the general public have become increasingly aware of AVs and have begun to think about their potential impacts. There is hope that AVs could bring about promising benefits, including improved adherence to traffic controls, reductions in greenhouse gas emissions (especially via integration with shared systems), and greater mobility for those unable to drive (Millard-Ball, 2018). They also have the potential to address road safety. AVs that can detect and respond to the movements of all road users could improve safety not only for vehicle occupants, but for pedestrians, bicyclists, and other vulnerable road users as well. AVs could also mitigate the dangers posed by human behaviors such as fatigued, distracted, or impaired driving. Sensors within AVs provide a wealth of data about the vehicle's surroundings, and internal software allows vehicles to learn from previous experiences and enables vehicle behavior to be updated in response to changing conditions (USDOT, 2018). Clearly, the possibilities for AVs to improve road safety are manifold.

At the same time, there remain valid concerns regarding AVs' effect on road design and congestion. Some worry that widespread deployment of AVs may increase vehicle miles traveled (VMT), reduce transit use, and exacerbate sprawl (Freemark, Hudson, and Zhao, 2019). Others fear that AVs may, in fact, have a negative impact on road safety, particularly for vulnerable outside-the-car users. These concerns are signficiant because the ability of AVs to deliver any benefits will depend not only on how the technology is integrated and employed, but also on how all roadway users perceive and respond to sharing roads with AVs and on how AVs' impacts on people and communities play out. Understanding people's perceptions of AVs and their safety impacts will therefore be crucial to effective planning and policymaking for the integration of AVs into existing transportation systems.

Moreover, the vast majority of communities are currently unprepared for widespread AV deployment. A 2019 article in the Journal of the American Planning Association found that despite a growing understanding of AVs and their potential impacts, both positive and negative, few municipal governments in the United States have begun to seriously plan for AV integration (Freemark, Hudson, and Zhao, 2019). That these same municipalities envision wider AV availability within the decade only further emphasizes the need to begin making preparations now.

In an effort to better understand the public's comprehension of and concerns regarding AVs–and ultimately plan for safe and effective AV integration–this report examines the perceptions of AVs' safety impacts on vulnerable road users, specifically pedestrians, bicyclists, and those with disability. Part I of the report includes a literature review that covers existing research regarding pedestrians' and bicyclists' perceptions of AVs and helps to identify where further research is needed. The literature review informs the design of the survey and focus groups that follow.

Part II of the report discusses findings from a survey of New Jersey adults about the perception of the potential impact of autonomous vehicles on pedestrians, bicyclists, and people with disability. This discussion explores how demographic characteristics, walking and bicycling frequency, and familiarity with autonomous vehicles relate to respondents' perceptions of AVs' safety impacts on vulnerable road users.

Part III of the report discusses findings from three focus groups conducted to provide supplemental qualitative information regarding how pedestrians, bicyclists, and those who require mobility aids presently view autonomous vehicles and their potential impacts on safety for those three groups. Findings from the focus groups are then compared with survey results to provide a deeper understanding of the public's perceptions of AVs' safety impacts.

Motivated by the growing belief that autonomous vehicles will soon become available and affordable to a wider range of people, this report provides important insights into how the general public, and vulnerable road users themselves, perceive AVs' anticipated safety impacts for pedestrians, bicyclists, and people with disability.

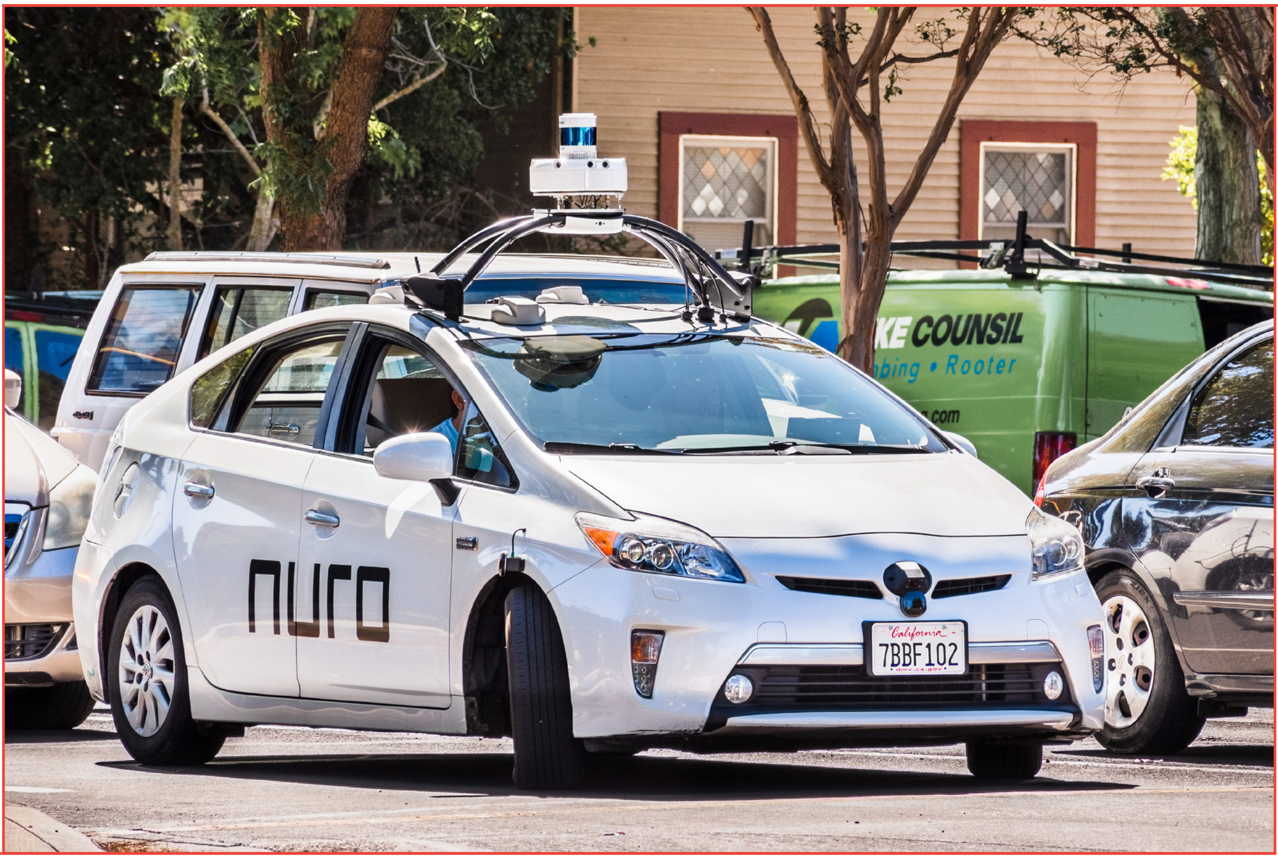

Photo: Nuro Autonomous Vehicle Driving on a Street in Silicon Valley, Sep 17, 2019
Mountain View, CA
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Part I: Literature Review

Due to the increasing popularity of AVs and automated technology, there has been a surge of research interest in autonomous mobility both in academia and for-profit sectors in the past few years (Chan, 2017). A lot of recent research on AVs focuses on the technological or market development of AVs (Anderson et al., 2010), or AVs' potential impacts, such as on policymaking (Vellinga, 2017) and land use planning (Alexiadis, 2009; Appleyard et al., 2018). Some research takes a more human-centered approach and examines public perceptions of AVs or humans' interactions with AVs. However, most research focuses on the perspectives of drivers, potential buyers, and vehicle passengers–their interactions with and perceptions of AVs, their willingness to drive, own, or ride an AV, or share the road with AVs as a human driver (Schoettle and Sivak, 2014; Dai and Howard, 2014).

There is only a small body of research that prioritizes the perspectives of vulnerable road users (ex. pedestrians, cyclists, mobility-device users) and their interactions with AVs. Such research is crucial to ensuring the safety of vulnerable road users when AVs are more widely introduced, especially with the increasing number of people who walk, bike, scooter, and otherwise self-propel for a variety of purposes. It is also crucial because the innovation of AVs will not only change the hardware and operation of vehicles, but will likely necessitate changes to the built environment of our communities. Better understanding and considering the needs of vulnerable road users in the design, implementation, and policymaking of AVs is necessary to build and sustain an equitable and resilient autonomous future.

While AVs are not presently permitted on New Jersey's roads, in January of 2019, Governor Murphy established the New Jersey Advanced Autonomous Vehicle Task Force under Bill AJR 164 to study autonomous vehicles and recommend laws, regulations, and rules that New Jersey could enact to introduce AVs safely. Nationally, the number of states that permit the operation and testing of autonomous vehicles is gradually increasing. Since 2011, 41 states have enacted either legislation or executive orders related to autonomous vehicles (NCSL, 2020). It is expected that enabling legislation for autonomous vehicles will continue to advance, including their eventual legalization in New Jersey. Research on the perceptions and concerns of vulnerable road users is important to ensure that policies and practices are in place to integrate AV use in New Jersey safely. This literature scan synthesizes recent AV research in the US to inform the design and implementation of a statewide survey and focus groups to better understand how pedestrians and bicyclists presently view AVs and their potential to enhance safety.

Pedestrians' and Bicyclists' Perceptions of AVs

Why are Attitudes and Perceptions Important for AV Research?

Perceptions are a person's interpretation and experience of reality; they are influenced by one's history, location, belief systems, social interactions, and other factors (Munhall, 2008). Perceptions are dynamic and are evolving. As Bauer et al. describe, they include "an element of volition and action: people choose to 'see' things in certain ways, and the social and cultural determinants of those choices differ across time and place." (Bauer et al., 2006). Perceptions are powerful because they become truths and frameworks in how one apprehends different objects and issues, and they inform and shape one's behaviors, actions, and decisions. For example, research on attitudes towards AV technology illustrates that AV acceptance varies by several factors, including but not limited to age, gender, and location (Deb et al. 2017, Bansal and Kockelman, 2017; Schoettle and Sivak, 2014). However, this research does not explicitly address the attitudes and perceptions of those who walk and bicycle primarily for utilitarian or recreational purposes.

Given AVs' potential to drastically impact land use patterns and transportation behaviors, the real and perceived impacts of AVs on the most vulnerable roadway users must be considered in the design and implementation of AVs and the transportation/land use system that supports them. Active transportation modes and micromobility options have been shown to address critical first mile/last mile gaps, particularly in neighborhoods underserved by conventional transit and historically marginalized. Because increased active transportation can contribute to stronger local economies and healthier and more socially cohesive populations (Brown and Hawkins, 2013; Owens and Sandt, 2017), AVs and transportation infrastructure planning should consider the needs of active transportation users. However, the unknown speed of technology development and assumptions embedded in crash avoidance systems could impair pedestrian and bicyclist safety before there is a common understanding of how vulnerable users' travel behaviors and interactions with vehicles may need to change (Botello et al., 2019) or consensus on how the laws that govern shared use of roadways may need to be modified.

Addressing attitudes and perceptions of active transportation users in AV research is also vital to ensure that the integration of AV does not disproportionately impair safety for disadvantaged communities, including low-income, minority, and disabled populations. Equity is increasingly considered an important part of bicycle/pedestrian policy, planning, and implementation efforts. There is a growing body of research that shows how race/ethnicity, gender, and disability impact access to safe and comfortable bicycle and pedestrian facilities, as well as how stereotypes and discrimination silence minorities in planning and policy decision making processes and reproduce dominant representations of bicyclists as "[guys] in spandex…athletic, slim…on a racing bike" (Blickstein and Brown, 2016; Lee, Jones, and Sener, 2016; Lubitow, 2017; Lugo, 2018). This body of literature has raised several important questions: who has access to safe bicycle and pedestrian facility infrastructure?; what barriers inhibit disadvantaged populations from bicycling or walking more frequently?; and who is involved in the design, planning, decision-making, and implementation processes for transportation initiatives? These questions have implications for the safe and equitable integration of AVs and, with few exceptions, have not been addressed in current AV research.

AV Research Landscape Regarding Bicyclists and Pedestrians

There are two general focus areas within the small body of research on bicyclists and pedestrians' perceptions of AV. The first of these addresses the general attitudes that pedestrians and bicyclists have about the safety benefits of AVs. Secondarily, this research focuses on pedestrian and bicyclists' concerns about interacting with AVs.

Studies show that pedestrians and bicyclists generally have a favorable view of AVs and their ability to enhance overall traffic safety. For instance, a pedestrian receptivity questionnaire for fully autonomous vehicles (FAV)[1] found that more than 65% of participants believed that FAVs would enhance the overall transportation system and make roads safer, and 67% of participants indicated that FAVs would function effectively in the presence of pedestrians and bicyclists crossing intersections (Deb et al., 2017). Using survey results from Bike PGH, a Pittsburgh-based organization that promotes safe mobility options for road users, Panmetsa et al. similarly found that 62% of respondents thought that AVs have the potential to reduce both fatalities and injuries (Panmetsa et al., 2019). These findings are supported by results from semi-structured interviews with walking/biking and C/AV[2] experts that show that AVs could be safer than human drivers due to the predictability and reliability of AV behavior (Botello et al., 2019). Respondents from Botello et al.'s study also shared that the adoption of AVs could lead to infrastructure changes that further enhance roadway safety, assuming that roadway space saved due to AVs could be reallocated to dedicated walking and/or bicycling facilities (Botello et al., 2019). However, Botello et al. warn that as AV integration advances, active travel rates could decline as AV convenience and safety draw people away from active modes (Botello et al., 2019).

While some studies show that pedestrians and bicyclists generally view AVs as positive, they also illustrate concerns about interacting with AVs. In a poll conducted by SurveyMonkey, a very low percentage of people would feel safe as "a pedestrian in the area of a self-driving car." (Georges, n.d.). Another poll conducted by YouGov reflected a similar result. About six in ten people would feel unsafe as pedestrians in cities with autonomous vehicles (Sanders, 2019). In a survey conducted by Advocates for Highway and Auto Safety as well as a survey conducted by Consumer Watchdog, about 80% of survey respondents expressed apprehension about sharing the road with AVs as motorists, bicyclists, and pedestrians (Advocates for Highway and Auto Safety, 2020, Consumer Watchdog 2018).

Other studies show that pedestrians are particularly concerned about their safety when interacting with AVs without any prior exposure. In Deb et al.'s study, participants without previous direct AV interactions had mixed attitudes about safely sharing roads with AVs, with responses fluctuating based on assumptions rather than direct experience. Panmetsa et al.'s study similarly concludes that people have different perceptions towards AVs depending on experience with them. They found that bicyclists and pedestrians with direct AV interaction experience were more likely to have positive attitudes about safely sharing roads with AVs (Panmetsa et al., 2019). For instance, 67% of all pedestrians and 70% of all bicyclists with prior direct AV experience agreed that AVs could reduce injuries and fatalities, compared to 58% of those without previous AV interaction (Panmetsa et al., 2019). In addition, the mean reported approval of Pittsburgh as an AV proving ground on a scale from 1 to 5, was 4.1 for pedestrians and 4.06 for bicyclists who had interactive experience, and 3.67 for pedestrians and 3.78 for bicyclists without prior AV interaction (Panmetsa et al., 2019). Panmetsa et al. consequently recommend that policymakers provide opportunities for the public to interact with AVs as one way to overcome negative perceptions of AV's impact on road safety.

Vulnerable Road Users/AV Interaction

Multiple studies identify concerns over the gap in knowledge that road users have about AV operation and how pedestrian behavior could change over time in response to growing confidence in AVs. This research asserts that as AVs become increasingly common and able respond to the presence of non-motorized road users, pedestrians and bicyclists may alter their behavior. For instance, Botello et al. show that cyclists and pedestrians might behave more assertively due to diminished concerns about getting hit (Botello et al., 2019). Deb et al. echo similar concerns, finding that pedestrians who exhibit risky roadway behaviors, due to factors such

1 The Society of Automated Engineers (SAE) divides vehicle automation into six levels. A Fully Autonomous Vehicle (FAV) is categorized as a level five, which means that the vehicle can control all driving tasks in some conditions without human control (Deb et al., 2017; Owens and Sandt, 2017).

2 C/AV refers to Connected and Autonomous Vehicles. Connected vehicles use wireless communication to share information such as presence, speed, direction of travel, braking, signal phase and timing, and road and traffic conditions to other road users. C/AV describes vehicles that are both connected and automated (Botello et al. 2019; Owens and Sandt, 2017).

as inexperience, stress, or aggressiveness, could take advantage of FAVs' detection/braking systems to cross roads without paying attention (Deb et al. 2017).

Millard-Ball's research using game theory and "cross chicken" to model road user interactions with AVs shows similar findings. Millard-Ball argues that there is no need for pedestrians to communicate with AVs because the perceived risk of crossing in front of an autonomous vehicle is nonexistent – pedestrians know that the vehicle will stop (Millard-Ball, 2018). Millard-Ball further argues that as AV technology improves and "behaves" more cautiously on the road, pedestrians and cyclists might be incentivized to change previously established behavioral norms since there is less risk crossing in front of an AV compared to a car with a human driver. However, Millard-Ball explains that such logic assumes that road users can readily distinguish AVs from human-operated vehicles and that there are substantially fewer human drivers on the road.

In contrast to the assumptions that AVs would be readily identifiable and that those on foot and bicycle would shift to riskier behavior, Botello et al. assert that pedestrians and cyclists might not be able to perceive or understand the intention of AVs. Botello et al. explain that pedestrians and cyclists would not know if AVs have identified them, would not be able to make eye contact with a human driver, and might not be able to predict how AVs would respond to their presence (Botello et al., 2019). A survey conducted by the League of American Bicyclists (LAB) reinforces the concern that pedestrians and bicyclists have about not being able to use eye contact to communicate travel intent (League of American Bicyclists, 2014).

It is also unclear whether AVs would understand the intentions, body language, or hand gestures of pedestrians and bicyclists (Botello et al., 2019). Several studies point out that current autonomous technology cannot effectively detect non-motorized users or accurately predict movement (Clamann et al., 2019; Deb et al., 2017; Botello et al., 2019). To ensure safe interaction between AVs and vulnerable road users, it is important to understand what kind of information pedestrians and bicyclists need from AVs, how to best provide this information, and how AV technology can better interpret human intentions and behaviors.

As research to date shows, despite AVs' potential safety benefits, they might not accommodate the needs of vulnerable roadway users. What pedestrians and bicyclists perceive to be safe on the road might differ from what is required under current traffic regulations and expected norms. For example, in some places in the US, vehicles are only required to give a two-foot passing distance for bicyclists (Botello et al., 2019). However, this is not a comfortable or safe passing distance (Botello et al., 2019). Understanding what pedestrians and bicyclists perceive as safe is vital in the programming and design of autonomous technology.

