# Tell Me What I Need To Know: Consumers' Desire for Information Transparency in Self-Driving Vehicles

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Fully autonomous or "self-driving" vehicles are an emerging mobility technology with a host of potential benefits over conventional motor vehicles. Proponents argue that widespread adoption of self-driving vehicles may save countless lives and millions of dollars annually by minimizing the likelihood of deadly vehicle crashes. However, for such benefits to be realized, widespread consumer adoption of self-driving technologies is a prerequisite. Prior research suggests that while consumers are broadly optimistic about the potential of vehicle automation, there are significant concerns that may undermine consumer adoption, such as the transparency of vehicle operation. There is insufficient research into consumers' desire to understand a self-driving vehicle's intent and decision-making process and its impact on their willingness to adopt. We conducted a study using a 63-question internet-based survey distributed in the United States to licensed drivers 18 years of age and older (n= 996) to examine consumer preferences of the information transparency of self-driving vehicles. Our findings suggest that middle-aged and older consumers of high household income were generally optimistic about the information sharing behavior and transparency of self-driving vehicles upon availability.



## INTRODUCTION

As autonomous vehicle technology is made real, moving from the realm of science fiction to a near practical technology, the potential benefits of motor vehicles capable of driving themselves have become broadly discussed. Proponents suggest that by removing error-prone human beings from the cognitively demanding task of manual driving, crashes will become rare. The resulting loss of life and property will be minimized or even eliminated (Maddox, 2018; Winston, 2021). Personal vehicle ownership itself may become obsolete as consumers may opt for access to Transportation as a Service (TaaS) platforms over the expense and overhead of owning a personal vehicle (Dillahunt, Kameswaran, Li, & Rosenblat, 2017). A shift in this regard may result in re-imagining urban environments, no longer inundated with personal vehicles, and environmental benefits from fewer net vehicles on the roadways (Mousavi, Osman, Lord, Dixon, & Dadashova, 2021). For these potential benefits to become a practical reality, however, consumer adoption is vital. However, given that the fully autonomous or "self-driving" vehicle of the near future represents a seismic shift in personal mobility, it is difficult to fully conceive the barriers to consumer adoption that might emerge.

While studies suggest that a broad range of consumers are optimistic about vehicle automation's potential benefits, recent studies have suggested potential roadblocks to widespread self-driving vehicle use. While issues of perceived risk, trust in the technology, and fine-grained control of AVs have been discussed in the literature (Ribeiro, Gursoy, & Chi, 2021); for some consumers, there may be an even more significant barrier to use. Transparency, or user awareness of system status and intent, has been raised as a barrier to AV use by users with disabilities and older adults (age 65+) (Brinkley, Daily, & Gilbert, 2018; Brinkley et al., 2020; Huff, DellaMaria, Posadas, & Brinkley, 2019). In a 2017 study by Brinkley et al. (2017), the study's 38 visually impaired participants indicated that they were optimistic about the potential mobility benefits that a self-driving vehicle may present. Anyone concerned about their ability to interact with and control the vehicle and their awareness of the vehicle's intent and decision-making processes. These findings are reinforced by Brewer and Kameswaran (2018), who found in a separate study that even individuals with limited usable vision desired a means to exercise control over an AV's decision-making and behavior. In a 2019 study focused on older adults 65 and over, Huff et al. (2019) found that while their older adult participants were similarly optimistic about the benefits of AV technology, they were concerned about their ability to understand the vehicle's intent and decision-making processes. While transparency is a theme raised across AV-related studies involving persons with disabilities and older adults, there exist significant knowledge gaps regarding the degree to which a lack of transparency may generally impact widespread consumer adoption. To investigate these issues, we have distributed a 63-question Internet-based survey in the United States, which collected 996 responses from persons aged 18 and older. Respondents were asked to provide their general opinions regarding self-driving vehicles, comment on their hopes for the technology, reflect on their willingness to use such vehicles. They were asked to respond to a series of questions related to transparency and visibility of system status. We argue that this research furthers our goal of contributing to the literature research that furthers consumer preferences regarding AV technologies and additionally sheds light on views from the older adult community. Research of this type will become increasingly critical if the widespread consumer adoption of this technology is realized.

