RESEARCH BRIEF

Users' Trust in and Concerns about Automated Driving Systems

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Automation technology is rapidly progressing and becoming more common in production vehicles. This technology can range from driver support features, where the system assists drivers on some driving tasks, through more advanced automated driving features, where the driver has fewer responsibilities while behind the wheel. Experts foresee vehicles with these automation technologies contributing to the reduction in human error–induced crashes. Additionally, automated vehicles (AVs) can decrease road congestion, fuel consumption, and emissions through more efficient traffic operations and route planning (Suresh and Manivannan, 2014; Fagnant and Kockelman, 2015) and improve travel options, particularly for the elderly and disabled (Nordhoff et al., 2016). In order to maximize these benefits, large-scale market penetration of AVs, as well as infrastructure changes, are critical. Towards this, it is essential to secure public trust for these technologies. It is equally important to understand how trust varies with the types and capabilities (or levels) of the automated technology.

In the past several years, numerous studies have examined public attitudes, beliefs, and acceptance of AVs with mixed results. Some studies find participants have positive sentiments about AVs (Penmetsa et al., 2019), while other studies find participants have neutral (Pettigrew et al., 2018) or even negative opinions about AVs (Nielsen and Haustein, 2018). In several studies, even those participants who agreed that AVs would offer potential benefits and had an overall positive attitude towards AVs expressed concern about AV-related issues, such as system equipment failure and vehicle performance in unexpected situations (Schoettle and Sivak, 2014; Kyriakidis et al., 2015; Cunningham et al., 2019a). Another major concern for participants, as reported by Liljamo et al. (2018), is AVs not responding with similar morals as the drivers when presented with dangerous situations. Although these studies provided great insights about public opinion toward AVs, most of them assessed only for fully automated vehicles.

The study that AAA Foundation for Traffic Safety conducted in 2019 (Kim et al., 2019b) examined public understanding of and expectation about AVs and the rationales behind their distrust and discomfort toward vehicle automation. As a follow up to the study, this brief aims to examine people's trust in, adoption of, and concerns about different levels of AVs. The results show that overall, people were more likely to trust lower-level AVs (Levels 2 and 3 (SAE International, 2018)) than higher-level AVs to reduce crashes, and more people preferred to own vehicles with lower levels of automation. Additionally, compared with those trusting AVs to prevent crashes, people who distrusted AVs were significantly more concerned about all AV-related potential issues, such as technology malfunctioning, drivers' over-reliance on automation, technology distraction/annoyance, vehicle hacking, and data privacy. This exemplifies the importance of public education and training on AVs' capabilities and limitations in order to increase public trust and reduce concern.

Methods

The data used for this study came from the *Traffic Safety Culture Index*, a national online survey annually conducted by AAA Foundation (AAA Foundation for Traffic Safety, 2020b). In 2018, a set of questions inquiring about public understanding, expectations, and concerns across different levels of AVs (following SAE J3016 at that time (SAE International, 2016)) was added and are referred to as the *Emerging Transportation Technology* questions (ETT). Further details about the development of this questionnaire are available in two previous publications (Kim et al., 2019b; Kim et al., 2021).

For these data, an online research panel was used to survey U.S. residents ages 16 or older in English and Spanish in the fall of 2019. The panelists were recruited based on standard probability-based random digit dial and address-based sampling methods to be representative of the U.S. household population. A total of 3,511 respondents completed the survey. Weights applied to the survey data accounted for the probabilities of being selected as online panelists and as survey respondents, as well as non-response at both recruitment stages. Further, weights were adjusted to align respondents' characteristics to those of the U.S. population.

As summarized in Table 1, 48% of the weighted data were male, 5% were under the age of 19, and 19% were 65 years or older.

This study conducted descriptive analyses with a Pearson's Chi-squared test on weighted data and reported results on the following topics:

- Prevalence of public trust and adoption of automated vehicles in 2019 compared with 2018.
- Prevalence of public concerns about automated vehicles in 2019 compared with 2018.
- People's concerns about automated vehicles in relation to their degree of AV trust.

Numerous studies have examined drivers' trust of automated vehicles using a wide range of definitions and contexts (Raats et al., 2019; Ehsani et al., 2020). For example, Lee (2020) considered trust as "a multi-faceted term that mediates how people rely on, accept, and tolerate vehicle technology." In the current study, trust was measured with the survey item "*How much would you trust each level of technology to reduce the likelihood of a crash happening?*" Further, adoption was measured by respondents' preferred level of AV to own in the next couple of years, if cost was no barrier.