Other Factors that Influence Attitudes toward AVs

It is important to note that other factors also influence attitudes toward AVs. Deb et al.'s research suggests that demographics shape pedestrians' perceptions of AVs. Using three factors (safety, interaction, and compatibility) to measure different demographic groups' attitudes toward FAVs, Deb et al. found that male pedestrians felt safer around FAVs, found it easier to interact with FAVs, and were more likely to support AV integration than women. Furthermore, while most respondents held positive views about FAV's influence on safety, younger pedestrians were more comfortable interacting with FAVs and were more likely to support FAVs integration into existing transportation infrastructure (Deb et al., 2017). A survey conducted by YouGov similarly found that younger people have fewer concerns about AVs than older folks. Almost three-fourths of those surveyed over 55 indicated that they would feel "somewhat unsafe" or "very unsafe" as pedestrians in an AV integrated transportation system, compared to 48% of people between the ages of 18 and 24 (Sanders, 2019).

Other studies surveying public opinion towards AVs and willingness to purchase AVs similarly conclude that older people and women are less interested in AVs than men and younger people (Anderson and Smith, 2017; Bansal and Kockelman, 2017; Schoettle and Sivak, 2014). Pedestrian behavior and compliance with traffic laws also correlate with acceptance of FAVs, with those exhibiting more conservative pedestrian behavior more likely to view FAVs as safe. In addition, Deb et al. consider how land use patterns and views toward innovation adoption influence attitudes towards FAV, finding urban dwellers more receptive than those residing in rural areas and people who embrace innovation more accepting of FAVs. These findings are consistent with other research results that, while not focused on vulnerable road users, similarly found urbanites to have more positive attitudes toward AVs compared to those living in rural areas (Schoettle and Sivak, 2014; Cox Automotive 2018).

Conclusion

This literature scan informs the design and implementation of the statewide survey of the attitudes and perceptions of vulnerable road users towards AVs in New Jersey, described in the next part of this report. Because the establishment of law and policy on AVs tends to be influenced by the level of support from the public and transportation advocates, research on the perceptions of pedestrians, bicyclists, and safety advocates is necessary to gauge New Jersey's readiness for AV deployment and to flag key areas of concern for policymakers, AV manufacturers, and vulnerable road users. As Panmetsa et al. argue, "public perception plays a crucial role in the rate of new technology acceptance and adoption by personal choices to adopt and willingness to support government actions to support changes." (Panmetsa et al., 2019). Given New Jersey's varied geography, AV integration and the potential to reap safety benefits will likely vary based on differences in transportation infrastructure, land use patterns, and local road safety education and enforcement. It is our hope that the statewide survey conducted as part of this research will serve as a baseline for future assessments of AV acceptance by different roadway users, different demographic groups, and different community types (urban, suburban, rural).

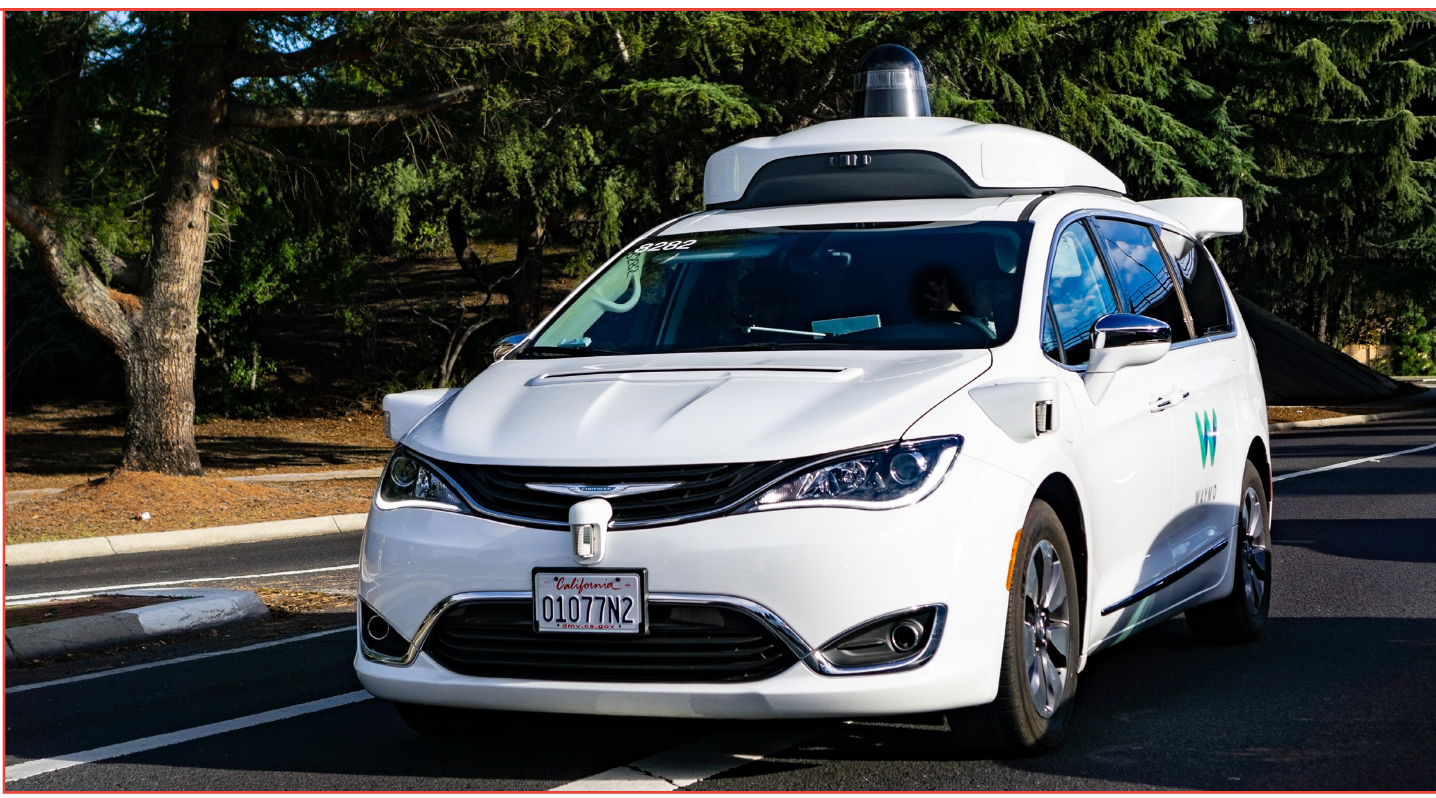

Photo: Waymo Self Driving Car Performing Tests on a Street Near Google's Headquarters, December 23, 2018 Mountain View, CA (cropped)
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Part II: The Survey

Part II of this report summarizes important findings from a survey of New Jersey adults about the perception of the potential impacts of autonomous vehicles on three specific population groups: pedestrians, bicyclists, and people with disability. A total of 1,001 adults (age 18+) participated in the random digit dialing telephone (RDD) survey, conducted by the Eagleton Center for Public Interest Polling of Rutgers University in October 2020.

The survey was motivated by the fact that there is a growing belief among transportation researchers and planners about autonomous vehicles soon becoming available and affordable to larger populations despite their potential safety impacts not being fully understood. While some believe that autonomous vehicles will enhance traffic safety because of the newer technology of the vehicles and improvements to the transportation infrastructure necessitated by fully automated vehicles, others are skeptical because it is not yet known how such vehicles will interact with road infrastructure, other vehicles, pedestrians, and bicyclists. The survey results show how the general population of New Jersey perceives the potential traffic impact of autonomous vehicles.

The survey focuses on the traffic safety impact of autonomous vehicles on people with disability, pedestrians, and bicyclists because these three populations could be particularly vulnerable with an increase in the number of autonomous vehicles on roadways in New Jersey. Because the survey included questions about the respondents' walking frequency, bicycling frequency, and use of mobility devices (e.g., canes, walkers, wheelchairs, and scooters typically used by people with ambulatory disability), the survey results can be analyzed to (a) examine how pedestrians, bicyclists, and people with disability perceive the impact of autonomous vehicles on themselves, and (b) compare the perception of these groups with the perception of others.

In addition to the questions on potential traffic safety impact, the survey also included a question on familiarity with autonomous vehicles. Because fully automated vehicles are still in various experimental phases, "familiarity" in this research simply means an understanding of the broad concept of autonomous vehicles rather than actual experience using autonomous vehicles. Similarly, "perception" of autonomous vehicles' traffic impact in this research simply means a general perception rather than a perception based on actual use or technological know-how of autonomous vehicles.

It is worth mentioning at the outset that the variable representing some respondents as "people with disability" in this research was derived from a survey question inquiring about the use of mobility devices instead of a question asking whether the respondents had a disability. Thus, the respondents identified as people with disability in this research are essentially afflicted by ambulatory disability and not necessarily by other types of disability recognized by the Census or the American Community Survey (e.g., hearing, visual, self-care, etc.). However, the term "people with disability" has been used throughout this report instead of "people with ambulatory disability" for the sake of brevity. It is also worth noting that the term "autonomous vehicle" has been used throughout this report, although such vehicles are also known as "self-driving cars." Finally, it is worth noting that totals in some tables in this report may not exactly match the totals one would obtain by aggregating the values shown in the tables because of rounding of weighted values.

This part of the report is divided into six sections, which describe the survey itself; the survey respondents' characteristics, including socioeconomic characteristics and familiarity with autonomous vehicles; the perception of safety regarding autonomous vehicles' potential traffic impact on various population groups; a brief discussion on the results of statistical models predicting the perception of safety; and key findings from the process.

Methodology

The primary data collection method for this research is a random digit dialing (RDD) telephone survey of New Jersey residents aged 18 or over. The survey was conducted between October 18 and 24, 2020. Although some respondents had both a cell phone and land line phone, 60% of the respondents used cell phones and 40% used land line phones to answer the survey questions. The survey generated data from 1,001 respondents with an adjusted margin of error of ±3.8% at 95% confidence level, meaning that a response reported from the survey data could have been within a range of -3.8% and +3.8% in 19 out of 20 cases.

The survey data were weighted so that the sample data become representative of the non-institutionalized adult population of New Jersey. The weighting procedure corrected the raw sample data by taking into account the differences in the distribution of sex, age, education, region, race/ethnicity, and phone use between the survey sample and New Jersey's adult population. The survey sample was highly representative of the geographic distribution of the adult population at the county level.[1]

1 The correlation coefficient (r) between the counties' actual adult population and the sample was +0.94, meaning that the two distributions are positively correlated at a very high level (r can take a maximum theoretical value of +1.0).

The Respondents

Demographic and Socioeconomic Characteristics

This section provides a description of the survey respondents regarding their demographic and socioeconomic characteristics, including sex, age, race/ethnicity, educational attainment, household income, number of vehicles in household, use of mobility devices that are typically used by people with disability, and familiarity with autonomous vehicles. A review of these characteristics is important because the key survey responses regarding the perception of traffic safety regarding autonomous vehicles will be examined for several of these population groups in a later section.

Of the 1,001 respondents, 47.7% were male and 52.3% were female. The age distribution of the respondents is shown in Table 1. As shown at the bottom of the table, 38 respondents (3.8%) refused to provide information on their age. The respondents were evenly distributed among the age groups between age 25 and age 75, but people aged below 25, 65-74, and 75+ constituted smaller proportions because of smaller population size in those age groups.

Table 1. Age of the respondents.

Age	No. of respondents	Percent, including Refused	Percent, excluding Refused
18-34	90	9.0	9.4
25-34	160	16.0	16.6
35-44	171	17.1	17.8
45-54	169	16.9	17.5
55-64	177	17.6	18.3
65-74	115	11.5	11.9
75+	81	8.1	8.4
Total excluding Refused	963	96.2	100.0
Refused	38	3.8	
Total including refused	1001	100.0	

The race and ethnicity of the survey respondents are shown in Table 2. As shown at the bottom of the table, 40 (4%) respondents were either uncertain of their race or refused to provide the information. It is to be noted that the category Hispanic excludes Hispanics identified as white or Black. When those respondents are included, the proportion of Hispanic respondents increases from 6.7% to 17.7%, whereas the proportion of white and Black respondents decreases from 65.4% and 13.3% to 58.3% and 12.1%, respectively.

The educational attainment of the respondents is shown in Table 3. At 25.9%, the respondents who completed high school but did not pursue college education constitute the largest category, followed by respondents who acquired a bachelor's degree (21.8%) and respondents who acquired graduate or professional degree (18.6%). Aggregation of the two categories with the highest level of education shows that 40.4% of the respondents have at least a bachelor's degree. Similarly, it can be estimated by aggregating categories that 30.2% of the respondents attended college but did not acquire a bachelor's degree and 3.6% did not complete high school.

Table 2. Race and ethnicity of the respondents.

Race/Ethnicity	No. of respondents	Percent, including Don't know/Refused	Percent, excluding Don't know/Refused
White	629	62.8	65.4
Black	128	12.8	13.3
Asian	68	6.8	7.1
Multi-racial	64	6.4	6.7
Hispanic	64	6.4	6.7
Other	8	0.8	0.8
Total excluding Don't know/Refused	960	96.0	100.0
Don't know/Refused	40	4.0	
Total including Don't know/Refused	1001	100.0	

Table 3. Education attainment of the respondents.

School/grade completed	No. of respondents	Percent, including Refused	Percent, excluding Refused
8th grade or less	9	0.9	0.9
Grades 9, 10 and 11	26	2.6	2.7
Grade 12	255	25.5	25.9
Vocational or technical school	45	4.5	4.6
Some College	168	16.8	17.0
2-year college/Associates degree	85	8.5	8.6
4 Year College/Bachelor's degree	216	21.6	21.8
Graduate or professional degree	184	18.4	18.6
Total excluding Refused	989	98.9	100.0
Refused	13	1.3	
Total including Refused	1001	100.0	

Table 4. Annual household income of the respondents.

Annual household income	No. of respondents	Percent, including Refused	Percent, excluding Refused
< $50K	272	27.2	30.7
$50K ≤ $100K	299	29.9	33.8
$100K ≤ $150K	151	15.1	17.0
≥ $150K+	164	16.4	18.5
Total	887	88.7	100.0
Refused	114	11.4	
Total	1001	100.0	

Table 5. Ownership or access to household vehicles.

No. of vehicles	No. of respondents	Percent, including Refused	Percent, excluding Refused
None	55	5.5	5.6
One	304	30.4	30.6
Two	372	37.2	37.4
Three or more	262	26.1	26.4
Total excluding Refused	993	99.2	100.0
Refused	8	0.8	
Total including Refused	1001	100.0	

The distribution of the respondents by annual household income is shown in Table 4. The table shows that respondents with less than $50,000 household income constitute approximately 31% of all respondents and a little over 64% belong to households with less than $100,000 income. On the whole, each income group in Table 4 includes a sufficient number of households to examine the effect of income on other survey responses.

Table 5 shows the respondents' ownership or access to household vehicles. Since the survey respondents were asked about ownership of or access to a household vehicle, the vehicles could have been leased or owned. The table shows that 5.6% of the respondents belong to households without a vehicle, whereas the large majority belong to households with at least one vehicle. The table also shows that having two vehicles is the most common practice among the respondents.

The survey did not include a question asking if the respondents had any disability, but it included a question inquiring if the respondents used any mobility devices typically used by people with an ambulatory (i.e., walking) disability. Those who mentioned that they used mobility devices were asked if they used canes, crutches, walkers, wheelchairs, or electric scooters. The responses to those questions are summarized in Table 6. It should be noted that the 75 respondents who mentioned using a mobility device are described as people with disability throughout this report.

Table 6. The use of mobility devices.

Mobility devices	Respondents*	Percent of all respondents	Percent of mobility device users
Any mobility device	75	7.6	100.0
Cane	59	5.9	78.7
Crutch	7	0.7	9.3
Walker	31	3.1	41.3
Wheelchair	9	0.9	12.0
Electric scooter	10	1.0	13.3

* Because some respondents use multiple devices, the sum is larger than 75.

Table 6 shows that 75 respondents used at least one type of mobility device, representing 7.6% of the 993 respondents (eight of the 1,001 respondents did not respond to the question). The use of canes is the most common practice among those respondents, followed by walkers. In contrast, the use of crutches, wheelchairs, and electric scooters is less common. According to the American Community Survey Public Use Microdata Samples (ACS PUMS), 12.2% of New Jersey residents aged 18+ have a disability, including cognitive, ambulatory, independent living, self-care, vision, and hearing disability. However, because the survey only inquired about the use of mobility devices that are commonly used by people with ambulatory disability, the survey respondents can be compared with the proportion of New Jersey residents who have that particular type of disability only. According to ACS PUMS, 7% of NJ residents aged 18+ have an ambulatory disability, meaning that a slightly larger proportion of the survey respondents reported using a mobility device (7.6%) than the proportion of New Jersey residents having an ambulatory disability.

Walking and Bicycling Frequency

The survey included two questions on the frequency of walking and bicycling outside. The responses to the question on walking are summarized in Table 7 and the responses to the question on bicycling are summarized in Table 8. Table 7 shows that all respondents answered the question on walking, whereas Table 8 shows that 11 respondents did not answer the question. Table 7 shows that 61.5% of the respondents walked daily or almost daily, whereas 88.3% walked outside at least several times a week. In contrast, only 0.6% never walked outside and 1.6% walked less than once a month.

As expected, Table 8 shows that the frequency of bicycling is far lower than the frequency of walking. While 65.5% of the respondents mentioned walking daily or almost daily, only 5.5% mentioned bicycling at that level of frequency. While only 0.6% of the respondents never walked outside and 1.5% walked less than once a month, 53.3% of the respondents never bicycled and another 14.8% bicycled less than once a month.

Table 7. Frequency of walking outside.

Frequency of walking	No. of respondents	Percent	Percent, excluding Refused
Daily/almost daily	615	61.5	5.6
Few days a week	268	26.8	30.6
Once a week	53	5.3	37.4
A few times a month	36	3.6	26.4
Once a month	7	0.7	100.0
Less than once a month	15	1.5	
Never	6	0.6	
Total	1001	100.0	

Table 8. Frequency of bicycling outside.

Frequency of bicycling	No. of respondents	Percent, including Refused	Percent, excluding Refused
Daily/almost daily	55	5.5	5.5
Few days a week	82	8.2	8.3
Once a week	52	5.2	5.2
A few times a month	84	8.4	8.5
Once a month	43	4.3	4.4
Less than once a month	146	14.6	14.8
Never	528	52.7	53.3
Total excluding Refused	990	98.9	100.0
Refused	11	1.1	
Total including Refused	1001	100	

Familiarity with Autonomous Vehicles

Given that the primary objective of this research is to examine people's perception of traffic safety from autonomous vehicles for pedestrians, bicyclists, and people with disability, it is important first to examine people's familiarity with autonomic vehicles. The specific question in the survey for examining people's familiarity with autonomous vehicles was: "How familiar are you with self-driving, also known as autonomous, vehicles?" The responses to the question are shown in Table 9.