## RELATED WORK

The study described in this manuscript was motivated by knowledge gaps in the related research on autonomous vehicles. To provide context to the study, we provide background on vehicular automation levels, consumer research broadly on AVs, and levels of vehicular transparency.

### Levels of Vehicular Automation

The Society of Automotive Engineers (SAE) has described six levels of vehicular automation. The National Highway Traffic Safety Administration (NHTSA) adopted these levels of automation, the primary regulatory body responsible for vehicle automation in the United States. SAE/NHTSAautomation levels are documented in the SAE J3016 standard (SAE International, 2018), which describes escalating autonomy in levels 0 through 5. Level 0, for instance, represents the absence of automation and conventional manual driving. Level 3 vehicles, however, have technology that supports "conditional automation," meaning that automated driving is possible under certain conditions. In level 2 vehicles such as Tesla's equipped with Autopilot (Tesla, n.d.) or GM vehicles equipped with SuperCruise (Cadillac, n.d.), the vehicle is capable of periods of automated driving. However, the human driver must be prepared to assume manual control when notified by the vehicle. In level 5 vehicles, which do not currently exist, the vehicle can perform all driving functions under all conditions. However, the driver may have the option of assuming manual control if desired. At present, only automation levels 0 through 3 are commercially available in the United States.

### Consumer Opinions on Autonomous Vehicles

There has been tremendous growth within the past decade in the body of literature that explores consumer/user sentiment regarding autonomous vehicles. We survey this literature to provide clarity regarding the contribution of this manuscript. While the previously described research contributes much to understanding consumer sentiment regarding autonomous vehicles, we argue that issues regarding visibility of system status or what we refer to as "Transparency," previously defined, have been insufficiently explored. We argue that the present report is unique in its focus on understanding consumer preferences broadly for transparency in the AV context while also exploring what constitutes "true" transparency for the average consumer.

## METHOD

We conducted a survey study to explore consumer perception of what the level of transparency may be exhibited by an autonomous vehicle. We draw on the definition from Rawlins (2008) who views transparency as "the deliberate attempt to make available all legally releaseable information, whether positive or negative in nature, in a manner that is accurate, timely, balanced, and unequivocal...". Both Rawlins and Balkin (1999) identified three dimensions of transparency: informational, participatory, and accountability. From the literature, in the context of self-driving vehicles, we define transparency as the vehicle's communication of its operational status, understanding of its environment, and communication of its decision-making process. Respondents completed a 60+ question survey asking them about their perceptions of accountability, communication effort, information sharing, and concerns of AVs and their intent to purchase and willingness to pay. Given the perceived benefits of AVs for the older adult community, our analysis and results are centered around the respondents' age group. The survey questions are available at the following link HERE.

### Survey Instrument

We constructed a 65-question survey using two instruments: measuring transparency and trust in organizations (B. R. Rawlins, 2008) and measuring trust in automation and intention of use (Gold, Körber, Hohenberger, Lechner, & Bengler, 2015) . We also added questions about respondents' buying intention of self-driving vehicles based on their communication and information-sharing behaviors, confidence in their ability to operate a self-driving vehicle, and confidence in self-driving vehicles. Our definition of transparency was added at the beginning of the survey for participants. For this paper, we present results from the analysis of the transparency questions of Rawlins (2008).

### Participant Recruitment

We recruited participants through Amazon Mechanical Turk (MTurk) to participate in the study. Amazon MTurk is an online crowd-sourcing platform for recruiting 'workers' to accept and complete jobs administered by 'requesters,' who compensated the workers upon completion. A common concern with performing experiments on Amazon MTurk is the quality of the data due to 1) workers with low or no reputation or approval ratings and 2) inattentive workers (Peer, Vosgerau, & Acquisti, 2014). To improve the quality of data, we restricted the sample to workers with a 95% approval rating and have completed at least 5,000 jobs. Additionally, we added several attention check questions (ACQs) in our survey. Workers who answered 00 or more ACQs incorrectly were not compensated for their assignment, and their data were excluded from the analysis. To ensure workers complete the survey fully, they must enter into the MTurk assignment form the five-digit survey code generated by the survey once they complete all the questions.