Results

Public trust and adoption of automated vehicles

Table 2 shows that in general, people were more likely to trust lower-level AVs (Levels 2 and 3) than higher-level AVs for crash prevention. The results showed no considerable changes between 2018 and 2019 overall. People between the ages of 25 and 39 were most likely to trust Level 5 (full driving automation), while people ages 65 or older were least likely to trust Level 5. A noticeable change from 2018 to 2019 was found for the 19 to 24 age group—a decrease from 51% to 33% for trust of Level 4 automation, while no considerable changes were found in other age groups. Also, more men than women trusted higher levels of automation (i.e., Levels 4 and 5) across both years.

With respect to adoption, overall, more respondents indicated that they were 'most comfortable' owning vehicles with lower levels of automation as shown in Table 3. In relation to age, people in the youngest age group (<19) were more comfortable owning vehicles with higher levels of automation, while people in the oldest group (≥65) were more comfortable owning vehicles with lower levels of automation than those in other age groups. Men were more comfortable owning Levels 4 and 5 AVs than women, but both agreed they were most comfortable owning Level 0 (no automation) and Level 1 and least comfortable with Level 4. In 2019, compared with 2018, there was a substantial increase in respondents reporting they felt most comfortable owning vehicles with either no automation or just Level 1. This was especially true for the age group 19 to 24 years, an increase of 15 percentage points from 13% in 2018 to 28% in 2019.

Public concerns of automated vehicles in relation to their reported AV trust degree

Table 4 shows respondents' level of concern regarding several automation-related issues. As shown, public concern about AV technology malfunctioning increased as the AV level increased—76% were extremely or very concerned about malfunction at Level 5 automation. Additionally, people indicated that expensive purchase prices were another major concern for Levels 4 and 5 AVs. For Level 3 vehicles, people's top concern was drivers over-relying on the technology. Comparing results from 2018 with 2019, people showed increased concern about

drivers' over-reliance of Level 3 automation technology, whereas the concern about vehicle hacking in Level 4 decreased considerably in 2019.

Interestingly, people who reported distrusting AVs were significantly more concerned about all issues compared with those who reported trusting AVs, regardless of automation levels (see Figures 1 to 4). Over 80% of participants who distrusted Levels 2, 3, and 4 considered technology malfunctioning the greatest concern. Following this concern were drivers' over-reliance and lack of driving control for these levels of automation. The top three concerns regarding Level 5 automation were no control of driving, technology malfunctioning, and no manual driving option. Paradoxically, among those who trusted Level 5 automation, having no control of driving and no manual driving option were the least reported concerns (see Figure 4).

In contrast, the top concern for those who trusted AVs was the expensive purchase price across all AV levels, including Levels 3, 4, and 5 if these vehicles would become available on the market. For Level 4 automation, almost 70% of those who trusted this level expressed concerns about its future pricing, while only 30% of them were concerned about the technology being distracting and/or annoying (the least concern as shown in Figure 3). The second top concern among those who trusted AVs was the technology malfunctioning across all AV levels.

Discussion

Survey results from this work suggest that people are less likely to trust AV technologies for crash prevention as the automation levels increased; there were no considerable changes between 2018 and 2019. Similarly, more people prefer to own vehicles with lower automation levels, and the result was more pronounced in 2019 compared with 2018. Many people reported that they trust AV technology to reduce crash risks but are uncomfortable owning them.

An individual's discomfort and reluctance with adopting higher level AVs could come from concerns such as technology failure, data privacy, cybersecurity, legal liability, and regulations (Cunningham et al., 2019b; Chen et al., 2020). One study (Kim et al., 2019a) reported that both the general public and experts in AV industries indicated safety attributes not only as the most important benefit, but also as the top concern for AV technologies. In the present work, both those who trusted and distrusted AVs to reduce crash risks noted technology malfunctioning as one of their top concerns. However, compared with those trusting AVs, people who distrusted AVs were significantly more concerned about all potential AV related issues across all levels. These included drivers' over-reliance on automation, lack of or no driving control, technology distraction/annoyance, vehicle hacking, and data privacy.