Table 9 shows that 19.7% of the respondents are very familiar and 35.6% are somewhat familiar with autonomous vehicles, indicating that 55.3% are at least somewhat familiar, whereas the remaining 44.7% are either not very familiar or not at all familiar. Variations in the familiarity with autonomous vehicles is shown by the respondents' age in Figure 1, by educational attainment in Figure 2, and by race/ethnicity in Figure 3. The familiarity of people with disability is compared with others in Figure 4. A comparison of familiarity with autonomous vehicles is made in Figure 5 among people with different levels of household income. With the anticipation that people having more vehicles in household could be more familiar with autonomous vehicles, a similar comparison is made in Figure 6 among the respondents by classifying them according to the number of vehicles in household. A comparison of familiarity is made between frequent walkers and less frequent walkers in Figure 7, whereas a comparison is made between bicyclists and non-bicyclists in Figure 8.

Table 9. Familiarity with autonomous vehicles.

Familiarity	No. of respondents	Percent, including Refused	Percent, excluding Refused
Very familiar	196	19.6	19.7
Somewhat familiar	354	35.4	35.6
Not very familiar	194	19.4	19.5
Not familiar at all	250	25.0	25.2
Total excluding Refused	994	99.3	100.0
Refused	7	0.7	
Total including Refused	1001	100.0	

Figure 1 shows that the proportion of being very familiar is the highest for respondents in youngest age group, age 18-34, whereas the proportion of least familiar is the highest for age 75+. Although familiarity with autonomous vehicles seems to be generally higher for lower age groups and lower for higher age groups, Figure 1 shows that familiarity may not consistently decrease with age. That may be because some older people are more familiar with autonomous vehicles than some younger people due to education, culture, or simply curiosity.

Figure 2 shows familiarity of the respondents by educational attainment. It shows that the proportion of respondents being not at all familiar decreases with every level of educational attainment. It also shows that the proportion being very familiar is the highest and the proportion being not at all familiar is the lowest among those with the highest level of education (i.e., respondents who acquired education beyond a bachelor's degree). Although these results show that the familiarity with autonomous vehicles is generally higher for people with higher education than people with lower education, the relationship is not necessarily linear. For example, among the respondents with bachelor's degrees, about 56% are very familiar or somewhat familiar, whereas among the people who attended colleges but did not acquire a bachelor's degree, 58% are very familiar or somewhat familiar.

Figure 1. Familiarity with autonomous vehicles by respondents' age.

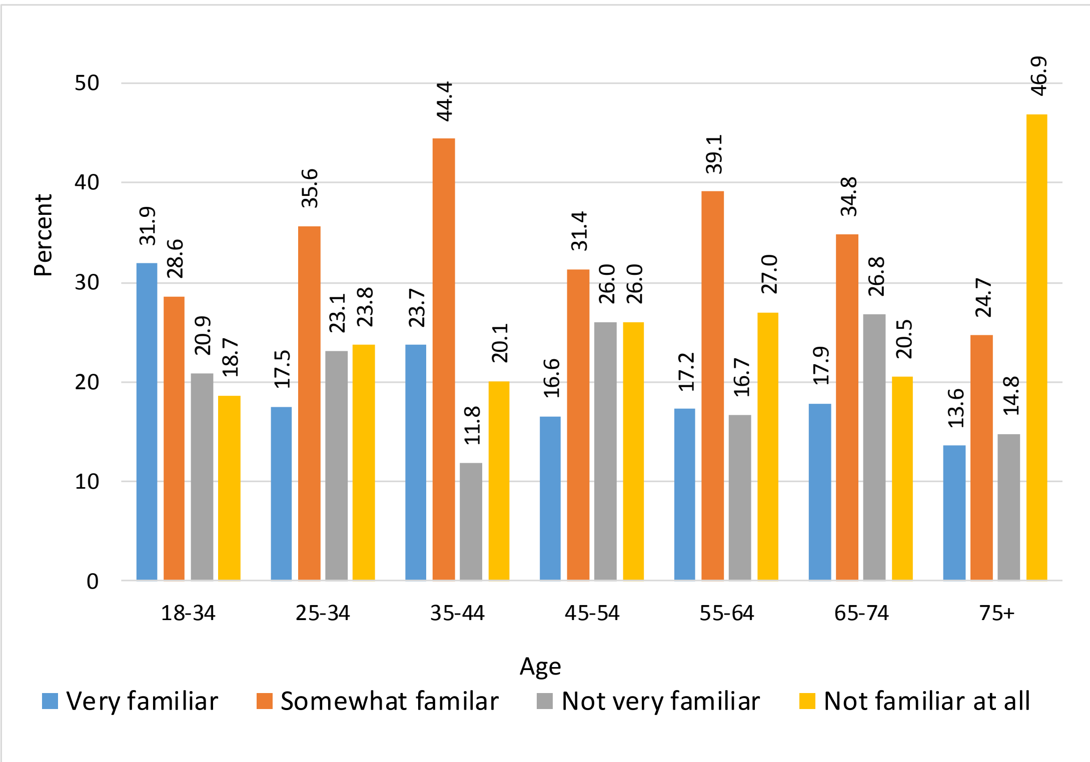


Figure 2. Familiarity with autonomous vehicles by respondents' educational attainment.

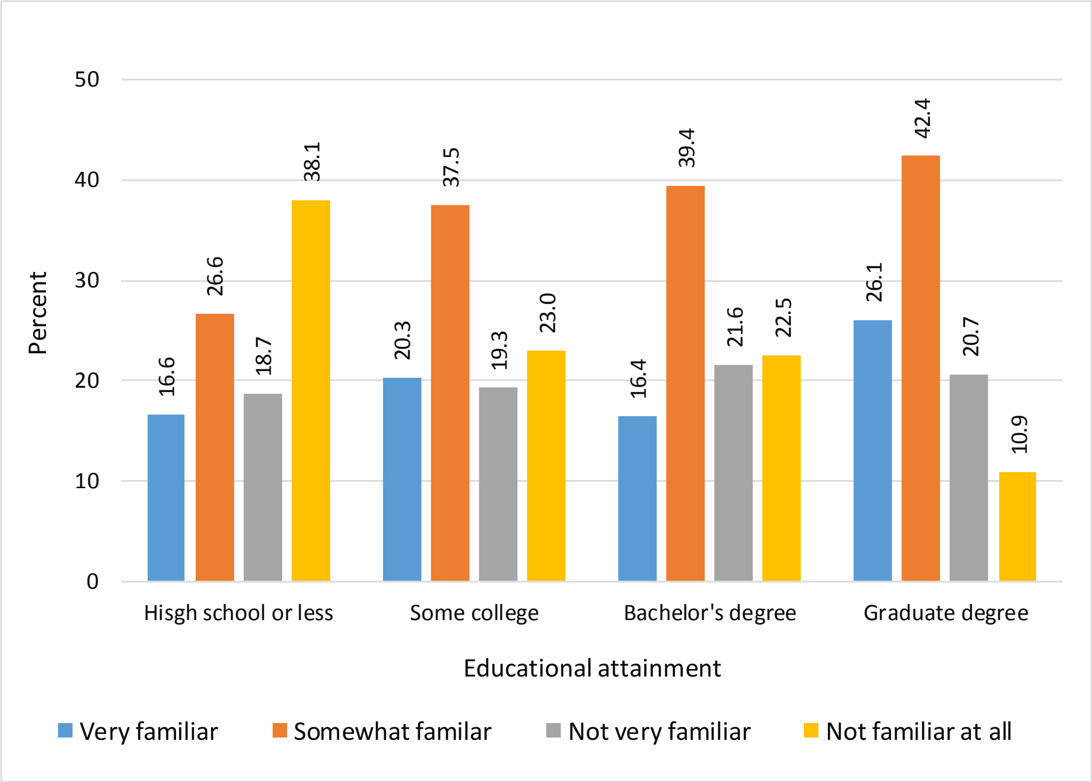


Figure 3. Familiarity with autonomous vehicles by respondents' race/ethnicity.

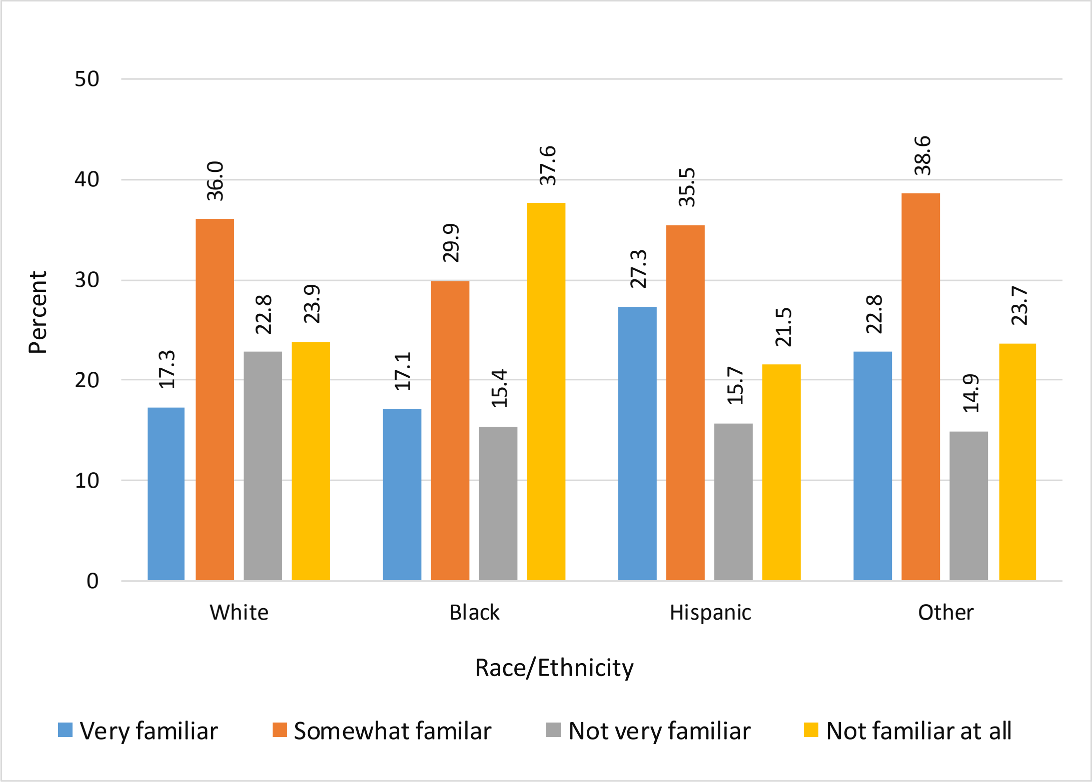


Figure 3 shows the respondents' familiarity with autonomous vehicles by race/ethnicity, where Asians were included in the "other" category and Hispanics were separated from white and Black respondents. It seems to indicate that the Hispanic respondents have the highest level of familiarity, followed by the respondents with "other" race/ethnicity. That is because the proportion of people being very familiar (27.3%) and the proportion of people being somewhat or very familiar (62.8%) is the highest for the Hispanic respondents, followed by people belonging to "other" race/ethnicity (22.8% very familiar and 61.4% very familiar or somewhat familiar). Although the proportion of respondents being not at all familiar is the highest (37.6%) for Black or African American respondents, when somewhat and very familiar are combined, the familiarity of Black respondents is only slightly lower than white respondents (47% versus 53.4%).

Figure 4 compares the familiarity with autonomous vehicles for the respondents with disability (i.e., respondents using mobility devices with respondents who mentioned not using mobility devices) with people without disability. Although one might expect people with disability to be less familiar because of the anticipation that older adults are more likely to have disability, Figure 4 shows results to the contrary: People who have disability are more familiar with autonomous vehicles than people without disability. Although the proportion of people being somewhat familiar with autonomous vehicles is nearly the same (36.5% versus 35.5%), a substantially larger proportion of people with disability are very familiar (27% versus 19.1%). When those mentioning somewhat familiar are aggregated with those mentioning very familiar, people with disability appear to be more familiar with autonomous vehicles (63.5% versus 54.6%).

Figure 4. Familiarity with autonomous vehicles by respondents' use of mobility devices.

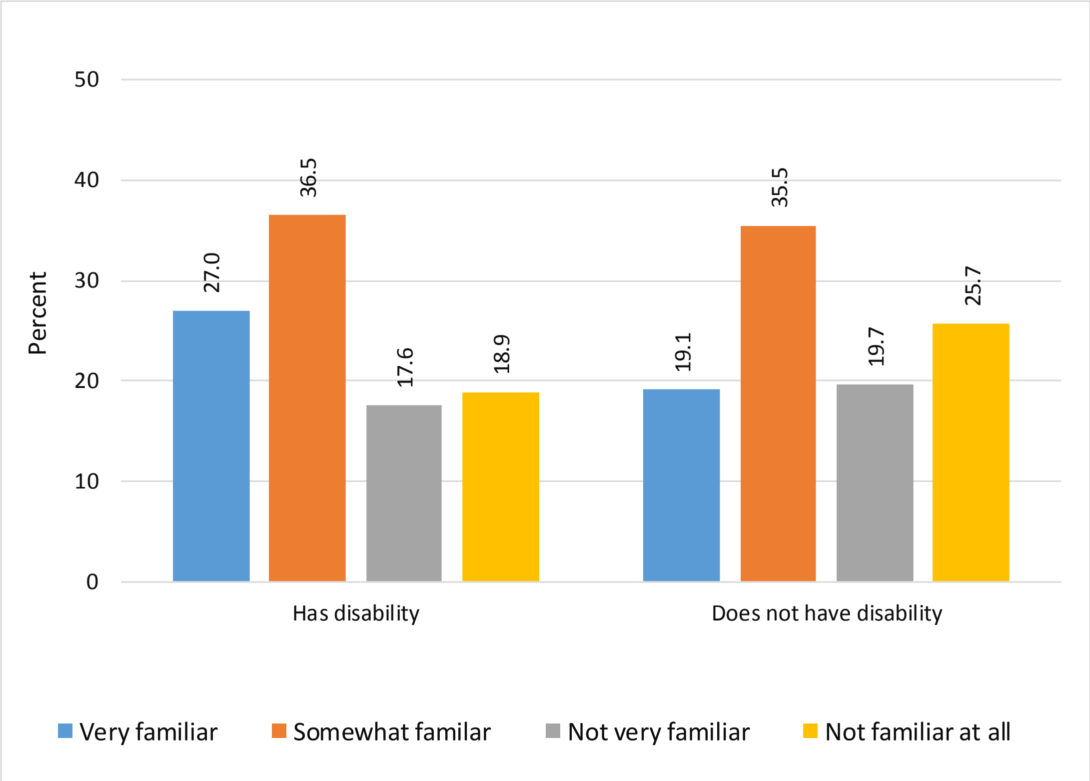


Figure 5. Familiarity with autonomous vehicles by respondents' household income.

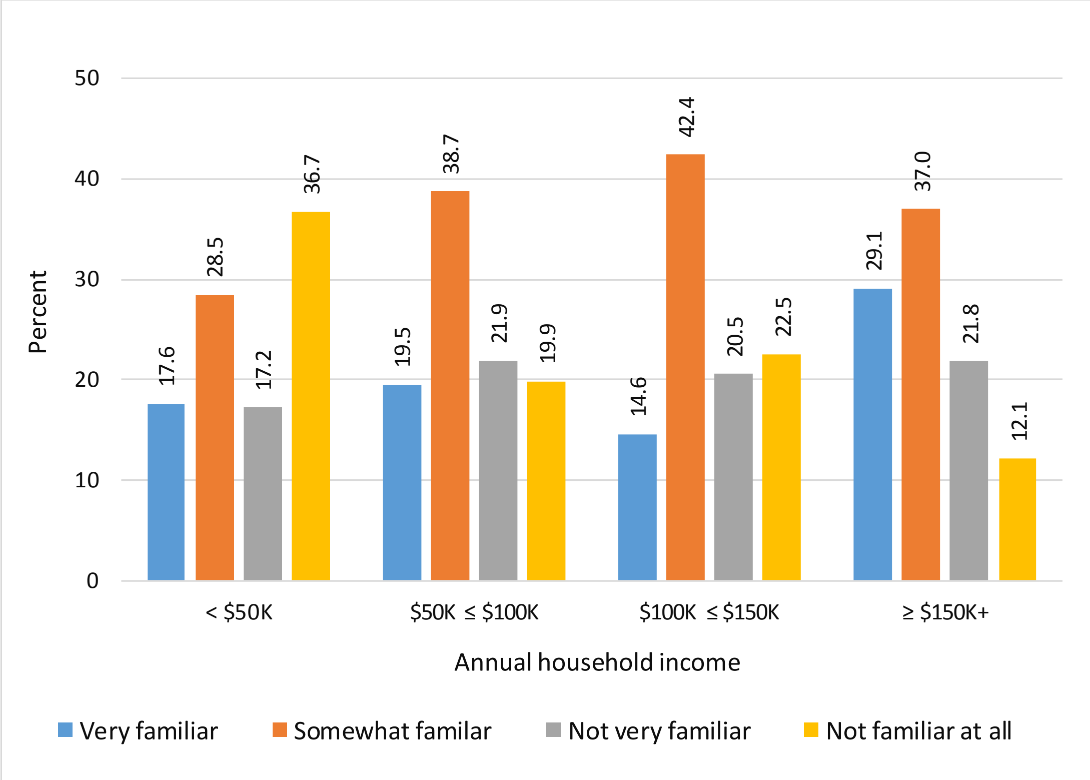


Figure 5 shows the respondents' familiarity with autonomous vehicles by household income. It shows that generally the familiarity of higher-income respondents is higher than lower-income respondents, but the difference in familiarity is the most discernible when a comparison is made between the highest- and the lowest-income respondents. While the proportion of people that are not at all familiar is the highest for the lowest-income respondents (36.7%), the proportion of people that are very familiar is the highest (29.1%) and the proportion of people not at all familiar is the lowest (12.1%) for the highest-income respondents. A reason for the greater familiarity of autonomous vehicles among the high-income respondents could be that they are more likely to be able to afford high-end vehicles having features of autonomous vehicles compared to lower-income people.

With the anticipation that people who have more cars in their households would be more familiar with autonomous vehicles, the respondents' familiarity with such vehicles was compared by classifying the respondents according to the number of vehicles they have in their households. The results are shown in Figure 6. It shows that the most distinct are those without any vehicle in their households, for the proportion of respondents that are very familiar is the lowest and the proportion of respondents that are not at all familiar is the highest among those without vehicles. When those that are not at all familiar and not very familiar are combined, the data suggest that almost 71% of the respondents with no vehicles in household are not familiar with autonomous vehicles. In contrast, among those with 3+ vehicles in household, only 41% are not familiar.