### Participant Demographics

In total, 996 participants (668 male, 325 female, one non-binary, two non-disclosed) took our survey. Participant ages ranged from 18 to 79 with a mean of 34.73 and standard deviation of 10.6. Regarding racial and ethnic diversity, 49.8% were White, 31.9% were Asian, 5.8% were of mixed race, 5.7% were Black, 4.8% were Hispanic or Latinx, and 2.0% were American Indian or Alaskan Native. Annual household income ranged from under $11,500 to over $76,500. Regarding employment, 78.4% of participants were full-time workers, 14.1% work part-time, 5.0% were unemployed, 1.1% were students, 1.0% were retired, and less than 1% were disabled. Regarding education, 66% of participants earned at least a Bachelor's degree, 7.4% earned a professional degree, 11% attended some college, 7.1% obtained a two-year degree, and 7.7% obtained a high school diploma GED, and less than 1% attended high school. When asked about their primary form of transportation, 62.2% drive a

passenger car, 13.2% ride a motorcycle, 4% drive a van or minivan, 3.6% drive a pickup truck, 11.4% use public transportation (i.e., bus or ridesharing), and 3.5% walk. Lastly, 10.8% of participants reported having a disability, with 36% reported having a visual disability, 25% having a motor disability, and auditory, cognitive, and other disabilities made up 13% of respondents each.

## RESULTS

We focus our results on responses from the first 27 questions of the survey on the 1) accountability, 2) communication effort, 3) information sharing, and 4) concerns of autonomous vehicles and the differences in perceptions based on the age and annual household income of the respondents. Prior work has shown how older adults believe AVs will improve their mobility and independence (Gluck, Boateng, Huff Jr., & Brinkley, 2020; Gluck, Huff, Zhang, & Brinkley, 2020; Huff et al., 2019; Huff, Zhang, & Brinkley, 2020). Past survey studies regarding autonomous vehicles reveal that people with higher household income are more likely to purchase and own AVs and are willing to pay more beyond the price of a conventional vehicle to acquire autonomous driving functionality (Bansal, Kockelman, & Singh, 2016; Daziano, Sarrias, & Leard, 2017).

We conducted multiple one-way ANOVAs to find statistically significant effects of age and income on the survey responses, separated by each factor of human-vehicle interaction. There were three age groups for analysis. Young adults were respondents age 18-35, middle-aged were those ages 36-64, and older adults were those ages 65 and older. There were eight levels of income, ranging from under $11,500 to over $76,500.

### Accountability

There were six statements regarding consumer's opinions of the accountability of AVs. Older adults (M = 4.28, se = .1) were more likely than middle-aged (M = 3.58, se = .06) and young adults (M = 3.77, se = .04) to believe that AVs would understand how their decisions would affect them (Q1). Older adults (M = 4.32, se = .12) were more likely than middle-aged (M = 3.92, se = .04) and young adults (M = 4.19, se = .05) to believe that AVs would provide useful information to make informed decisions (M = 4.32, se = .1) (Q2). Middle-aged adults (M = 4.16, se = .05) were more likely than young adults (M = 3.93, se = .04) to believe that AVs would share results from their diagnostic scans (Q6). Middle-aged adults (M = 4.16, se = .05) than young adults (M = 3.96, se = .04) to believe that AVs would shared updates and updated system information (Q7).

People making over $76,500 (M = 4.26, se = .06) were more likely than those making between $11,500 and $25,000 (M = 3.82, se = .07) and between $35,000 and $45,000 (M = 3.83, se = .08) to believe that AVs would provide useful information to make informed decisions (Q2). People making over $76,500 (M = 4.21, se = .07) were more likely than those making between $11,500 and $25,000 (M = 3.85, se = .08) and between $35,000 and $45,000 (M = 3.88, se = .08) to believe that AVs would share results from their diagnostic scans (Q6). People making between $55,000 and $65,000 (M = 3.89, se = .1) were more likely than those making between $11,500 and $25,000 (M = 3.54, se = .08) to believe AVs will inform them of its actions and the rationale behind it (Q4). People making between $65,000 and $76,500 (M = 4.22, se = .08) and over $76,500 (M = 4.25, se = .06) were more likely than those making between $11,500 and $25,000 (M = 3.75, se = .08) and between $25,000 and $35,000 (M = 3.86, se = .08) to believe that AVs will share updates and updated system information and explain what it means (Q7).