Regardless of AV level, purchase price was another major concern to most respondents when any AV level becomes available for sale. For example, for the fully automated vehicles—the ultimate goal of AV technology—even those who trusted these vehicles to reduce crash risks, rated purchase price as the top concern if they would become available for purchase. Kim et al. (2019a) also found the financial burden of the initial purchase and continued maintenance of AVs to be one of the main concerns by consumers in the general public.

To reduce public concerns, stakeholders from academia, industry, and government have been making considerable efforts to educate the public on AVs' capabilities as well as explaining their limitations. The AAA Foundation has also participated in these contributions by organizing multiple technical forums (AAA Foundation for Traffic Safety, 2018; 2019; 2020a) and conducting research on a variety of topics related to emerging technologies. For example, a recent AAA Foundation study examined

the impact of information on consumer understanding of Level 2 automation (Singer & Jenness, 2020). In this study, training that emphasized system capabilities led to greater confidence—and in some cases overconfidence—in the system and higher likelihood of incorrect belief about system capabilities, compared with training that emphasized system limitations. Another study conducted by AAA Foundation and SAFER-SIM University Transportation Center examined the impact of drivers' understanding of AV technologies on their performance and safety (Gaspar et al., 2020). This driving-simulator-based study showed that drivers who had greater understanding (i.e., a strong mental model) of adaptive cruise control, a common advanced driver assistance system, used the technology more appropriately and had superior performance when dealing with some of the technology's limitations, relative to those who had a weak mental model.

The results from both studies suggest the importance of people understanding the functions as well as limitations of AV features for better performance and safety. As people gain more experience with and knowledge about AVs based on accurate and balanced information, they would develop "strong" mental models, which could also help ease AV-related concerns and, subsequently, potentially lead to higher trust and comfort in the technologies.

Table 1. Survey respondents by age and sex

2019	n (unweighted)	% (weighted)
Total	3,511	100
16–18	941	5
19–24	97	7
25–39	545	26
40–64	1,214	43
>=65	714	19
Male	1,767	48
Female	1,744	52

Table 2. Strongly/somewhat trust in AV to reduce crash occurrence (by age and sex)

2019 (Δ*)	Level 2	Level 3	Level 4	Level 5
Total	56% (+1 pp)	45% (+1 pp)	37% (+1 pp)	35% (+2 pp)
16–18	52% (−8 pp)	49% (−1 pp)	43% (0 pp)	40% (+1 pp)
19–24	66% (+4 pp)	48% (−2 pp)	33% (−18 pp)	32% (−3 pp)
25–39	57% (+4 pp)	50% (+6 pp)	45% (+3 pp)	43% (0 pp)
40–64	56% (+2 pp)	44% (0 pp)	34% (+2 pp)	34% (+3 pp)
>=65	55% (−2 pp)	42% (+3 pp)	36% (+4 pp)	26% (+4 pp)
Male	56% (+2 pp)	49% (+5 pp)	42% (+2 pp)	42% (+7 pp)
Female	56% (0 pp)	43% (0 pp)	34% (+1 pp)	29% (−2 pp)

Survey item: "How much would you trust each level of technology to reduce the likelihood of a crash happening?" with response options for 'strongly trust', 'somewhat trust', 'neither trust nor distrust', 'somewhat distrust', and 'strongly distrust'.

**Numbers in ( ) indicate increases/decreases in percentage point compared with 2018 statistics.*

Table 3. Preferred automation level to own if cost was no barrier (by age and sex)

2019 (Δ*)	Level 0–1	Level 2	Level 3	Level 4	Level 5
Total	28% (+9 pp)	20% (−4 pp)	23% (−2 pp)	12% (−2 pp)	17% (0 pp)
16–18	22% (+7 pp)	16% (−5 pp)	21% (−5 pp)	17% (+3 pp)	24% (+1 pp)
19–24	28% (+15 pp)	13% (−11 pp)	33% (+6 pp)	7% (−12 pp)	19% (+2 pp)
25–39	22% (+5 pp)	18% (+1 pp)	20% (−4 pp)	19% (0 pp)	21% (−3 pp)
40–64	31% (+11 pp)	20% (−5 pp)	23% (−2 pp)	11% (−3 pp)	16% (0 pp)
>=65	32% (+7 pp)	25% (−7 pp)	22% (−3 pp)	8% (−1 pp)	12% (+4 pp)
Male	28% (+11 pp)	17% (−4 pp)	21% (−4 pp)	14% (−3 pp)	20% (0 pp)
Female	29% (+6 pp)	22% (−4 pp)	25% (−1 pp)	11% (−1 pp)	14% (0 pp)

Survey item: "If cost was no barrier and you could own a vehicle with any level of automated technology within the next couple of years, with what level would you be most comfortable?" with response options for 'Levels 0 and 1', 'Level 2', 'Level 3', 'Level 4', and 'Level 5'.