Figure 6. Familiarity with autonomous vehicles by number of vehicles in household.

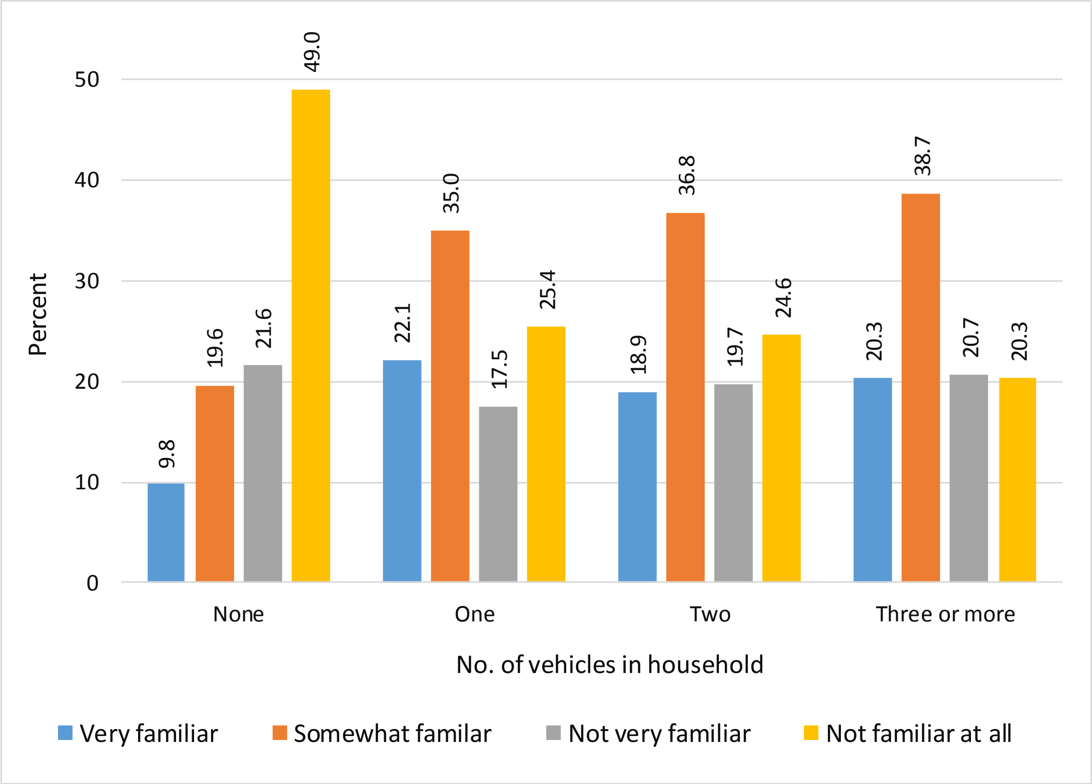
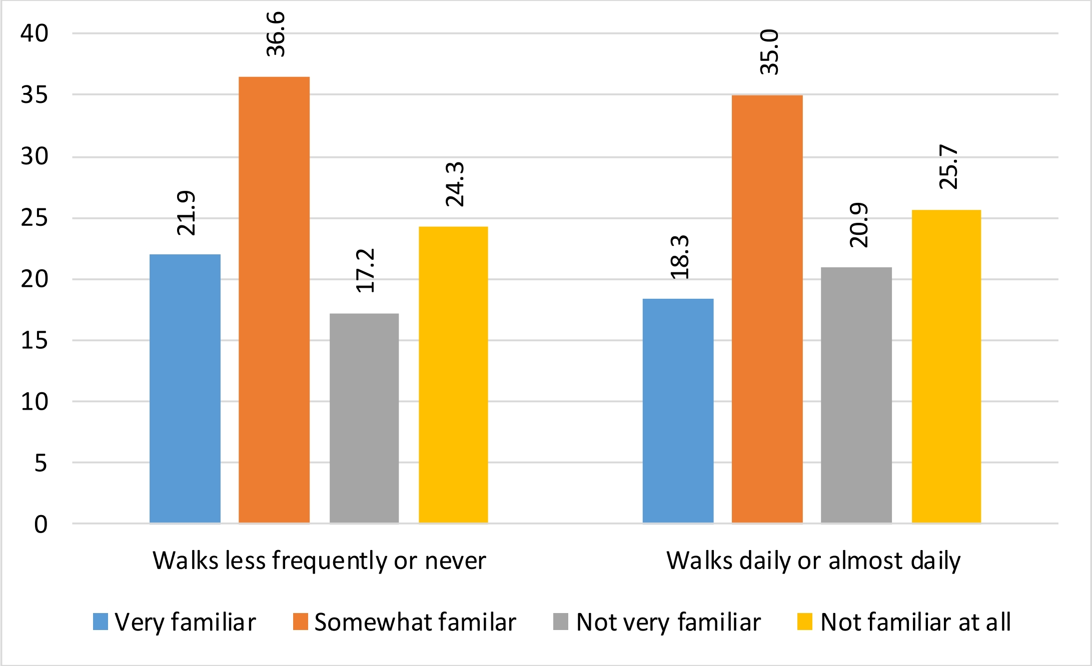


Figure 7. Familiarity with autonomous vehicles by frequency of walking.

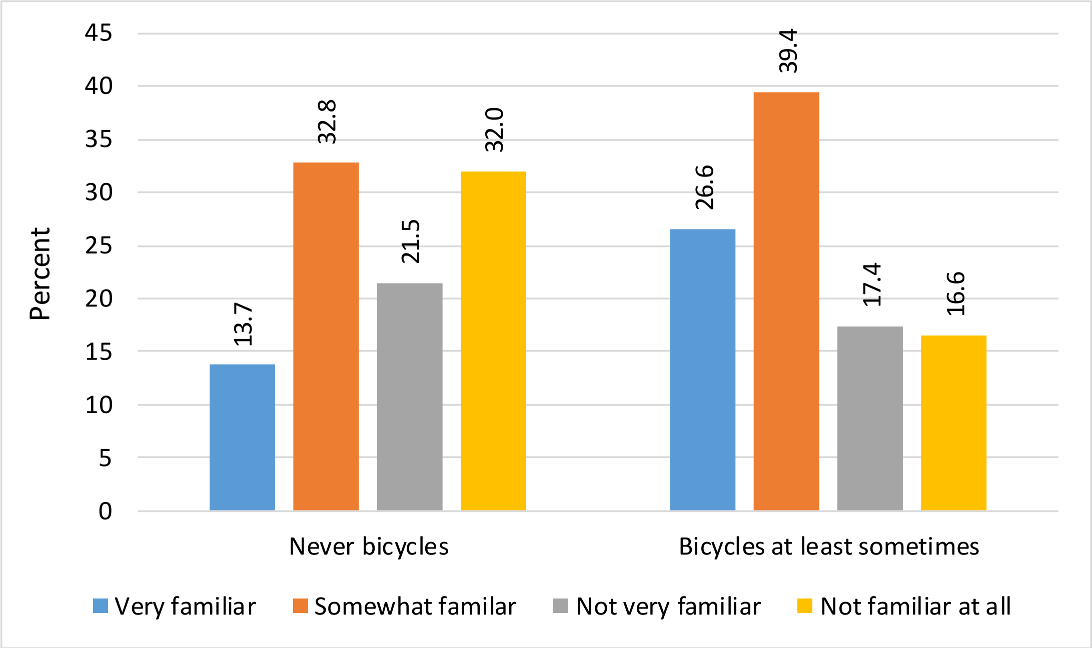


A comparison is made in Figure 7 between frequent walkers and less frequent walkers regarding their familiarity with autonomous vehicles. For this purpose, the respondents who mentioned walking daily or almost daily were considered frequent walkers and the respondents who walked less frequently were considered less frequent walkers (see Table 7 for detailed walking frequency). The figure shows that a slightly larger proportion of the less frequent walkers are familiar with autonomous vehicles compared to the frequent walkers. When very familiar and somewhat familiar are combined, 58.5% of the less frequent walkers are familiar, whereas 53.4% of the frequent walkers are familiar.

A comparison of familiarity with autonomous vehicles is made in Figure 8 between bicyclists and non-bicyclists. The respondents who mentioned never bicycling were considered non-bicyclists, whereas the respondents who mentioned bicycling at least sometimes were considered bicyclists (see Table 8 for detailed bicycling frequency). Figure 8 shows that bicyclists are far more familiar with autonomous vehicles than non-bicyclists. For example, almost twice as many bicyclists mentioned being very familiar with autonomous vehicles as non-bicyclists (36.6% bicyclists versus 13.7% non-bicyclists). When the respondents mentioning very familiar and somewhat familiar are combined, 66% of the bicyclists compared to only 46.5% of the non-bicyclists are familiar. Thus, while frequent walkers are modestly less familiar with autonomous vehicles than less frequent walkers, bicyclists are substantially more familiar than non-bicyclists.

It is worth mentioning that the survey data also included a question on political party affiliation. The analysis of familiarity showed that the difference in familiarity with autonomous vehicles is very small when categorized by political party. For Democrat, Independent, and Republican respondents, the proportion familiar (sum of very and somewhat familiar) is 54.8%, 55.2%, and 55.6%, respectively. Given this similarity, the results are not shown graphically.

Figure 8. Familiarity with autonomous vehicles by frequency of bicycling.



To sum up, the comparison of familiarity with autonomous vehicles for various population groups shows mostly expected results. For example, younger respondents are generally more familiar than older respondents, highly educated respondents are more familiar than less educated respondents, respondents with higher income are more familiar than respondents with lower income, and respondents with more vehicles in their households are more familiar than respondents with less vehicles. The results also show that frequent walkers are modestly less familiar with autonomous vehicles than less frequent walkers, whereas bicyclists are substantially more familiar than non-bicyclists. However, the comparison among racial/ethnic groups and between respondents with and without disability did not show expected results. It is also worth noting that even when a discernible pattern of familiarity is shown by a comparison, the observed relationships do not necessarily indicate a linear relationship. For example, although people with high income are more familiar with autonomous vehicles, it is not as if familiarity is higher for every higher income level than every lower income level. The same can be said of age, education, and number of vehicles in household. Differences in familiarity are evident primarily between the extreme levels of these variables (e.g., highest age versus lowest age, no vehicles in household versus 3+ vehicles in household, highest income versus lowest income, etc.).

Safety Perception of Autonomous Vehicles

The most important question in the survey was about the traffic safety perception of autonomous vehicles. The exact text of the question was, "Please tell me if you think self-driving vehicles will increase traffic safety, decrease traffic safety, or not make much of a difference to traffic safety in New Jersey for each of the following groups?" followed by the mention of pedestrians, bicyclists, and people with disability. The three population categories were randomized in the RDD survey so that the order of the categories changed from respondent to respondent. It is worth noting that the specific language to describe people with disability in this context was "those who are disabled and/or use a mobility device or aid."

The responses to the question on perceived traffic safety from autonomous vehicles for people with disability, pedestrians, and bicyclists are shown in Table 10. The top part of the table shows the responses for all respondents, the middle part shows the responses of the those who are very familiar or somewhat familiar with autonomous vehicles, and the bottom part shows the responses of those who are not very familiar or not at all familiar with such vehicles. For simplicity's sake, the respondents who are "very familiar" or "somewhat familiar" have been termed "more familiar" and the respondents who are "not very familiar" or "not at all familiar" have been termed "less familiar" in the discussion below.

Several important observations can be made from Table 10. First, the respondents generally (i.e., all respondents combined) perceive that autonomous vehicles will substantially improve traffic safety for people with disability, moderately worsen traffic safety for bicyclists, and slightly worsen safety for pedestrians. This can be inferred from the fact that 41.6% of all respondents believe that such vehicles will improve safety for people with disability compared to only 31% who believe they will worsen their safety (a difference of +10.6 percent points), 32.2% believe that such vehicles will improve safety for bicyclists compared to 38.8% who believe they will worsen bicyclist safety (a difference of -6.6 percent points), and 33.9% believe that autonomous vehicles will improve safety for pedestrians compared to 34.8% who believe they will worsen pedestrian safety (a difference of -0.9 percent points). A reason for more respondents believing that autonomous vehicles will improve traffic safety for people with disability, but not for pedestrians and bicyclists, could be that the respondents perceived people with disability as potential users of autonomous vehicles (i.e., as passengers) as well as pedestrians, but they did not perceive pedestrians and bicyclists as potential autonomous vehicle users.

Second, the perception that autonomous vehicles will improve traffic safety for people with disability is held by all respondents combined, the respondents with more familiarity with autonomous vehicles, as well as the respondents with less familiarity. However, the perception that autonomous vehicles will improve traffic safety for people with disability is more noticeable among people more familiar with autonomous vehicles

Table 10. Perception of traffic safety from autonomous vehicles.

	Person with disability		Pedestrian		Bicyclist	
Respondent category	**Respondents**	**Percent**	**Respondents**	**Percent**	**Respondents**	**Percent**
All respondents						
Increase traffic safety	415	41.6	338	33.9	320	32.2
Decrease traffic safety	309	31.0	347	34.8	386	38.8
Make no difference	200	20.1	232	23.3	219	22.0
Don't know	72	7.2	79	7.9	70	7.0
Total	997	100.0	996	100.0	995	100.0
Respondents more familiar with autonomous vehicles						
Increase traffic safety	261	47.7	221	40.4	202	37.1
Decrease traffic safety	167	30.5	188	34.4	214	39.3
Make no difference	95	17.4	112	20.5	103	18.9
Don't know	24	4.4	26	4.8	26	4.8
Total	547	100.0	547	100.0	545	100.0
Respondents less familiar with autonomous vehicles						
Increase traffic safety	152	34.3	115	25.9	116	26.2
Decrease traffic safety	137	30.9	157	35.4	171	38.6
Make no difference	106	23.9	118	26.6	113	25.5
Don't know	48	10.8	54	12.2	43	9.7
Total	443	100.0	444	100.0	443	100.0

(47.7%) than among people with less familiarity (34.3%). Third, people with more familiarity with autonomous vehicles are more optimistic about traffic safety from such vehicles than people with less familiarity. Irrespective of whether it is about people with disability, pedestrians, or bicyclists, a larger proportion of the more familiar respondents believe that such vehicles will improve safety compared to the less familiar respondents.

Fourth, for all respondents combined, the negative perception of the effect of autonomous vehicles on bicyclists is more discernible than the negative perception of the effect on pedestrians. While the net difference between those who perceive a positive effect and a negative effect is only 0.9 percentage points regarding pedestrian safety, the difference is 6.6 percentage points regarding bicyclist safety. Fifth, although for all respondents, the proportion of people perceiving a positive effect on pedestrians is slightly smaller than the proportion perceiving a negative effect (33.9% positive versus 34.8% negative), a substantially greater proportion of the respondents who are more familiar with autonomous vehicles have a positive perception about pedestrian safety (40.4%) than a negative perception (34.4%). However, even among the familiar respondents, the proportion with a negative perception is larger than the proportion with a positive perception regarding bicyclist safety (37.1% positive versus 39.3% negative). Finally, the most important observation for the analysis of safety perception is that people who are more familiar with autonomous vehicles are more optimistic about their positive safety impact on people with disability, pedestrians, and bicyclists than people who are less familiar.

The perception of autonomous vehicles' safety impact on persons with disability, pedestrians, and bicyclists was also analyzed by taking into account the survey respondents' demographic and socioeconomic classification. For the comparison between population groups, the respondents whose response was "Don't know" regarding the impact of autonomous vehicles were omitted. Some of the categories of personal characteristics were also combined so that the distinctions were more discernible. For example, although the survey collected data on the respondents' age, education, and household income by using several categories of each variable, the categories were collapsed to create simplified variables with two or two or three categories (e.g., Age 45+ or lower; Bachelor's degree+ or lower; Income < $50K+, $50K ≤ $150K, $150K+; etc.).

Figure 9 shows the perception of autonomous vehicles' potential impact on people with disability, pedestrians, and bicyclists by sex of the respondents. The figure clearly shows that a greater proportion of females perceive autonomous vehicles to be less safe than males. For all three categories, the proportion of females who believe that autonomous vehicles will decrease safety is greater than the proportion of males, whereas the proportion of females who believe that autonomous vehicles will increase safety is smaller than the proportion of males. This may reflect a greater apprehension of women about traffic safety in general, which has been documented by many studies on gender differences in bicycling.

Figure 10 shows the perception of traffic safety from autonomous vehicles by the age of the respondents, where respondents have been classified into two age groups: Age < 45, and Age 45+. As expected, the figure shows that a larger proportion of younger adults believe autonomous vehicles will be safer compared to older adults. For all three categories of potentially vulnerable people—people with disability, pedestrians, and bicyclists—a larger proportion of younger adults believes autonomous vehicles will increase safety and a smaller proportion believes that they will decrease safety compared to people of older ages.

Figure 11 shows the perception of safety from autonomous vehicles by educational attainment of the respondents, where the respondents' educational attainment has been classified into two categories: A bachelor's degree or higher level of education, or less than a bachelor's degree. It shows that people with a bachelor's degree or higher are more optimistic about

Figure 9. Perception of safety from autonomous vehicles for people with disability, pedestrians, and bicyclists by sex of respondents.

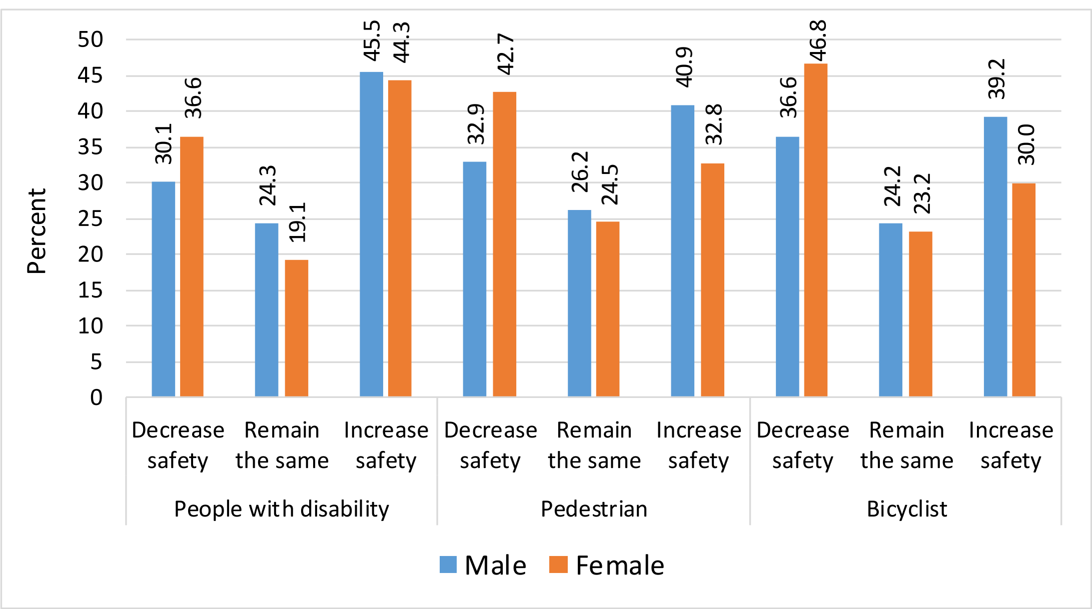


Figure 10. Perception of safety from autonomous vehicles for people with disability, pedestrians, and bicyclists by age of respondents.