### Communication Efforts

There were six statements regarding consumers' opinions about an AV's role in communicating with its owner. Young adults (M = 3.67, se = .06) were more likely than middle-aged adults (M = 3.34, se = .06) to believe that AVs will request feedback regarding information quality (Q8). Young adults (M = 3.66, se = .04) were more likely than middle-aged (M = 2.95, se = .07) and older adults (M = 2.3, se = .27) to believe that AVs would ask for their opinions in the decision-making process (Q13). Young adults (M = 3.59, se = .04) were more likely than middle-aged (M = 3.0, se = .07) to believe that AVs would understand their owners and their needs (Q14). Middle-aged adults (M = 4.07, se = .05) were more likely than young adults (M = 3.81, se = .04) to believe that AVs will help them identify useful information (Q9). Middle-aged adults (M = 4.14, se = .05) were more likely than young adults (M = 4.0, se = .04) to believe that AVs would make it easy for them to find it (Q11).

People making between $55,000 and $65,000 (M = 4.07, se = .09) or over $76,500 (M = 4.04, se = .07) were more likely than those making between $11,500 and $25,000 (M = 3.64, se = .07) to believe that AVs will provide detailed information (Q10). People making between $55,000 and $65,000 (M = 4.14, se = .09) or over $76,500 (M = 4.17, se = .07) were more likely than those making between $11,500 and $25,000 (M = 3.76, se = .08) were the most likely to believe that AV will make it easy for them to find it (Q11). People making between $55,000 and $65,000 (M = 3.2, se = .1) were more likely than those making over $76,500 (M = 3.1, se = .09) to believe that AVs will ask for their opinions in the decision-making process (Q13).

### Information Sharing

There were seven statements on consumers' opinions regarding the way AVs should share information with them. For all the statements in this section, middle-aged adults were the most likely to believe in an AV being designed for certain information-sharing behavior. Middle-aged adults (MA) were more likely than young adults (YA) to believe that AVs will be designed to provide relevant (M = 4.28, se = .05 for MA vs M = 4.02, se =.04 for YA) (Q16), accurate (M = 4.5, se = .04 vs M = 4.12 for MA, se =.04 for YA) (Q20), reliable (M = 4.48, se = .04 vs M = 4.16 for MA, se =.04 for YA) (Q21) information in a timely fashion (M = 4.35, se = .05 for MA vs M = 4.0, se =.04 for YA) (Q15), and that is easy to understand (M = 4.28, se = .05 vs M = 4.04 for MA, se =.04 for YA) (Q19).

People making over $76,500 (M = 4.41, se = .06) were more likely than those making between $65,000 and $76,500 (M = 4.33, se = .07),between $55,000 and $65,000 (M = 4.21,

se = .08), between $45,000 and $55,000 (M = 4.05, se = .08), between $35,000 and $45,000 (M = 4.02, se = .08), between $25,000 and $35,000 (M = 4.11, se = .07), and between $11,500 and $25,000 (M = 3.75, se = .08) to believe that AVs will be designed to provide information in a timely fashion (Q15). People making over $76,500 (M = 4.52, se = .06) are more likely than those making between $35,000 and $45,000 (M = 4.2, se = .07), between $35,000 and $25,000 (M = 4.16, se = .08), and $11,500 and $25,000 (M = 3.98, se = .08) that AVs would provide information that is accurate (Q20). People making over $76,500 (M = 4.52, se = .06) are more likely than people from all the other income ranges to believe that AVs would provide information that is reliable (M = 4.57, se = .05) (Q21). People making over $76,500 (M = 4.33, se = .06) are more likely than those making between $11,500 and $25,000 (M = 3.9, se = .08) that AVs would provide information that is easy to understand (Q19). People making between $55,000 and $65,000 (M = 4.24, se = .09) or more than $76,500 (M = 4.28, se = .65) were more likely than those making between $35,000 and $45,000 (M = 3.96, se = .07), and between $11,500 and $25,000 (M = 3.89, se = .07) likely to believe that AVs will provide relevant information (Q16). People making between $55,000 and $65,000 (M = 4.06, se = .08) were more likely than those making between $11,500 and $25,000 (M = 3.6, se = .08) to believe that AVs will provide information comparable to conventional vehicles (Q17).