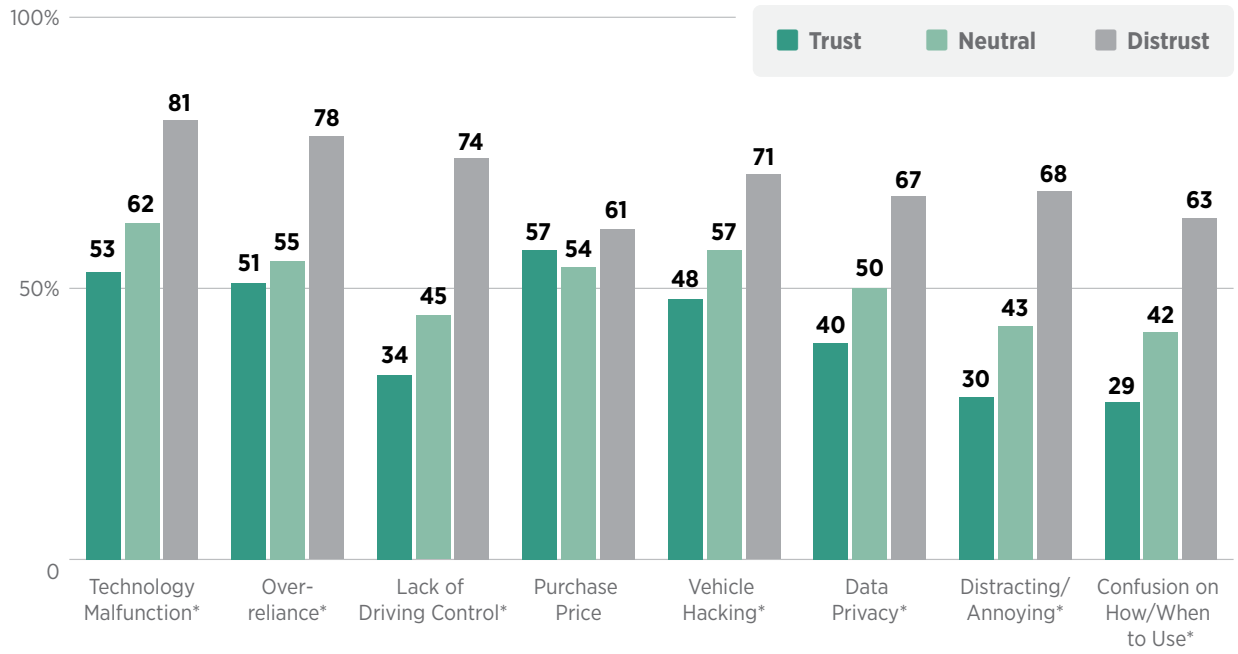
**Numbers in ( ) indicate increases/decreases in percentage point compared with 2018 statistics.*

Table 4. Proportion of respondents extremely/very concerned about each potential concern

2019 (Δ*)	Level 2	Level 3	Level 4	Level 5
Technology Malfunction	60% (−1 pp)	68% (+2 pp)	71% (0 pp)	76% (+1 pp)
Over-Reliance	57% (+4 pp)	72% (+10 pp)	67% (+1 pp)	NA
No Manual Driving Option	NA	NA	NA	72% (+1 pp)
No/lack of Driving Control	44% (+2 pp)	53% (0 pp)	60% (+2 pp)	73% (+3 pp)
Purchase Price	57% (+1 pp)	66% (+5 pp)	68% (+2 pp)	74% (+2 pp)
Vehicle Hacking	54% (+4 pp)	60% (+2 pp)	46% (−17 pp)	69% (+1 pp)
Data Privacy	47% (+2 pp)	53% (+4 pp)	55% (+3 pp)	60% (+3 pp)
Distracting/Annoying	41% (+5 pp)	45% (+4 pp)	48% (−1 pp)	NA
Confusion on How/When to Use	39% (+5 pp)	45% (+2 pp)	48% (+3 pp)	NA

Survey item: "Please rate the following potential concerns of Level [2, 3, 4, 5] automated vehicle technology" with response options for 'extremely concerned', 'very concerned', 'moderately concerned', 'slightly concerned', and 'not concerned at all'.