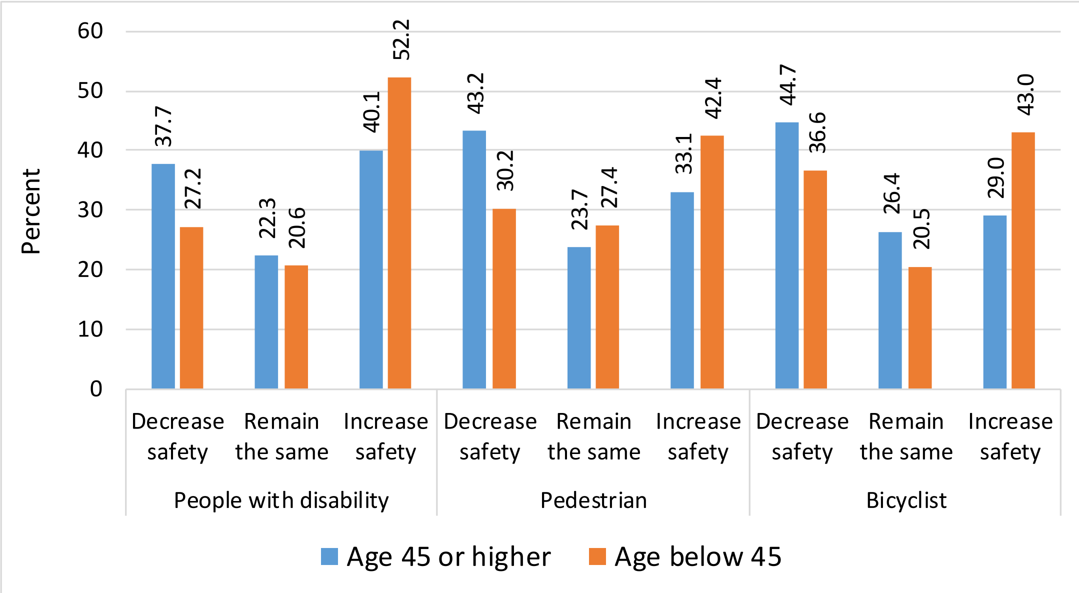
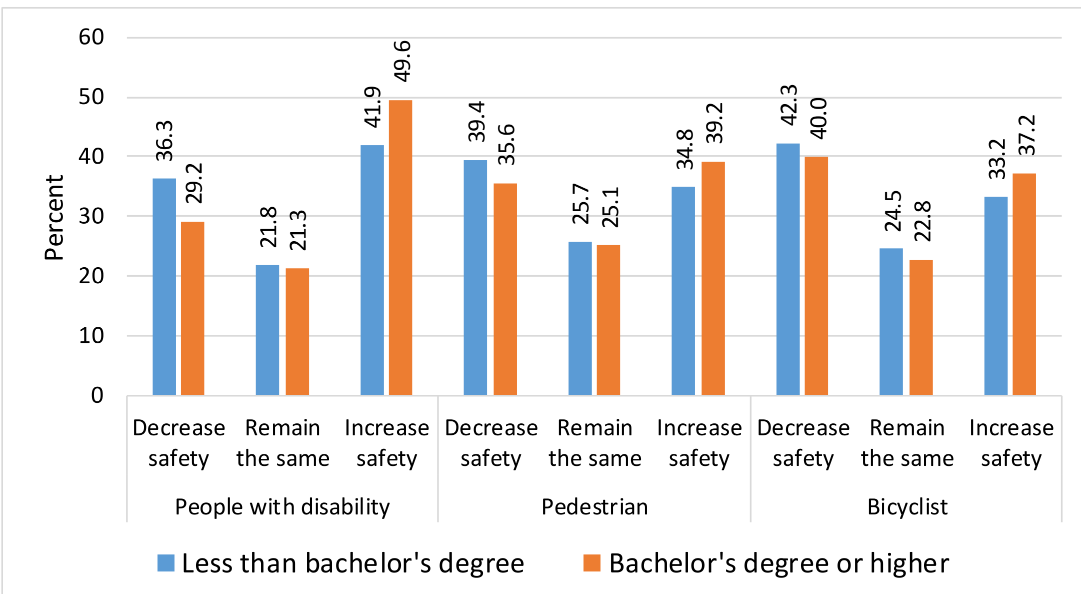


Figure 11. Perception of safety from autonomous vehicles for people with disability, pedestrians, and bicyclists by educational attainment of respondents.



the safety of autonomous vehicles than people with a lower level of education. That can be inferred from the fact that, compared to the respondents with less than a bachelor's degree, a substantially smaller proportion of respondents with a bachelor's degree or higher level of education believe autonomous vehicles will decrease traffic safety, whereas a larger proportion believes such vehicles will increase traffic safety. Although the respondents with a higher level of education are more optimistic about the safety from autonomous vehicles than the respondents with a lower level of education, it is noteworthy that the differences between the two groups in Figure 11 are not as substantial as the differences between males and females shown in Figure 9, or the differences between younger and older adults shown in Figure 10.

Figure 12 shows the perception of safety for people with disability, pedestrians, and bicyclists for three racial/ethnic groups: Whites, Blacks, and Hispanics. The category termed "other" is intentionally excluded because it includes diverse populations such as Asians and mixed-race respondents. It is evident from Figure 12 that the differences in perception of safety from autonomous vehicles among the racial/ethnic categories are not as distinct as they are between males and females, younger and older respondents, or between highly educated people and less educated people. One of the observations from Figure 12 is that the proportions of all three racial/ethnic groups who believe that autonomous vehicles will increase traffic safety for people with disability are greater than the proportions of those who believe such vehicles will decrease safety. The results are more ambiguous regarding safety for pedestrians and bicyclists. Yet, a distinction between white respondents and Black and Hispanic respondents regarding pedestrian safety perception is noticeable. Among white respondents, the proportion believing that autonomous vehicles will increase pedestrian safety is smaller than the proportion believing that such vehicles will decrease pedestrian safety, but the proportion of both Black and Hispanic respondents believing that autonomous vehicles will increase pedestrian safety is larger than the proportion believing that such vehicles will decrease pedestrian safety. One can hypothesize from these results that a greater propensity to walk by Black and Hispanic respondents could be the reason for the discrepancy.

A comparison is made in Figure 13 between respondents with disability and respondents without disability regarding the perception of traffic safety from autonomous vehicles for people with disability, pedestrians, and bicyclists. It shows that a larger proportion of respondents with disability perceive that autonomous vehicles will decrease safety for people with disability compared to respondents without disability (41.4% versus 32.7%), and a smaller proportion of the respondents with disability perceive such vehicles will increase safety compared to the respondents without disability (35.7% versus 45.7%). Such a clear distinction between respondents with disability and without disability is absent regarding traffic safety for pedestrians and bicyclists. For example, regarding pedestrian safety, almost a similar proportion of respondents with

Figure 12. Perception of safety from autonomous vehicles for people with disability, pedestrians, and bicyclists by racial/ethnic identity of respondents.

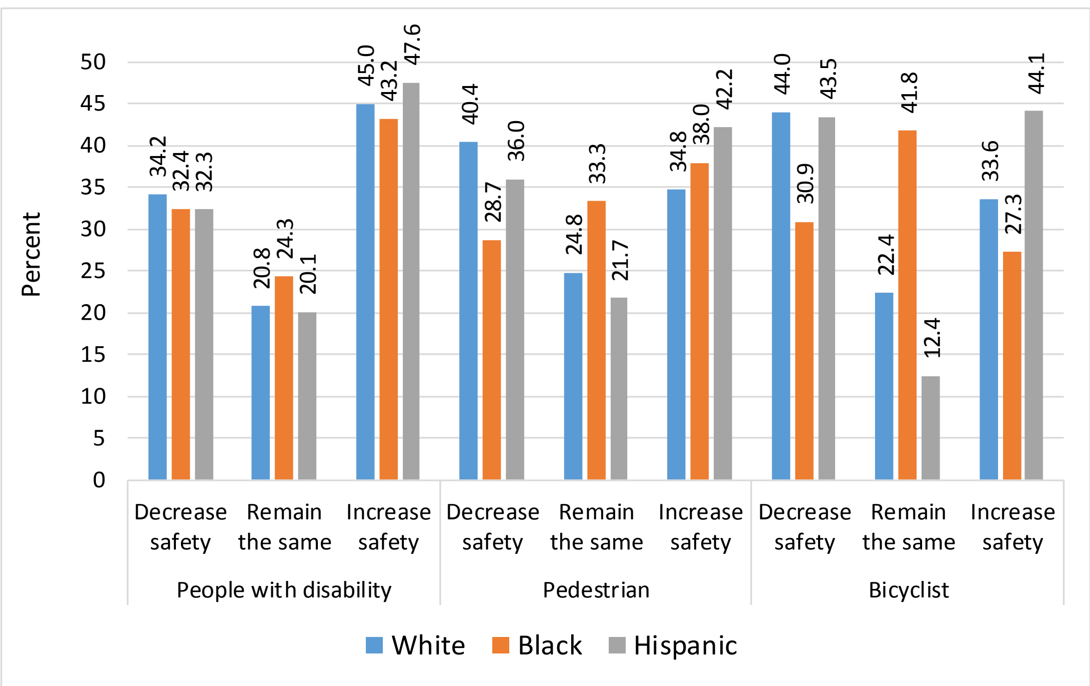


Figure 13. Perception of safety from autonomous vehicles for people with disability, pedestrians, and bicyclists by disability status.

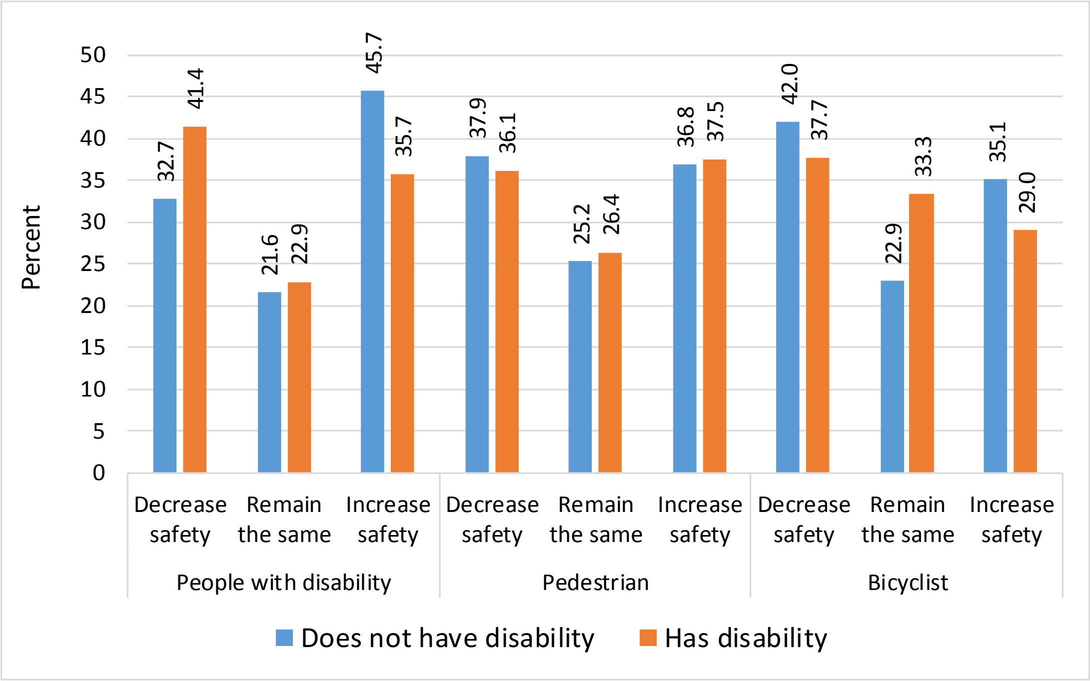
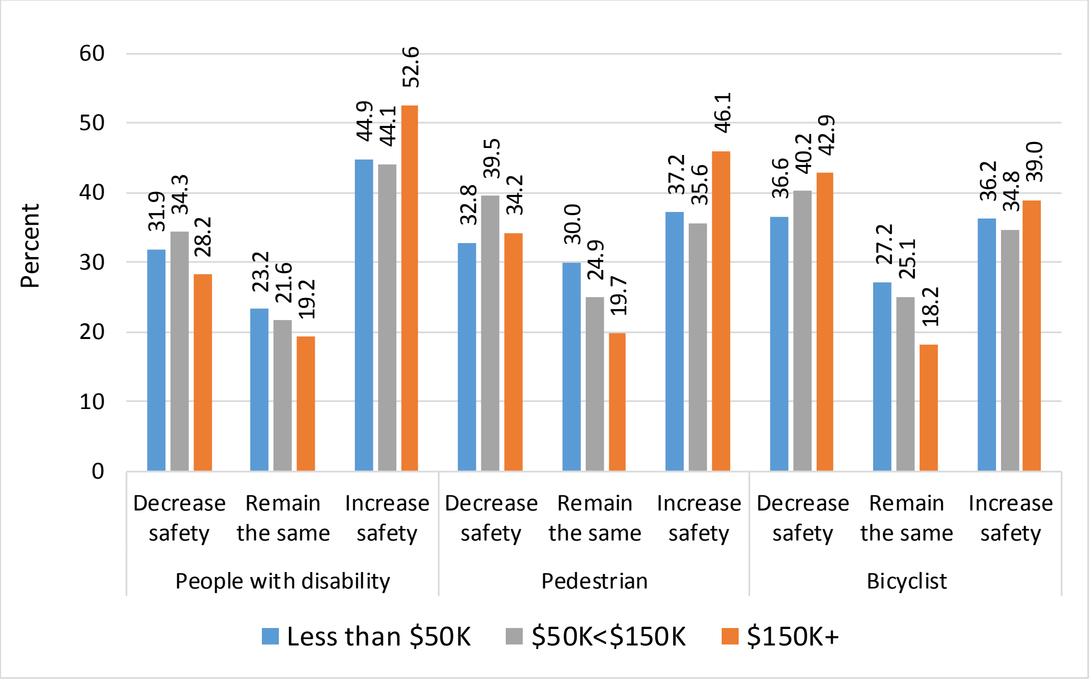


Figure 14. Perception of safety from autonomous vehicles for people with disability, pedestrians, and bicyclists by household income.

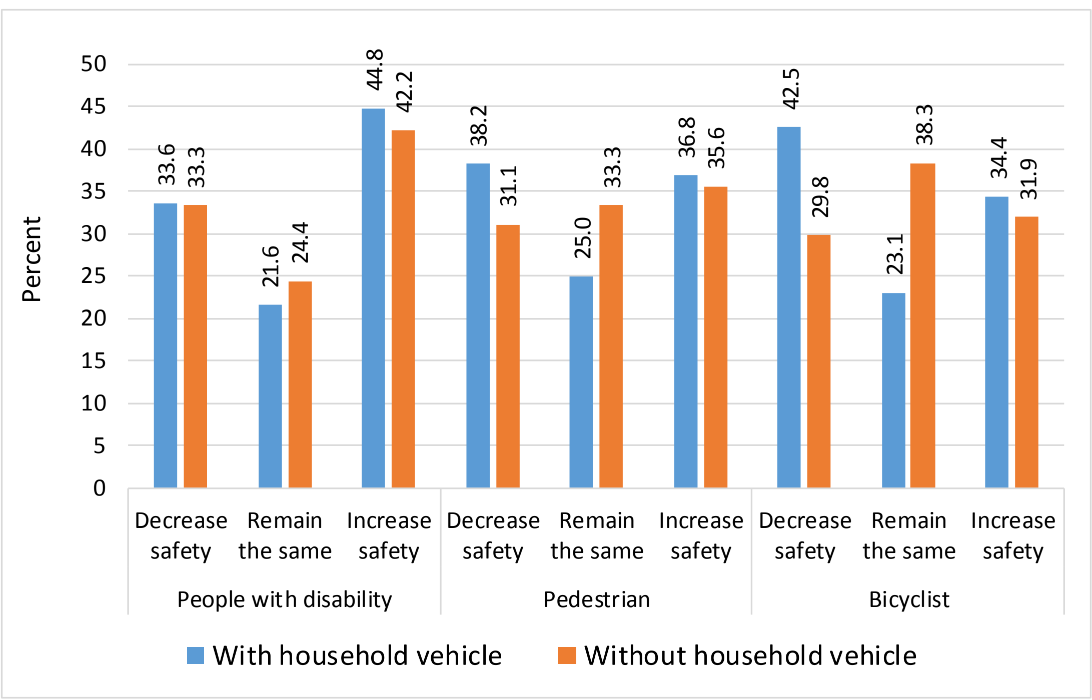


disability and without disability believe that autonomous vehicles will increase pedestrian safety. The proportion of those believing that autonomous vehicles will decrease pedestrian safety is only slightly larger for the respondents without disability. Regarding bicycling safety, the proportion of respondents believing that autonomous vehicles will decrease safety is much larger for the respondents with disability and without disability than the proportion of both groups believing that they will increase safety. However, a clear distinction does not emerge from the comparison because the proportion of respondents among the respondents without disability is larger than the proportion of respondents with disability for both increase and decrease of traffic safety (because a large proportion of the respondents with disability are neutral).

Figure 14 shows the perception of traffic safety for people with disability, pedestrians, and bicyclists by classifying the respondents into three household income groups: Less than $50K (low income), $50K<$150K (medium income), and $150K+ (high income). It shows that a far larger proportion of all three income groups believe that autonomous vehicles will increase traffic safety for people with disability (44.9%, 44.1%, and 52.6%, respectively for low, medium, and high income) compared to the proportion believing that they will decrease safety (31.9%, 34.3%, and 28.2%, respectively). Regarding pedestrian safety, only for the respondents with medium income, the proportion believing that autonomous vehicles will decrease safety is larger than the proportion believing that they will increase safety (39.5% versus 35.6%), whereas for both low-income and high-income respondents, the proportion believing that such vehicles will increase safety is larger than the proportion believing that they will decrease safety. Regarding traffic safety for bicyclists, a larger proportion of respondents in all three income groups believe autonomous vehicles will decrease safety instead of increasing safety, but the proportion of low-income respondents perceiving a decrease is only slightly larger than the proportion perceiving an increase (36.6% versus 36.2%).