### Concerns

There were six statements about consumers' opinions about concerns they may have about AVs. Young adults (M = 3.32, se = .05) were more concerned than middle-aged adults (M = 3.03, se = .07) about AVs providing only part of the information (Q22). Older adults (M = 3.56, se = .26) were more concerned than middle-aged (M = 2.9, se = .07) and young adults (M = 3.25 se = .04) that AVs would leave out details from the information provided (Q23). Young adults (M = 2.89, se = .05) were more concerned than middle-aged adults (M = 2.26, se = .07)that AVs will intentionally provide information difficult to understand (M = 2.89, se = .05) (Q24). Young adults (M = 3.14, se = .05) were more concerned than middle-aged adults (M = 2.7, se = .07)that AVs will be slow to provide information (Q25).

People making over $76,500 (M = 2.56 , se = .1) were less concerned than those making between $45,000 and $55,000 (M = 3.07, se = .1), between $35,000 and $45,000 (M = 3.04, se = .1), between $35,000 and $25,000 (M = 3.2, se = .1), and $11,500 and $25,000 (M = 3.24, se = .1) about AVs being slow to provide information (Q25). People making over $76,500 (M = 2.32 , se = .1) were less concerned than those making between $35,000 and $45,000 (M = 2.81, se = .1), between $35,000 and $25,000 (M =2.87, se = .1), and $11,500 and $25,000 (M = 2.97, se = .2) about AVs intentionally providing information challenging to understand (Q24).

## DISCUSSION

Findings from the analyses showed that the respondents' age and household income significantly impacted consumers' perceptions of autonomous vehicles' abilities to facilitate communication of information and the transparency of their actions. Age played an important role in consumer perceptions of the communication effort, information sharing behavior, and concerns of AVs. In particular, Middle-aged (36 - 64 years old) and older adults (65 and older) were more optimistic about AVs' capabilities than young adults. This finding is surprising given the past literature that supports younger adults as more accepting and willing to adopt AVs than older adults (Abraham et al., 2016; Brugeman, Dennis, & Spulber, 2016; Schoettle & Sivak, 2015). Additionally, older adults were more optimistic about AVs being more transparent in their decision-making and considering their feedback. This finding contradicts findings from prior work explaining how older adults were not convinced that AVs would be designed for their needs nor understand them (Gluck, Boateng, et al., 2020; Huff et al., 2019). One explanation is the increasing visibility and publicity of autonomous driving technologies. As AVs are being promised to be available in the near future, there is more significant publicity about their benefits and on-road testing in many news outlets. Hence, as more older adults learn about them and their capabilities, they may become more informed and accept them. However, older adults were more concerned than the other age groups about AVs not providing complete information. Household income played a significant role, particularly in the accountability and information sharing of AVs. In both sections, respondents with higher household income ($55k+) were more optimistic about AVs sharing information about its driving system status, diagnostic scan results, and the rationale behind its decision-making. These findings align with past survey studies that show a correlation between males, high educational attainment, high household income, and more tech-savvy and their more positive outlook on AVs (Bansal et al., 2016). Respondents with lower household income ($45K or lower) expressed the most significant concerns about the AVs' intention to show information challenging to comprehend and its slow delivery. This detail was similar to past studies that show how people from lower socioeconomic statuses may have a more negative perception of AVs (Bansal et al., 2016; Kyriakidis, Happee, & de Winter, 2015).

## CONCLUSION

This paper aims to present an exploration of how potential future consumers of autonomous vehicles perceive their designed transparency, communication, and information sharing behavior. We examined if respondents' age and household income would impact their perception of autonomous vehicles and at which levels of each variable. Our findings show that middle-aged and older adults have a more positive outlook of autonomous vehicles and their perceived transparency versus younger adults, which contradicts prior work. However, similar to the literature, respondents with high household income were more optimistic about autonomous vehicles than those from lower-income. In future work, we will examine if other demographic variables (i.e., race, gender, ability, education) may impact future consumers' perceptions regarding autonomous vehicles. This work aims to inform researchers with initial insights

about public opinions of autonomous vehicle technology's perceived transparency. Consumers have a tremendous impact on shaping the future of automated vehicles and their adoption.

## ACKNOWLEDGEMENT

This material is based upon work supported by the National Science Foundation under Grant No. 2000187.

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