**Numbers in ( ) indicate increases/decreases in percentage point compared with 2018 statistics.*



*Note: * indicates that statistics between groups were significantly different at a 0.05 significance level.*

*Using the survey item "How much would you trust each level of technology to reduce the likelihood of a crash happening?" **Trust** includes those who responded to the question with 'strongly trust' or 'somewhat trust', **Neutral** includes those who responded with 'neither trust nor distrust', and **Distrust** includes those who responded with 'somewhat distrust' or 'strongly distrust'.*

Figure 1. Proportion of respondents who were concerned about Level 2 AVs issues, in relation to their AV trust degree

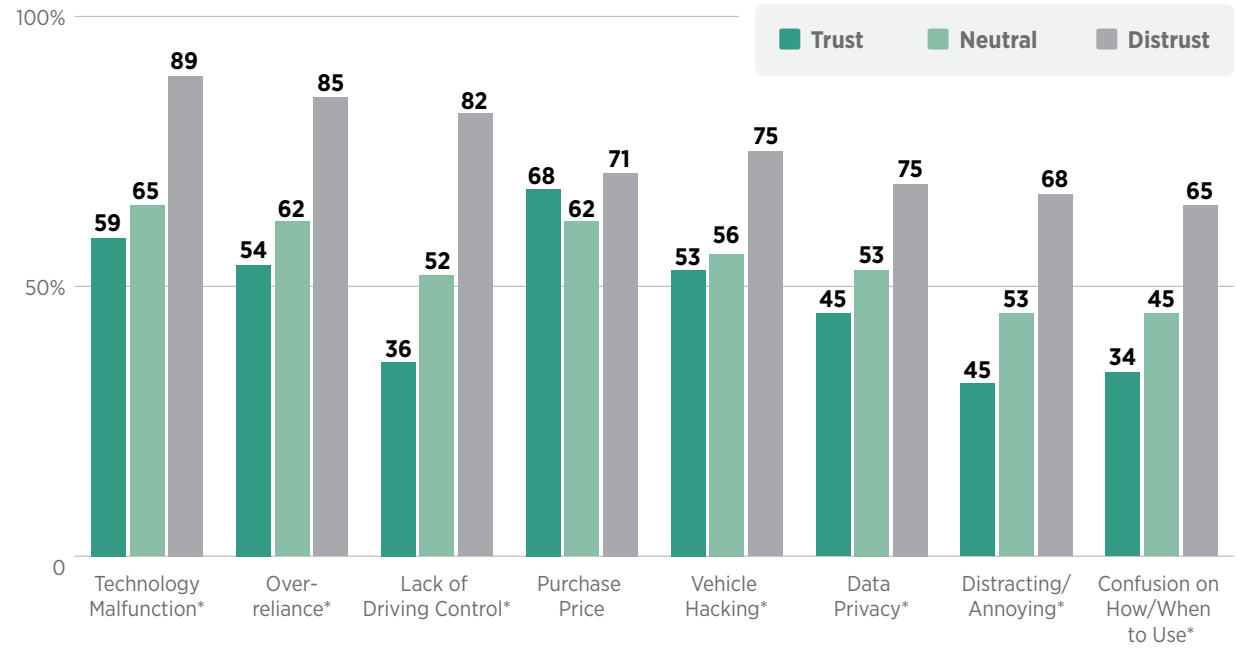


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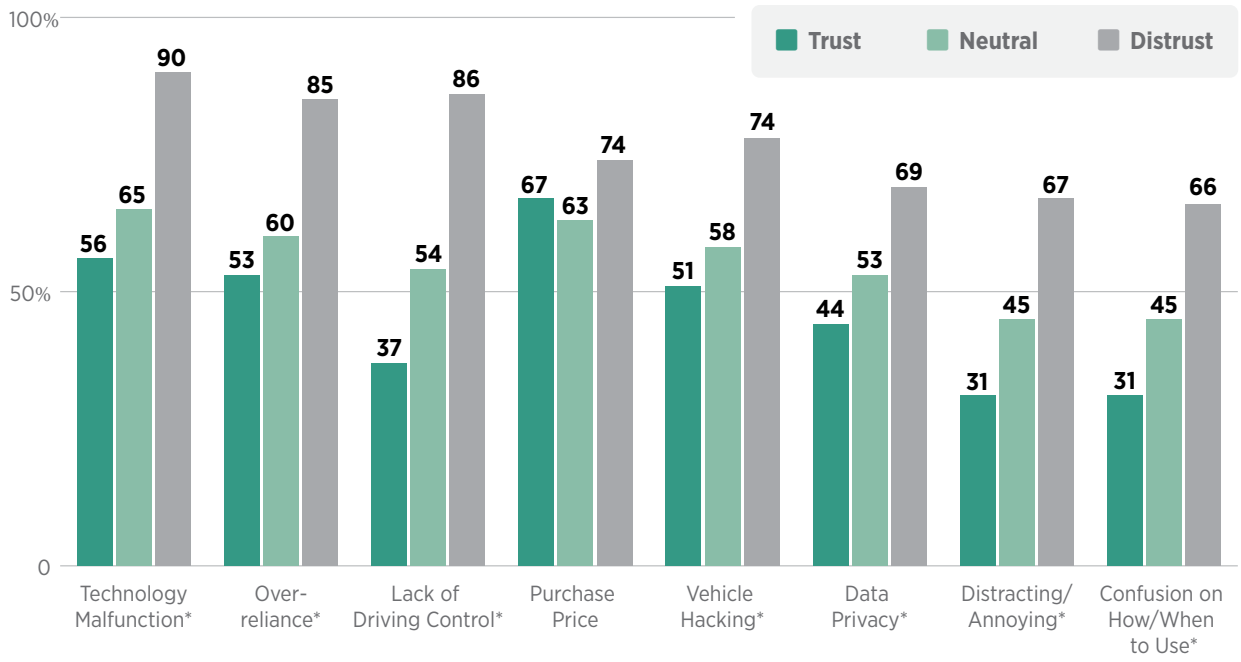
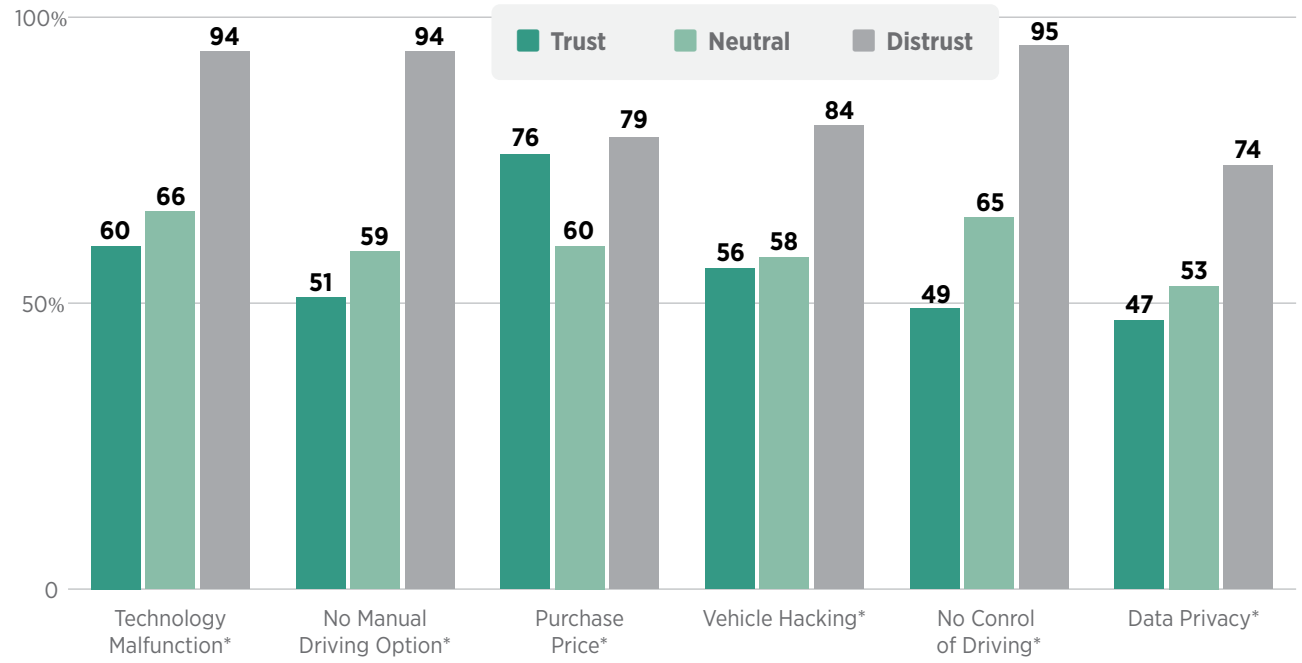
Figure 2. Proportion of respondents who were concerned about Level 3 AVs issues, in relation to their AV trust degree