A comparison is made in Figure 15 between the respondents who have no vehicle in their households (i.e., zero-vehicle households) with respondents who have at least one vehicle regarding their perception of safety from autonomous vehicles on people with disability, pedestrians, and bicyclists. It shows

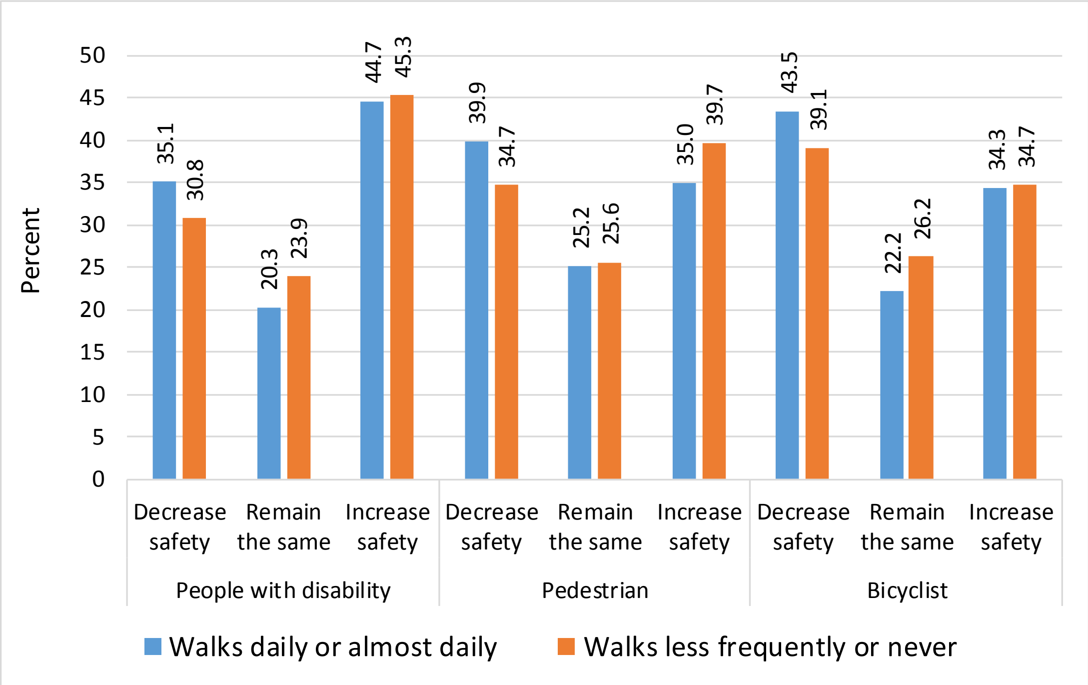
Figure 15. Perception of safety from autonomous vehicles for people with disability, pedestrians, and bicyclists by presence and absence of vehicle in household.



only a modest difference between the two groups of respondents regarding the perception of safety for all three population groups. For example, a smaller proportion of respondents of both groups of respondents believe that autonomous vehicles increase safety for people with disability compared to those who believe such vehicles will decrease safety, and the difference between the two groups is very small (33.6% and 33.3% believe safety will decrease, whereas 44.8% and 42.2% believe safety will increase). Regarding pedestrian safety, a smaller proportion of respondents without vehicles (31.1%) believe autonomous vehicles will decrease safety compared to respondents with household vehicles (38.2%), but a smaller proportion of the former group also believe autonomous vehicles will increase safety than the latter group (35.6% and 36.8%, respectively). Similarly, regarding safety for bicyclists, a larger proportion of respondents from households with vehicles believe that autonomous vehicles will decrease safety compared to respondents from households without vehicles, but a larger proportion of the former group also believe that such vehicles will increase safety. Thus, among the respondent groups compared so far, the distinction in safety perception seems to be the weakest between respondents with vehicles in household and respondents without vehicles in household.

A comparison is made in Figure 16 between the respondents who walk regularly and the respondents who walk less often regarding their perception of safety from autonomous vehicles. To make a distinction between regular walkers and others, those who mentioned walking daily or almost daily were considered frequent walkers, whereas respondents who walked less often or did not walk at all were considered less frequent walkers (see Table 7 for detailed classification of walking frequency in the survey). Regarding safety for people with disability, the figure shows that a larger proportion of the frequent walkers believe that autonomous vehicles will decrease safety compared to less frequent walkers (35.1% versus 30.8%, respectively), whereas the proportion of respondents believing that such vehicles will increase safety is almost identical for the two groups of respondents (44.7% versus 45.3%). Regarding pedestrian safety also, a larger proportion of frequent walkers believe that autonomous vehicles will decrease safety compared to less frequent walkers (39.9% versus 34.7%), and a smaller proportion of the former group believe that such autonomous vehicles will increase safety compared the latter group (35% versus 39.7%). Regarding safety for bicyclists also, a larger proportion of frequent walkers believe that autonomous vehicles will decrease safety compared to

Figure 16. Perception of safety from autonomous vehicles for people with disability, pedestrians, and bicyclists by respondents' walking frequency.



less frequent walkers (43.5% versus 39.1%), whereas the proportion of frequent walkers and less frequent walkers believing that autonomous vehicles will increase safety is almost identical (34.3% and 34.7%). On the whole, the comparison of safety perception between frequent walkers and less frequent walkers suggests that people who walk frequently are more apprehensive about an adverse safety impact of autonomous vehicles on people with disability, pedestrians, and bicyclists than less frequent walkers. The frequent walkers' greater apprehension about an adverse safety impact of autonomous vehicles is consistent with the greater apprehension of the respondents with disability about such vehicles' adverse impact on people with disability.

A comparison is made in Figure 17 between the respondents who bicycle at least sometimes with the respondents who never bicycle regarding their perception of autonomous vehicles' impact on people with disability, pedestrians, and bicyclists. To make a distinction between bicyclists and non-bicyclists, the respondents who mentioned never bicycling were considered non-bicyclists, whereas those who bicycled at least sometimes were considered bicyclists (see Table 8 for detailed bicycling frequency). The figure shows that for both bicyclists and non-bicyclists, the proportion believing that autonomous vehicles will increase safety for people with disability is larger (48.6% and 41.3%) than the proportion believing that they will decrease safety (30.4% and 36.3%). However, among the bicyclists, the difference in the proportion of those believing in increase in safety and those believing in a decrease in safety is larger, indicating that bicyclists are more optimistic about the safety impact of autonomous vehicles on people with disability than non-bicyclists.

A clear distinction between bicyclists and non-bicyclists is evident regarding the perception of safety for pedestrians as well. While a larger proportion of non-bicyclists believe that autonomous vehicles will decrease safety for pedestrians (40.3% of non-bicyclists versus 35.7% of bicyclists), a larger proportion of bicyclists believe that they will increase safety (33.1% for non-bicyclists versus 40.4% of bicyclists). Regarding safety for bicyclists, the bicyclists are almost evenly divided; while 40.2% of them believe that autonomous vehicles will decrease bicyclists' safety, 39.8% believe that they will increase safety. In contrast, a far larger proportion of non-bicyclists believe that autonomous vehicles will decrease safety for bicyclists (43.6%) instead of increasing safety (29.3%). Thus, although bicyclists are evenly split about a potential positive or negative safety impact of autonomous vehicles on bicyclists, non-bicyclists are

Figure 17. Perception of safety from autonomous vehicles for people with disability, pedestrians, and bicyclists by respondents' bicycling frequency.

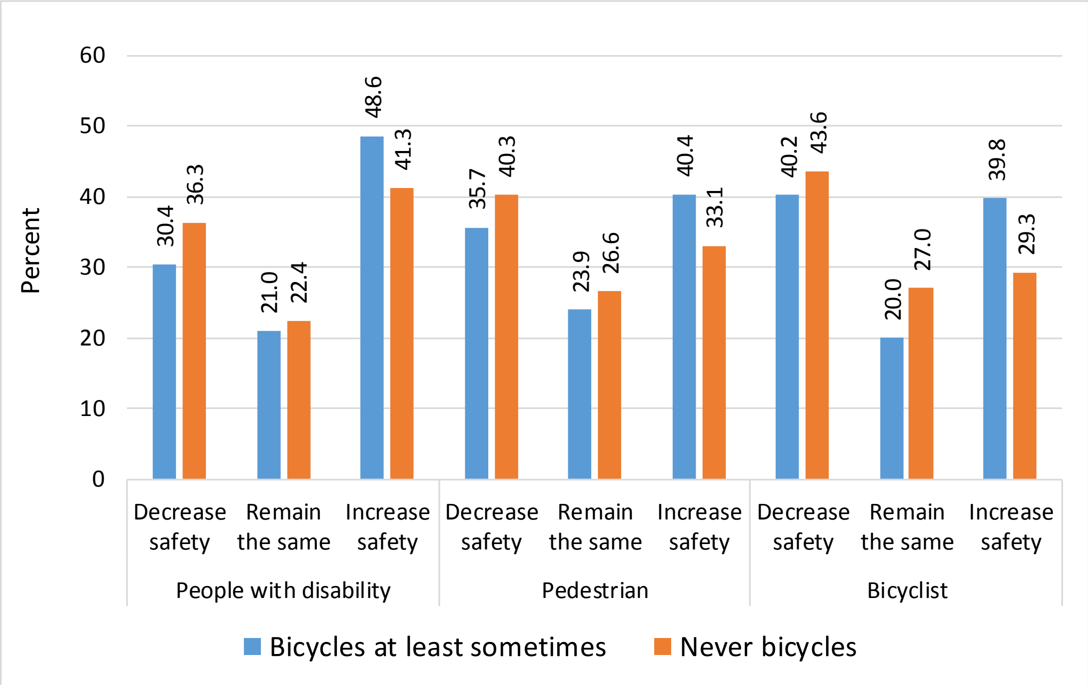
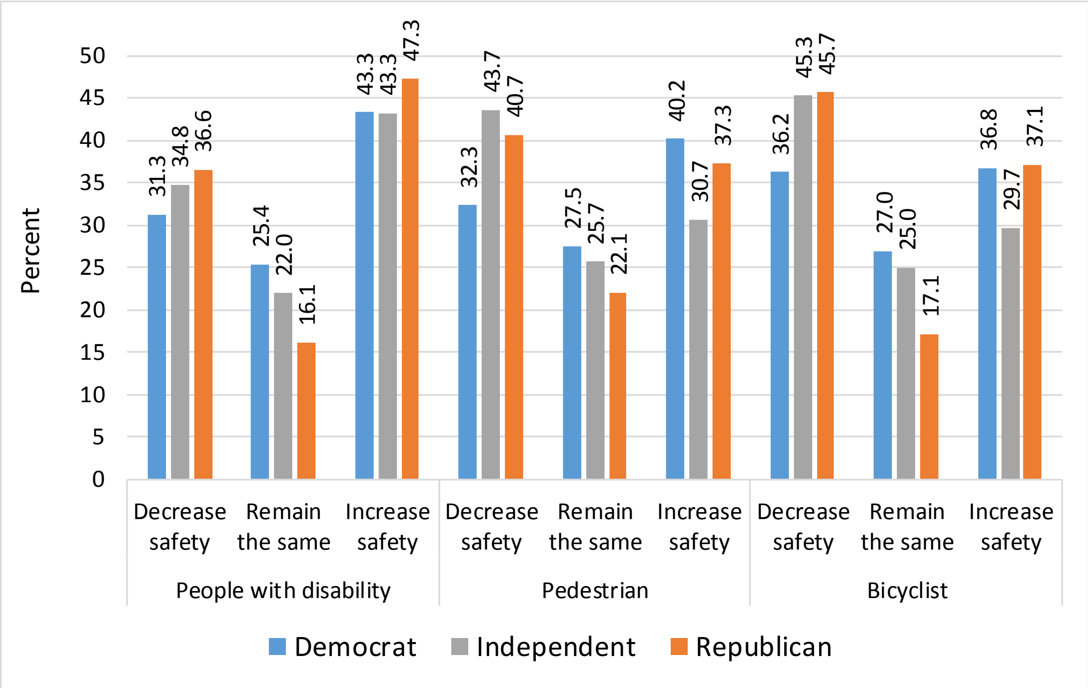


Figure 18. Perception of safety from autonomous vehicles for people with disability, pedestrians, and bicyclists by respondents' political party affiliation.



far more apprehensive about their negative impact on bicyclists. On the whole, bicyclists appear to be more optimistic about the safety impact of autonomous vehicles because they are also less apprehensive about the negative impact on people with disability and pedestrians compared to non-bicyclists. A reason for bicyclists' lower apprehension about autonomous vehicles' safety impact could be their bicycling experience in challenging traffic conditions, whereas non-bicyclists' greater apprehension could be their lack of experience or fear of being exposed to traffic.

Finally, Figure 18 shows the perception of safety from autonomous vehicles by the respondents' political party affiliation. The figure shows no clear distinction between Democrats, Republicans, and Independents. Regarding safety for people with disability, for example, the figure shows that a substantially larger proportion of all three groups believe that autonomous vehicles will increase safety. Regarding safety for pedestrians and bicyclists also, the differences in responses do not show any pattern. The only noticeable pattern is that the proportion of Democrats believing that autonomous vehicles will decrease safety is smaller than the proportion of Republicans regarding all three vulnerable population groups. However, the proportion of Democrats believing that autonomous vehicles will increase safety is not correspondingly higher.

Statistical Modeling

The discussions above on the association between various characteristics of the survey respondents and the perception of the safety impact of autonomous vehicles on the three vulnerable population groups were based on simple cross-tabulation without any statistical tests or models. Although such analyses can provide useful insights about the potential effects of those characteristics on the perception of safety, they do not provide a complete understanding of the effects because such analyses do not control for the respondents' other characteristics. When the respondents' other characteristics are not controlled for, the results can sometimes be misleading.

To obtain a more comprehensive understanding of the effects of the variables on the perception of safety impact on the three vulnerable population groups, three ordered probit models were used. The dependent variable of each model was obtained from the response to the survey question on perception, which had three categories: (a) increase safety, (b) safety will remain the same, and (c) decrease safety. In addition to the variables on the characteristics of the respondents, two explanatory variables were included in the models that represented the characteristics of the municipalities where the respondents lived. These two variables were socioeconomic status and built environment. In all three models, three dummy explanatory variables were included: bicyclist (i.e., one who bicycles at last sometimes), frequent walker (i.e., one who walks daily or almost daily), and people with ambulatory disability (i.e., people who use mobility devices such as walkers, wheelchairs, scooters, etc.). The statistically significant model results are summarized below.

- Greater familiarity with autonomous vehicles is associated with the perception that autonomous vehicles will increase safety for all three population groups.
- Compared to women, men are more inclined to believe that autonomous vehicles will increase safety for all three population groups.
- Compared to non-bicyclists, bicyclists are more inclined to believe that autonomous vehicles will increase safety for both bicyclists and pedestrians.
- Frequent walkers are unsure whether autonomous vehicles will increase or decrease safety of all three groups.
- People with ambulatory disability are more inclined to believe that autonomous vehicles will decrease their own safety, but they are ambivalent about the effect on pedestrians and bicyclists.
- People with high household income (income ≥ $150,000) are more inclined to believe that autonomous vehicles will increase safety of pedestrians and people with disability, but are unsure about the effect on bicyclists,
- Compared to Republicans and Independents, Democrats are more inclined to believe that autonomous vehicles will increase safety of pedestrians and bicyclists, but they are unsure about the effect on people with disability.
- People with higher education (≥ a bachelor's degree) are more inclined to believe that autonomous vehicles will increase safety of people with disability, but are unsure about the effect on the other two population groups.
- People who have three or more vehicles in household seem to believe that autonomous vehicles will decrease safety of pedestrians, but are unsure about the impact on the other two groups.
- Neither the socioeconomic status nor the built environment of municipalities have a statistically significant effect on the perception of safety impact of autonomous vehicles.

Survey Summary

This part of the report presented results from a random digit dialing (RDD) survey of 1,001 New Jersey residents that was conducted to comprehend how the general population of the state perceive the potential traffic impact of autonomous vehicles on people with disabilities, pedestrians, and bicyclists. The survey clearly showed that substantially more people believe that autonomous vehicles will increase safety for people with disability (41.6%) than believe that they will decrease their safety (31%). However, a moderately larger proportion believe that they will worsen traffic safety for bicyclists (38.8%) than believe that they will increase safety (32.2%). The proportion of people believing that autonomous vehicles will decrease safety for pedestrians (34.8%) is also larger than the proportion of people believing that they will increase pedestrian safety

(33.9%), but the difference is smaller than the difference regarding bicyclist safety. The fact that people with disability are more vulnerable than average pedestrians and bicyclists and yet a larger proportion of New Jersey residents believe that autonomous vehicles will increase their safety while decreasing safety for pedestrians and bicyclists implies that there is a belief among New Jersey residents that people with disability will also benefit by using autonomous vehicles as drivers or passengers.

The perception of potential safety impact of autonomous vehicles for the general population does not match the perception of people with disability, pedestrians, and bicyclists regarding their own safety from autonomous vehicles. Although the perception of the general population seems to indicate that the overall impact on people with disability will be positive, their own perception seems to indicate that the overall impact will be negative given that a larger proportion of people with disability believe autonomous vehicles will contribute to a decrease in safety (41.4%) rather than an increase in safety (35.7%). The perception of pedestrians about their own safety is similar. While 39.9% of frequent walkers believe that autonomous vehicles will decrease pedestrian safety, only 35% believe that they will increase safety. Although the general population believes that bicyclist safety will be adversely affected by autonomous vehicles, bicyclists themselves are almost evenly split; while 40.2% of them believe that autonomous vehicles will decrease bicyclists' safety, 39.8% believe that they will increase safety. Bicyclists are not only more optimistic about their own safety than the general population; they are also more optimistic about the impact of autonomous vehicles on pedestrians and people with disability.

This research also showed that people who are familiar with autonomous vehicles have a more optimistic view about their potential traffic impact on people with disability, pedestrians, and bicyclists. For example, among the people who are familiar with autonomous vehicles, 47.7% believe that they will improve safety for people with disability compared to only 34.3% of those who are less familiar, whereas the proportion of people believing that autonomous vehicles will decrease safety for people with disability is almost the same for the familiar and the less familiar (30.5% and 30.9%). Similar differences between the familiar and less familiar were also observed regarding pedestrian and bicyclist safety, indicating that familiarity tends to reduce apprehension and increase optimism. Although it is reasonable to believe that familiarity decreases apprehension about the safety impact of autonomous vehicles, it should also be noted that familiarity in this research is not necessarily based on the respondents' actual experience with autonomous vehicles.