*Note: * indicates that statistics between groups were significantly different at a 0.05 significance level.*

*Using the survey item "How much would you trust each level of technology to reduce the likelihood of a crash happening?" **Trust** includes those who responded to the question with 'strongly trust' or 'somewhat trust', **Neutral** includes those who responded with 'neither trust nor distrust', and **Distrust** includes those who responded with 'somewhat distrust' or 'strongly distrust'.*

Figure 3. Proportion of respondents who were concerned about Level 4 AVs issues, in relation to their AV trust degree



*Note: * indicates that statistics between groups were significantly different at a 0.05 significance level.*

*Using the survey item "How much would you trust each level of technology to reduce the likelihood of a crash happening?" **Trust** includes those who responded to the question with 'strongly trust' or 'somewhat trust', **Neutral** includes those who responded with 'neither trust nor distrust', and **Distrust** includes those who responded with 'somewhat distrust' or 'strongly distrust'.*

Figure 4. Proportion of respondents who were concerned about Level 5 AVs issues, in relation to their AV trust degree

REFERENCES

AAA Foundation for Traffic Safety (2018). *2017 Forum on the Impact of Vehicle Technologies and Automation on Users: A Summary Report* (Technical Report). Washington, D.C.: AAA Foundation for Traffic Safety.

AAA Foundation for Traffic Safety (2019). *2018 Forum on the Impact of Vehicle Technologies and Automation on Vulnerable Road Users and Driver Behavior and Performance: A Summary Report* (Technical Report). Washington, D.C.: AAA Foundation for Traffic Safety.

AAA Foundation for Traffic Safety (2020a). *2019 Forum on the Impact of Vehicle Technologies and Automation on Users—Design and Safety Implications: A Summary Report* (Technical Report). Washington, D.C.: AAA Foundation for Traffic Safety.

AAA Foundation for Traffic Safety (2020b). *2019 Traffic Safety Culture Index* (Technical Report). Washington, D.C.: AAA Foundation for Traffic Safety.

Chen, S. Y., Kuo, H. Y., & Lee, C. (2020). Preparing Society for Automated Vehicles: Perceptions of the Importance and Urgency of Emerging Issues of Governance, Regulations, and Wider Impacts. *Sustainability*, 12(19), 7844. https://doi.org/10.3390/su12197844

Cunningham, M. L., Regan, M. A., Horberry, T., Weeratunga, K., & Dixit, V. (2019a). Public opinion about automated vehicles in Australia: Results from a large-scale national survey. *Transportation research part A: policy and practice*, 129, 1-18. https://doi.org/10.1016/j.tra.2019.08.002

Cunningham, M. L., Regan, M. A., Ledger, S. A., & Bennett, J. M. (2019b). To buy or not to buy? Predicting willingness to pay for automated vehicles based on public opinion. *Transportation research part F: traffic psychology and behaviour*, 65, 418-438. https://doi.org/10.1016/j.trf.2019.08.012

Ehsani, J. P., Michael, J., & Igusa, T. (2020). Public health principles to inform testing and build trust in automated vehicles. *Injury prevention*, 26(5), 494-498. https://doi.org/10.1136/injuryprev-2019-043136

Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice*, 77, 167-181. https://doi.org/10.1016/j.tra.2015.04.003

Gaspar, J. , Carney, C., Shull, E. & Horrey, W.J. (2020). *The Impact of Driver's Mental Models of Advanced Vehicle Technologies on Safety and Performance* (Technical Report). Washington, D.C.: AAA Foundation for Traffic Safety.