Other analyses in this report also provided valuable insights. The analysis of familiarity with autonomous vehicles, for example, showed that younger people, people with higher education, and people from households with higher household income are more familiar with autonomous vehicles. The analysis of the perception of autonomous vehicles' safety impact also showed that many of the same populations have a more optimistic outlook about traffic safety impact. It is possible that the more optimistic outlook of some these population groups is because of their greater familiarity, but it is also possible that personal and household characteristics directly and independently affect both familiarity and safety perception.

The statistical models showed that the two variables that consistently affect the perception of safety from autonomous vehicles are familiarity and gender. Like men and people with greater familiarity, bicyclists, Democrats, and people with higher household income are also optimistic about a positive traffic safety impact of autonomous vehicles, but their beliefs are not consistent for the three population groups. One of the most insightful findings from the statistical models is that people with ambulatory disability are highly concerned about a negative safety impact of autonomous vehicles on people with disability.

Part III: Focus Groups

As part of the study, VTC held three virtual focus group discussions via Zoom with people who live and/or work in New Jersey. The focus groups, conducted in November and December 2020, aimed to provide supplemental information regarding how pedestrians, bicyclists, and those who require mobility aids presently view autonomous vehicles and their potential impacts on safety.

Participants were asked about their level of comfort and experiences with walking and bicycling in their communities, how they view the integration of AVs on roads, how they might interact with AVs at intersections, and their opinions over the types of infrastructure improvements and other actions that need to happen to ensure the safe integration of AVs on New Jersey roadways in the future. In addition to the focus group discussion, participants completed a pre-screening survey that included demographic questions, as well as other questions about participants' transportation patterns and experiences with bicycling.

The goal of the focus groups was to provide additional qualitative information to supplement the data gathered from the RDD telephone survey. By providing a forum for more open-ended discussion, the research team was able to hear safety concerns that may not have been evident from survey respondents' answers. At the same time, the information collected from the focus groups offers a point of comparison to the results of the telephone survey. Findings from the focus groups, as well as similarities and differences between the concerns raised in the focus group discussions and the responses gathered from the survey, are described below.

Methodology

VTC recruited participants using social media and networking with various transportation-related groups and organizations in the State. VTC encouraged these groups to share the announcement for focus group participants via email lists and social media platforms. In addition, VTC prepared a pre-screening survey to collect basic information about potential participants related to travel patterns and demographics. The survey responses were used to select participants. Two focus groups targeted those who bicycle recreationally and also drive (bicycle focus groups), while the third selected participants who require mobility aids (disability focus group).

Participant Characteristics

All participants in all three focus groups lived in New Jersey, and eight of the 14 total participants also worked in the State. All but one of the 14 participants identified as White or Caucasian, with one member of the disability focus group identifying as Hispanic/Latinx. Both bicycle focus groups were majority male, while the disability focus group was entirely female. Participants in all three groups were diverse in age.

In the first bicycle focus group, all participants bicycled at least on a weekly basis, and most bicycled for recreation/exercise purposes. All male participants in this group (71%) identified as avid bicyclists and would be comfortable riding on all types of facilities, while all female participants (29%) indicated that they enjoyed bicycling but would feel more comfortable if they were physically separated from vehicle traffic. Most participants in this group drove primarily to commute and accomplish daily errands.

In the second bicycle focus group, three-quarters of participants bicycled at least on a weekly basis, with one who bicycled at least on a monthly basis and one who bicycled a few times per year. More than half (63%) bicycled for recreation/exercise purposes, with 25% of participants who bicycled primarily for transportation/commute. Three-quarters of participants identified as avid bicyclists comfortable riding on all types of facilities, with the balance of those who enjoyed bicycling, but would feel more comfortable if they were physically separated from vehicle traffic. Interestingly, for more than half (63%) of participants, driving was not their primary mode of transportation to commute and accomplish daily errands. Most participants in this group did not have sight, hearing, mobility, or cognitive impairment that had lasted or were likely to last for more than six months. One participant indicated that he experienced epilepsy, depression, and Asperger's syndrome.

In the disability focus group, all participants indicated that they rarely or never bicycled–participants either had no interest in bicycling or were physically unable. For two-thirds of the participants, driving was the primary mode of transportation to commute and accomplish daily errands. One participant had sight impairment and one other participant had hearing impairment. Four participants indicated that they had limited mobility and relied on a mobility aid to get around.

Findings from Bicycle Focus Groups

Participant Background and Impacts of COVID-19

Participants in the bicycle focus groups lived in a diverse set of New Jersey municipalities representing urban and suburban communities throughout the State. Most participants identified themselves as serious/avid bicyclists, and some were also involved in bicycle advocacy organizations and bicycle clubs.

Most participants lived in two-person households, and many lived in four-person households. Only one participant among the two focus groups lived alone. Most participants' households owned at least one car, with only one owning none. No participants lived with anyone who used a mobility aid.

Due to COVID-19, participants commuted a lot less for work or school. Most participants walked or bicycled a lot more locally for recreational purposes and saw more people walking and biking in their neighborhoods as well. Most avoided group rides and group hikes, and opted to walk, bike, and hike by themselves or with one or two other people. However, some reported that they bicycled a lot less outdoors, especially during the early stages of the pandemic, due to concerns of going to the hospital in the case of a crash, getting exposed to COVID-19, and diverting resources from where they were needed the most. Some participants observed that there was less vehicle traffic early in the pandemic but that cars went at a much faster speed.

> *"For the most part, I am not taking [transit] much at all compared to pre-COVID-19 days. I am walking a lot more in the neighborhood, a lot more bicycling locally on short trips just to get out and get fresh air. I am definitely spending a lot more time in my neighborhood than I ever did before, which is not a bad thing."*

> *"I did not want to ride and get into an accident and then have to go to the hospital and get exposed to it or divert the resources from people who needed it. That is why I am pretty much staying inside now. I would feel pretty selfish if I did go out and ride."*

Generally, participants in the bicycle focus groups expressed an optimistic view of technology, with over half of the participants indicating they are quick to adapt to new gadgets and enjoy the challenge of figuring out how to use new technology.

Perception of AV

Participants offered a range of responses when asked about their initial perceptions of autonomous vehicles. Some participants thought AVs would make the roads safer, while others expressed uncertainty regarding AVs' technology and concern over AVs' ability to recognize pedestrians and bicyclists on the road. Although some participants recognized that AVs would not commit human error, such as speeding, most were still worried about the safety of AVs. They were especially concerned about AVs' impact on the built environment and the safety of non-motorized transportation users. One participant commented that, unless the road network and design improved, having safer vehicles would not necessarily enhance transportation safety. However, one participant, who also owns a vehicle with some autonomous features, said that AVs can be safe if properly used. Only one person had previous interactions with an AV, having seen Google testing their autonomous vehicles on the road in Silicon Valley.

Safety of AV

Most participants thought that AVs would reduce the total number of fatalities because they would follow traffic rules, drive at slower speeds, and not commit human error or engage in distracted or drunk driving. While some participants thought AVs would reduce crashes, others thought AVs would not drastically reduce the number of crashes and were concerned about technological glitches and AVs' responses to unpredictable scenarios, such as interacting with pedestrians and cyclists. One participant commented that adding more vehicles to the road, whether they are autonomous or not, might further marginalize vulnerable road users.

> *"My assumption is that they are required to drive at or below the speed limit, unlike human drivers. I think just that sheer fact alone, while it might not reduce the number of crashes, it might help to reduce the number of fatalities and injuries."*

> *"My concern is for the safety of the most vulnerable road users...Many of our communities are communities where there is not a humongous volume of traffic, but there are a lot of people. People do a lot of unexpected things."*

> *"I see no proof that the AI involved is effective to protect and recognize people, bikes, animals, anything outside of the vehicle."*

Bike-Walk Activity

Most participants establish eye contact with drivers when bicycling and walking, but many of them also noted that drivers do not stop for them at crosswalks or intersections even when they established eye contact. Some participants commented that it is often difficult to make eye contact because drivers might not be looking for or at pedestrians and bicyclists.

> *"Even if you do make eye contact with the driver, they are looking right through you. Putting the onus on the walker or the bicyclist to have to do anything to make sure they are safe makes me crazy."*

Most participants would feel comfortable bicycling in any environment, though many would still prefer bicycling on low-speed suburban or rural roads or in protected bike lanes. Participants that bicycled regularly through urban environments expressed greater levels of comfortability bicycling on busy streets, but still expressed concerns over not having enough space to share the road with vehicles, getting doored, and bicycling on poor road conditions. One participant noted that protected bike lane networks lack connectivity.

As for walking, all participants preferred to walk on sidewalks, but some participants also noted that sidewalks often are too narrow and are not safe, especially for those who use a wheelchair. A few participants also indicated that connectivity is important to increase their sense of safety for both bicycling and walking. One person indicated that the pedestrian plazas and other outdoor spaces created because of COVID-19's indoor dining restrictions provided more pedestrian spaces in his community.

> *"Oddly, I find in the few instances where I have ridden in more open rural roads, I still don't feel very comfortable. Even though there might be less cars, they are going a lot faster, and there is often no cycling infrastructure there for you."*

> *"The challenge I have with anything like a bike path is that they don't go anywhere... One of the problems in New Jersey is that when they put up a park that involves bike/walk amenity, it is a micro plan."*

Pedestrian/Bicyclist Reaction to AVs at Intersections

When asked about jaywalking on low-traffic streets, most participants thought they would continue to jaywalk if there were no cars in sight. While some felt that their behavior would not change if there were AVs on the street, others believed they would be more concerned and careful about crossing intersections on foot if there were AVs on the road due to uncertainty around AV technology and how AVs react to pedestrians. Participants indicated that when bicycling, they would continue to roll through a stop sign on low-traffic/low-stress streets with AVs on the road. Depending on the environment (i.e., busier roadways), some participants indicated they would leave more time to roll and slow down so they could still brake and be safe in an AV-integrated transportation network.

While some participants imagined only small cars when "autonomous vehicle" was mentioned, others thought of larger trucks and buses. Some participants would be more cautious if there is an autonomous truck or bus on the road because larger vehicles have more blind spots and are harder to stop. To this point, one participant noted that size, rather than the autonomation of vehicles, would be the greater factor influencing their behavior. Another participant indicated that the design of the street also matters–her behavior might not change on streets that provide high visibility of incoming traffic but might change on roads with different configurations and traffic levels. Another participant wondered if behaviors might evolve in the future once people get used to sharing the road with autonomous vehicles.

Other Questions

When asked if the transportation infrastructure in their communities is ready for AVs and if there are changes that would expand the range that they would be willing to walk or bicycle, participants thought that having wider roads, and when appropriate, having dedicated space for bicyclists and pedestrians, would make them feel more comfortable walking and bicycling. Participants also noted that the GPS would need to be constantly updated and that AV mapping technology might limit the types of infrastructure changes and improvements that can happen. Two participants questioned how AVs would interact with light rails or atypical intersections and road designs. Participants noted that having a multi-modal emphasis in transportation design and planning is crucial in a future with AVs, and that that it is more important to provide a safe and accessible transportation network for all road users.

> *"I do think our streets are compatible because it is not as urban and it doesn't have that big of a population. I would be more concerned about an autonomous vehicle in a more urban setting."*

> *"The City is making changes to that street grid a lot. There is a lot of construction that is happening. There are streets closing, sidewalks closing, bike lane closing. Once all that is hard coded into the mapping technology that self-driving cars need, it will make it very difficult to implement any sort of change in our streetscape. That is really terrible. You don't have that flexibility in a growing city to allow the change that we need in the infrastructure."*

When asked to share if they think they need to know more about the technology to really understand and trust it, participants were roughly split. While some were optimistic about the benefits that AVs might bring to the transportation system, others were more tentative and noted they would need to know more about how the technology addresses the complex situations with other motorized vehicles and those on foot or bicycle.

Participants were also asked to share their thoughts about AVs' ability to reroute to avoid traffic and optimize time on a continuous basis. However, participants were more concerned about AVs' potential impact on congestion and traffic. Some shared that AVs might add congestion because some people might not mind traffic as much if they can multi-task in an AV, and they might choose to use an AV instead of taking public transit. One participant was concerned that increasing tolls on NJ parkways and turnpikes might reroute trucks and cars to side roads, which might add traffic to local road networks. Some participants noted that they would hope to see more shared-AV fleets being employed in the future to reduce congestion instead of increased private ownership of AVs.

> *"I would be concerned about congestion. If you can multi-task...you don't really care if you are in traffic. That might contribute to greater congestion."*

> *"If it is an AV that we are sharing, that is fine. Car ownership is not going to be the future. It is a bad investment."*

Findings from Disability Focus Group

Participant Background and Impacts of COVID-19

Aside from one participant who lived in an urban area and relied on public transit as her main mode of transportation, all five other participants lived in suburban communities and relied on driving (or being a passenger in a car) as their primary mode of transportation. One out of the five participants relied on her husband to drive the car because of sight impairment, and three of them drove an accessible van or car with hand controls and a lift. Many participants noted that getting to places is a significant challenge for them. Those who had experiences driving an accessible van reported that it often breaks down and is very expensive to retrofit and purchase one.

When asked to identify their experiences with various types of travel historically, five participants were/had been a motorist, everyone were/had been a passenger in a car, three participants were/had been someone who walked to places, and four participants were/had been someone who used transit.

Participants across the board traveled a lot less since COVID-19 and opted to use delivery services for groceries or have medical appointments via telehealth. Those who used public transit such as NJ TRANSIT, Access Link, or rideshare services before the pandemic noted that they rarely to never used them anymore. Participants who drove regularly before COVID-19 did not use their cars/vans as much as well. Some participants indicated that while COVID-19 reduced the amount of travel, they were able to participate in a lot more meetings and events because they were all conducted virtually.

> *"COVID-19 drastically changed everything about how I move around. I don't leave the house except to go walk...I have not used Access Link since the beginning of this pandemic. I've used the train twice...that is a drastic change from using multiple forms of transit six days of the week."*

When asked about their level of comfortability with new technology, participants were split, with some interested in new gadgets and others expressing hesitancy.

Perception of AV

Three participants thought that AVs were futuristic, and two participants perceived AVs as scary. One participant felt excited about AVs because they would give her greater mobility on the road.

When asked about their familiarity with AVs, one participant did not know anything about AVs and how they work, half of the participants felt that they knew a little bit but were generally unfamiliar with automated technology, and two participants felt that they had a moderate understanding of how AVs work and how they operate on roads.

Safety of AV

The majority of the participants noted that AVs could enhance road safety and reduce crashes because they would not commit human error. They would also allow people who should not be driving on the road, such as those with disabilities or those who are drunk, to be a passenger in a car instead. However, some participants voiced concerns over potential technological glitches that might happen with fully autonomous vehicles, creating chaos on roads, especially in urban areas. One participant questioned how humans would be able to differentiate an AV from a human-driven vehicle, and a few participants questioned if having a mix of autonomous vehicles and human-driven vehicles on the road would actually enhance safety because there would still be human drivers on the road. Two participants said they preferred to have hybrid cars with some autonomous functions, and one participant said that humans should still be actively engaged in the driving process. One participant who was sight impaired noted that she would feel much safer crossing a street if an AV approaches an intersection as opposed to a human-driven car.

> *"I know a number of individuals who should not be driving anymore due to dementia or vision problems...Once some of the kinks are worked out in AVs, they could be very good in reducing accidents and saving lives hopefully. For people who are tired, it could be a very positive thing."*

> *"I just don't know how the mix of autonomous vehicles and human drivers would actually reduce crashes because there are still humans on the road and the unpredictability of driving."*

> *"I suspect AVs would improve the possibility of people with different disabilities being able to drive, which I do find exciting. At the same time, for those of us who are already driving, giving up control would also be interesting."*

> *"I would feel so much safer crossing a street if there were AVs. Even though I carry a white cane, I am always afraid that people do not see me because I can't see if they can see me."*

Participants were asked to share the types of design features and considerations that would enhance safety if AVs were integrated on the road. Participants shared that it is vital for AVs to detect humans of different heights and skin colors, different types of mobility devices and aids, and animals of different sizes (ex. pets, service dogs) at crosswalks and intersections. Some participants, especially the participant who was sight impaired, also pointed out that AVs should be heard on the road. They shared that the quietness of electric vehicles had created safety problems for them. In addition, many participants pointed out that intersections should have longer crossing times for pedestrians, and raised safety concerns over drivers who rushed to make a right turn on red.

> *"Height of somebody needs to be a factor. Making sure that metal, wheelchairs, power chairs, or canes are being detected..."*

> *"I am thinking about police detection and how it was set up to see a white face better than any other colored faces and how that has needed to change over the years and has resulted in really negative impacts. Same goes for physical recognition of people [for AVs]."*

Other Questions

When discussing equity concerns, all of the participants asserted that AVs should not be a luxury that are affordable to only a few and should be accessible to the disability community. They identified the various benefits that AVs could bring. For instance, AVs could lower the cost and barriers for people with disabilities to own a car because retrofitting an existing car to accommodate disability needs can be very expensive. In addition, having AVs would expand housing and employment options for those who currently have limited mobility, and would allow people with disabilities to live more productive lives. However, participants pointed out that AVs might inevitably be out of reach financially as the disabled community, on average, has a lower annual income. Others commented on the importance of AVs having universal and inclusive design.

When asked to share aspects of AVs they would want to know more about, one participant commented that the reliability of an AV and the ease and cost of maintaining one were important factors for her to trust and use an AV in the future. Others discussed the positives of having a shared-AV service that could accommodate people with different disabilities and greatly enhance their mobility in a cost-effective way, especially for those who could not drive. Those who can drive would not need to spend money on owning a car or retrofitting one. AVs would reduce the inconveniences of owning an accessible van which is very expensive to purchase and often breaks down. One participant also noted that, while she still felt uncertain about shared AVs, AVs would be preferrable in a post-COVID future to eliminate close contact with a human driver.

> *“The rideshare idea is fabulous. Although the idea of having nobody in the car at the driver's seat is still a little terrifying to me, it would be a good COVID-19 option.”*

> *“I always like to remind folks that when you create anything that is universal, everybody can use it...If companies are interested in marketing themselves as a shared ride model, it is important to make sure that their fleets are universally designed as they create them, because it would be a lot cheaper to create them accessible than it would to retrofit them. You can use that ramp for so many things other than a wheelchair. I would encourage companies to think about the way that they are manufacturing the cars.”*

> *“If I could call for a service and they come and pick me up with no person in there, but I can ride my scooter onto this vehicle and it could drop me off at the mall right at the entrance...I could go and do things on my own and be totally independent... For the disabled community, this could be incredible.”*

Focus Group Similarities with Survey

Participant Characteristics

The two bicycle focus groups shared similar car ownership characteristics with the larger survey, with most participants owning one or two vehicles and a few owning three. Similarly, participants in the disability focus group primarily relied on private cars for transportation, with most living in suburban environments without easy access to transit.