Kim, M. K., Park, J. H., Oh, J., Lee, W. S., & Chung, D. (2019a). Identifying and prioritizing the benefits and concerns of connected and autonomous vehicles: A comparison of individual and expert perceptions. *Research in Transportation Business & Management*, 32, 100438. https://doi.org/10.1016/j.rtbm.2020.100438

Kim, W., Kelley-Baker, T., Sener, I., Zmud, J., Graham, M. & Kolek, S. (2019b). *Users' Understanding of Automated Vehicles and Perception to Improve Traffic Safety –Results from a National Survey* (Research Brief). Washington, D.C.: AAA Foundation for Traffic Safety.

Kim, W., Kelley-Baker, T., & Yang, C. Y. D. (2021). Public Understanding, Comfort, and Trust of Automated Vehicles. *Institute of Transportation Engineers*. ITE Journal, 91(1), 43-48.

Kyriakidis, M., Happee, R., & de Winter, J. C. (2015). Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. *Transportation research part F: traffic psychology and behaviour*, 32, 127-140. https://doi.org/10.1016/j.trf.2015.04.014

Lee, J. D. (2020). Driver Trust in Automated, Connected, and Intelligent Vehicles. In D. L. Fisher, W. J. Horrey, J. D. Lee, & M. A. Regan (Eds.), *Handbook of Human Factors for Automated, Connected, and Intelligent Vehicles*. Boca Raton, FL: CRC Press.

Liljamo, T., Liimatainen, H., & Pöllänen, M. (2018). Attitudes and concerns on automated vehicles. *Transportation research part F: traffic psychology and behaviour*, 59, 24-44. https://doi.org/10.1016/j.trf.2018.08.010

Nielsen, T. A. S., & Haustein, S. (2018). On sceptics and enthusiasts: What are the expectations towards self-driving cars? *Transport policy*, 66, 49-55. https://doi.org/10.1016/j.tranpol.2018.03.004

Nordhoff, S., Van Arem, B., & Happee, R. (2016). Conceptual model to explain, predict, and improve user acceptance of driverless podlike vehicles. *Transportation research record*, 2602(1), 60-67. https://doi.org/10.3141/2602-08

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. https://doi.org/10.1016/j.techfore.2019.02.010

Pettigrew, S., Talati, Z., & Norman, R. (2018). The health benefits of autonomous vehicles: Public awareness and receptivity in Australia. *Australian and New Zealand journal of public health*, 42(5), 480-483. https://doi.org/10.1111/1753-6405.12805

Raats, K., Fors, V., & Pink, S. (2019, December). Understanding Trust in Automated Vehicles. In *Proceedings of the 31st Australian Conference on Human-Computer-Interaction*, pp. 352-358. https://doi.org/10.1145/3369457.3369493

SAE International. (2016). *SAE Standard J3016: Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles.* Warrendale, PA: Author. https://www.sae.org/standards/content/j3016_201806/

SAE International. (2018). *SAE Standard J3016: Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles.* Warrendale, PA: Author. https://www.sae.org/standards/content/j3016_201806/

Schoettle, B., & Sivak, M. (2014). *A survey of public opinion about autonomous and self-driving vehicles in the US, the UK, and Australia.* University of Michigan, Ann Arbor, Transportation Research Institute. https://doi.org/2027.42/108384

Singer, J. & Jenness, J.W. (2020). *Impact of Information on Consumer Understanding of a Partially Automated Driving System* (Technical Report). Washington, D.C.: AAA Foundation for Traffic Safety.

Suresh, P., & Manivannan, P. V. (2014). Reduction of vehicular pollution through fuel economy improvement with the use of autonomous self-driving passenger cars. *Journal of Environmental Research and Development*, Vol 8(3A), 705-716.

ABOUT THE AAA FOUNDATION FOR TRAFFIC SAFETY

The AAA Foundation for Traffic Safety is a 501(c)(3) nonprofit, publicly supported charitable research and education organization. It was founded in 1947 by the American Automobile Association to conduct research to address growing highway safety issues. The organization's mission is to identify traffic safety problems, foster research that seeks solutions, and disseminate information and educational materials. AAA Foundation funding comes from voluntary, tax-deductible contributions from motor clubs associated with the American Automobile Association and the Canadian Automobile Association, individual AAA club members, insurance companies and other individuals or groups.

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