The disability focus group and the group of survey respondents who indicated that they use a mobility device are not directly comparable because of differences in the questions asked of each group. However, the use of mobility devices across both groups is largely similar, with many participants using canes, walkers, and wheelchairs. Two focus group participants indicated sight or hearing impairment. Survey respondents were not explicitly asked about this, although it is possible that some of the respondents who use canes do so to assist with sight impairment.

Perceptions of Autonomous Vehicles

When asked about their perceptions of the safety impact of AVs on pedestrians, bicyclists, and people with disability, participants in the disability focus group expressed concern. This was similar to the results of the survey, which demonstrated that people with disability were less optimistic about AVs' safety impact than those without disability. According to the survey, 46% of people without disability believed that AVs would increase safety for those with disability. Yet only 36% of those with disability felt the same way. At the same time, 33% of respondents without disability felt that AVs would decrease safety for people with disability, while 41% of those with disability felt the same way. (Roughly the same percentage of each group believed that safety would remain unchanged.) The greater degree of pessimism on the part of those focus group participants with disability is generally consistent with the results from the survey.

Beyond this, participants in the disability focus group raised concerns regarding the inclusivity of AV design. One participant noted that unless AVs incorporate some mode of producing external noise, it will be difficult for the sight-impaired to perceive that a vehicle is approaching. Others discussed the need for the autonomous vehicles themselves to be wheelchair accessible. These concerns are consistent with the survey results, where those with disability were less likely to believe AVs would improve safety for people with disability. While some focus group participants were optimistic about the potential for AV car-sharing systems to improve safety and mobility for people with disability, many felt that more granular issues of accessibility would need to be addressed first. Overall, the disability focus group agreed that autonomous vehicles need to be understood within the context of an integrated and multimodal transportation system. Otherwise the introduction and expansion of AVs on roadways will not improve safety for those with disability.

Focus Group Differences from Survey

Familiarity with Autonomous Vehicles

The survey results showed that, overall, about 55% of participants were at least somewhat familiar with autonomous vehicles, while about 45% were not very familiar or not familiar at all. As a whole, the focus group participants were slightly less familiar with AVs. In each group, at least half of the participants indicated that they were not very familiar with AVs.

These differences become starker when looking at specific segments of the survey group. For example, amongst survey respondents who use mobility devices, about 36% are at least somewhat unfamiliar with AVs. Yet for the disability focus group, more than half of the participants indicated that they were generally or totally unfamiliar with AVs. Furthermore, for survey respondents who bicycle at least sometimes, about 34% were unfamiliar with AVs, while at least of half of the participants in each of the bicycle focus groups were unfamiliar. Overall, focus group participants indicated a lower level of familiarity with AVs than those who responded to the survey.

Perceptions of Autonomous Vehicles

When discussing their perceptions of the safety impact of autonomous vehicles on pedestrians, bicyclists, and people with disability, focus group participants demonstrated a greater degree of pessimism than the survey group. In one of the bicycle focus groups, a majority of participants believed AVs would make roads safer by reducing the frequency or severity of vehicle-to-vehicle collisions, but would not necessarily improve safety conditions for bicyclists and pedestrians. Participants in the other two focus groups expressed doubt that AVs would make roads safer, noting that the addition of any vehicles to the road, autonomous or not, poses a threat to vulnerable road users. For bicyclists, this stands in contrast with the results from the survey, which showed that bicyclists were more optimistic than non-bicyclists about the safety impacts of AVs on pedestrians, bicyclists, and people with disability.

While some participants in all three focus group discussions felt that AVs could address safety issues associated with human error and distracted or impaired driving, others raised concerns over potential technological vulnerabilities and biases present in AV software. Some participants feared that AVs might not be able to recognize pedestrians or bicyclists in chaotic urban environments, potentially resulting in crashes and serious injuries. A few participants raised concerns about the potential for racial and other types of bias in AV technology, drawing comparisons to facial recognition software that is unable to adequately identify faces with darker skin tones, as well as emphasizing the need for AVs to be able to detect small children and people using mobility devices in crosswalks. Others were concerned with possible cybersecurity breaches in large-scale AV networks. Although it is difficult to make a direct comparison to the survey, since the survey did not ask questions about these issues in particular, it is clear that the focus group participants are overall less optimistic about the safety impacts of AVs on pedestrians, bicyclists, and those with disability.

Other Focus Group Concerns

The three focus groups raised additional concerns that were not addressed by the survey. Several participants noted the need for autonomous vehicle GPS data to be updated frequently, given that infrastructure improvements are occurring constantly. Without frequent updates to GPS to account for changes in the built environment, AVs may pose a threat to the safety of other road users, especially pedestrians, bicyclists, and people with disability.

While pointing out that the ability of infrastructure improvements to impact safety may be limited by AV technology, focus group participants noted that the opposite is also true: any potential AVs have for improving safety will be restricted by the built environment. Many participants were quick to point out that without supportive infrastructure improvements for pedestrians, bicyclists, and people with disability, AVs will not be able to have any significant impact on safety for vulnerable road users. Participants in all three focus groups stressed the need for multimodal planning and design, emphasizing that safe, accessible, and well-connected transportation networks should take precedence over systems designed primarily for AVs.

Focus Group Summary

As a supplement to the survey, the three focus groups provided qualitative and nuanced information regarding people's perceptions of AV safety impacts on pedestrians, bicyclists, and people with disability. By focusing specifically on bicyclists and those who use mobility aids, the focus groups were able to offer insight into how vulnerable road users believe they themselves will be impacted by AVs.

The greatest consistency between the focus group feedback and the survey data was apparent in the perceptions of AVs' safety impact by people with disability. In both the survey and the disability focus group, those with disability expressed heightened concern over autonomous vehicles' safety impacts, both generally and for people with disability in particular. Participants in the disability focus group elaborated on this, discussing various accessibility concerns posed by AVs. Though it is perhaps unsurprising that those who are already highly conscious of mobility and safety issues would express greater concern regarding AVs, this perspective was nevertheless corroborated by both the survey and focus group data.

Differences between the focus groups and the survey results were also apparent. Overall, focus group participants were both less familiar with AVs and less optimistic about AVs' ability to improve safety than survey respondents. This was especially apparent for bicyclists. The survey results showed that bicyclists were more likely than non-bicyclists to believe that AVs would increase safety for pedestrians, bicyclists, and people with disability. Yet participants in the bicycle focus groups were not as optimistic. Furthermore, focus group participants tended to draw a distinction between AVs' safety impact for pedestrians, bicyclists, and people with disability versus AVs' safety impact overall. While many participants believed that AVs could reduce the frequency and severity of vehicle-to-vehicle collisions, they were more skeptical about their ability to improve safety for more vulnerable road users.

Conclusion

Using information gathered through a telephone survey and three focus groups, this research examined the perceptions of AVs' safety impacts on vulnerable road users, specifically pedestrians, bicyclists, and those with disability.

Basic analysis of the survey showed that more people believe that autonomous vehicles will increase safety for people with disability than believing that they will decrease their safety. However, the opposite is true regarding the safety of pedestrians and bicyclists. The analysis also showed that the general population's perception of AVs' potential safety impacts differs from the perception of people with disability, pedestrians, and bicyclists regarding their own safety. Although the perception of the general population is that the overall impact on people with disability will be positive, those with disability feel that the overall impact of AVs will result in decreased safety for people with disability, and the same may be true for the perception of pedestrians about their own safety. On the other hand, although the general population believes that bicyclist safety will be adversely affected by autonomous vehicles, bicyclists themselves are almost evenly split. Bicyclists are not only more optimistic about their own safety than the general population, they are more optimistic about the impact of autonomous vehicles on pedestrians and people with disability as well.

Statistical modeling of survey results showed that the two variables that consistently affect the perception of AVs' safety impacts are familiarity with AV and gender. Like men and people with greater familiarity, bicyclists, Democrats, and people with higher household income are also optimistic about positive traffic safety impacts from autonomous vehicles, but their beliefs are not consistent for the three population groups. One of the most insightful findings from the statistical models is that people with ambulatory disability are highly concerned about a negative safety impact of autonomous vehicles on people with disability.

In addition to the survey, the three focus groups provided supplemental qualitative information regarding people's perceptions of AVs' safety impacts. The greatest consistency between the focus group feedback and the survey data was apparent in the perceptions of AVs' safety impact by people with disability. In both the survey and the disability focus group, those with disability expressed heightened concern over autonomous vehicles' safety impacts, both generally and for people with disability in particular.

Overall, focus group participants were both less familiar with AVs and less optimistic about AVs' ability to improve safety than survey respondents. This was especially apparent for bicyclists. Focus group participants also tended to draw a distinction between AVs' safety impact for pedestrians, bicyclists, and people with disability versus AVs' safety impact overall. While many participants believed that AVs could reduce the frequency and severity of vehicle-to-vehicle collisions, they were more skeptical about their ability to improve safety for more vulnerable road users.

The insights gained through this research provide a deeper understanding of the public's perceptions and concerns regarding AVs' safety impacts on vulnerable road users. It is our hope that the information contained within this report is used by planners and policymakers when determining safe and effective methods of AV integration, and that the survey and focus groups conducted as part of this research serve as a baseline for future assessments of AV acceptance by different roadway users, different demographic groups, and different community types.

Future Research

This study examined the perceptions of autonomous vehicles' traffic safety impacts on three groups of vulnerable road users: pedestrians, bicyclists, and those with disability. While the survey and focus groups conducted for this study did provide a number of insights regarding AVs' perceived safety impacts, there remain important areas of research that have yet to be addressed.

Notably, the focus group component of this study was limited by a lack of racial diversity–only one of the 14 focus group participants was a person of color. Key perspectives from BIPOC New Jersey residents were therefore not included in this part of the study, and the conclusions that were drawn may not apply to these groups. Future research should include focus groups that target BIPOC residents who walk, bicycle, and/or have disability. This research should also ensure that a diverse set of communities from all parts of the State are represented.

Future research should also examine how different variables influence perceptions of AVs' traffic safety impacts, such as AV mode (tractor-trailer vs. small truck vs. passenger car), time of day, and setting (urban vs. suburban vs. rural). Investigations into how these factors affect people's safety perceptions will provide a deeper understanding of AV safety concerns, especially for vulnerable road users, and better inform transportation decision-makers as autonomous vehicles become increasingly common on our roads.

To fully comprehend how people perceive the safety impacts of AV, research is also needed to examine the factors affecting familiarity with AV because the variable that affects the perception of AV safety most consistently is familiarity with AV. Because AVs are yet to make sufficient inroads, people's familiarity at this time most likely depends on their curiosity and attitude towards new technologies. Future research on the perception of AV safety should, therefore, also consider personal attributes such as attitudes. Finally, future research should consider how and at what geographic scale the perception of AV safety impact should be examined. That is because AVs are likely to affect different types of areas differently due to variations in transportation infrastructure and land uses.

Works Cited

Advocates for Highway & Auto Safety (2020). "Engine's Caravan Survey Public Opinion Poll – Public Concern about Driverless Cars is Strong, and the Support for Performance Requirements is Clear."

Alexiadis, V., Bitne, J., Blizzard, K., Campbell, R., Cheung, M. G., Flanigan, E., Hyde, J., Jensen, M., Krechmer, D., Osborne, J., Row, S., Tudela, A. (2009). "Connected Vehicle Impacts on Transportation Planning." USDOT.

American Automobile Association (2018). "Fact Sheet: Vehicle Technology Survey – Phase IIIB."

Anderson, M. and Smith, A. (2017). "Automation in Everyday Life." Pew Research Center.

Anderson, S., Iagnemma, K., Peters, S., Pilutti, T. (2010). "An Optimal-Control-Based Framework for Trajectory Planning, Threat Assessment, and Semi-Autonomous Control of Passenger Vehicles in Hazard Avoidance Scenarios." International Journal of Vehicle Autonomous Systems. 8(2): 190-216.

Appleyard, B., Johnson, M., Riggs, W. (2020). "A Design Framework for Livable Streets in the Era of Autonomous Vehicles." SSRN Electronic Journal. 8(1): 1–18.

Bansal, P. and Kockelman, K. M. (2017). "Are We Ready to Embrace Connected and Self-Driving Vehicles? A Case Study of Texans." Transportation 44: 1-35.

Bauer, M. W., Dowler, E., Gasperoni, G., Green, J. M. (2006). "Assessing Public Perception: Issues and Methods," from Health, Hazards and Public Debate: Lessons for Risk Communication from the BSE/CJD Saga, ed. Carlos Dora: 40-60.

Blickstein, S. and Brown, C. (2016). "Understanding Barriers to Bicycle Access and Use in Black and Hispanic Communities in New Jersey." Alan M. Voorhees Transportation Center.

Blickstein, S. and Brown, C. (2016). "Bicycling Among Black and Latino Women – Focus Group Summary Report." Alan M. Voorhees Transportation Center.

Blickstein S., Brown, C., Walia, R. (2018). "Bicycle Safety Enforcement & Education: Pilot and Key Findings." Alan M. Voorhees Transportation.

Botello, B., Buehler, R., Hankey, S., Jiang, Z., Mondschein, A. (2019). "Planning for Walking and Cycling in an Autonomous-Vehicle Future." Transportation Research Interdisciplinary Perspectives. 1 (100012): 1-8.

Brown, C. and Hawkins, J. (2013). "The Economic Impacts of Active Transportation in NJ." Alan M. Voorhees Transportation Center.

Chan, C. Y. (2017). "Advancements, Prospects, and Impacts of Automated Driving Systems." International Journal of Transportation Science and Technology. 6 (3): 208-216.

Clamann, M.P., Combs, T. S., McDonald, N. C., Sandt, L. S. (2019). "Automated Vehicles and Pedestrian Safety: Exploring the Promise and Limits of Pedestrian Detection." American Journal of Preventive Medicine 56(1): 1-7.

Consumer Watchdog (2018). "As Americans Hit the Road for Memorial Day, Consumer Watchdog Poll Finds Voters Want Congress to Apply the Brakes on Driverless Cars."

Cox Automotive (2018). "Evolution of Mobility: Autonomous Vehicles."

Dai, D., and Howard, D. (2014). "Public Perceptions of Self-Driving Cars: The Case of Berkeley, California." Transportation Research Board 93rd Annual Meeting. 14.

Deb, S., Strawderman, L., Carruth, D. W., DuBien, J., Smith, B., Garrison, T. M. (2017). "Development and Validation of a Questionnaire to Assess Pedestrian Receptivity toward Fully Autonomous Vehicles." Transportation Research Part C: Emerging Technologies 84: 178–195.

Freemark, Y., Hudson, A., and Zhao, J. (2019) "Are Cities Prepared for Autonomous Vehicles?." Journal of the American Planning Association, 85(2): 133-151.

Georges C. D. "Are Americans Ready for Self-Driving Cars? Here's What our Data Says." Survey Monkey.

Lee, R., Sener, I. and Jones, N. (2016). "Understanding The Role Of Equity In Active Transportation Planning In The United States". Transport Reviews 37(2): 211-226.

Lubitow, A. (2017). "Narratives of Marginalized Cyclists: Understanding Obstacles to Utilitarian Cycling Among Women and Minorities in Portland, OR." Transportation Research and Education Center (TREC): 1-41.

Lugo, A. (2018). Bicycle/Race: Transportation, Culture, Resistance. Microcosm Publishing.

Millard-Ball, A. (2018). "Pedestrians, Autonomous Vehicles, and Cities." Journal of Planning Education and Research 38 (1): 6-12.

Munhall, P.L. (2008). "Perceptions," from The SAGE Encyclopedia of Qualitative Research Methods. SAGE Publications, ed. Lisa M. Given: 606-607.

National Conference of State Legislatures (2020). "Autonomous Vehicles: Self-Driving Vehicles Enacted Legislation." Last Accessed 13 April, 2020. https://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx

New Jersey Department of Transportation (2020). "New Jersey 2020 Strategic Highway Safety Plan." Accessed 2 April, 2021. https://static1.squarespace.com/static/5daa109ed4fca675858f0522/t/5f6272584c82db5eaf4b1d52/1600287334032/NJ+2020+SHSP+Final+Report+-+09-08-2020.pdf

Penmetsa, P., Adanu, E. K., Wood, D., Wang, T., Jones, S. L. (2019). "Perceptions and Expectations of Autonomous Vehicles – A Snapshot of Vulnerable Road User Opinion." Technological Forecasting and Social Change 143: 9–13.

Rasouli, A., Tsotsos. J. K. (2019). "Autonomous Vehicles That Interact With Pedestrians: A Survey of Theory and Practice." IEEE Transactions on Intelligent Transportation Systems 21 (3): 1–19.

Sanders, L. (2019). "Six in Ten People Would Feel Unsafe as Pedestrians in Cities with Self-Driving Cars" in Profiles, Travel & Countries. YouGov.

Sandt, L., Owens, J. M. (2017). "Discussion Guide for Automated and Connected Vehicles, Pedestrians, and Bicyclists." Pedestrian and Bicycle Information Center.

Schoettle, B., Sivak, M. (2014). "A Survey of Public Opinion about Connected Vehicles in the U.S., the U.K., and Australia." University of Michigan Transportation Research Institute.

The League of American Bicyclists (2014). "Autonomous and Connected Vehicles: Implications for Bicyclists and Pedestrians." Accessed: 10 April, 2020. https://bikeleague.org/sites/default/files/Bike_Ped_Connected_Vehicles.pdf

United States Department of Transportation (2018). "Preparing for the Future of Transportation: Automated Vehicles 3.0." Accessed 31 March, 2021. https://www.transportation.gov/sites/dot.gov/files/docs/policy-initiatives/automated-vehicles/320711/preparing-future-transportation-automated-vehicle-30.pdf

United States Department of Transportation (2020). "Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0." Accessed 31 March, 2021. https://www.transportation.gov/sites/dot.gov/files/2020-02/EnsuringAmericanLeadershipAVTech4.pdf

United States Department of Transportation (2021). "Automated Vehicles Comprehensive Plan." Accessed 31 March, 2021. https://www.transportation.gov/sites/dot.gov/files/2021-01/USDOT_AVCP.pdf

Vellinga, N. (2017). "From the Testing to the Deployment of Self-Driving Cars: Legal Challenges to Policymakers on The Road Ahead." Computer Law & Security Review. 33(6): 847-863.