# Internal Sensors: Balancing Safety and Privacy in Semi-autonomous Cars

2018 AUTONOMOUS CARS ONLINE SURVEY SUMMARY REPORT

*A Collaborative Project by Open Roboethics Institute and the Korea Transport Institute*

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**Version** 0.1

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## INTRODUCTION

This study explores the increasing tension between improving the safety of semi-autonomous cars (SA) that has been calling for the installation of sensors inside a car, and its implications to privacy. Level 3 automated driving systems are still expected to have human drivers *on the loop*. That is, human drivers are expected to be able to take over control from an SA at moment's notice. Requiring a human to take over control over a vehicle after it has been driving with minimal input required from the human driver has been seen as problematic. Humans easily trust autonomous machines (automation bias) and are easily distracted from the mundane task of supervising an often well-performing, autonomous driving vehicle. With a series of fatal accidents highlighting this fragile link between SA and human drivers, whether there are adequate safety features installed in today's SAs have been a point of debate and public scrutiny.

A growing number of OEMs have learned from one another in installing more sensors *inside* SAs to monitor human driver's attention during semi-autonomous driving.

But does improved safety justify increasing the sophistication and quantity of sensors installed inside an SA? Do we already have a new norm on what expectation of privacy we should have in SAs compared to traditional, manually-driven cars (MD)? In this survey, we sought to better understand whether there are any significant tensions between safety and privacy from the viewpoint of the public, and whether the public's expectation of privacy differs for SAs in comparison to MDs.

## SURVEY DESIGN & RESULTS

After a set of demographic questions, the core of the survey consisted of seven questions. The full list of survey questions as well as the raw results from the survey are presented in Appendix A.

### PARTICIPANT DEMOGRAPHICS

Of the 1443 participants recruited, a total of 1374 participants from across the United States have consented to participate in our study. With this sample size, the results obtained in the study has a margin of error of 3%. The participant's gender was census balanced (45% male, 55% female), and basic balanced across age groups 18-29, 30-44, 45-60, and 60+ respectively.

Most of our participants have over 10 years of driving experience (71%), and 88% of the participants indicated that they currently own a car. The majority of the participants (53%) indicated that they have heard about autonomous cars a little, and 35% said that they heard a lot about them. This is quite consistent to the familiarity level we observed from our participants last year.

77% of our participants indicated that they have not been in a car accident within the last 5 years. Of those who have had an accident within the last 5 years, the majority indicated having had at least one minor accident where there was a damage to a car and no one was seriously hurt, and 25% have been involved in a serious accident where someone was seriously hurt or killed.
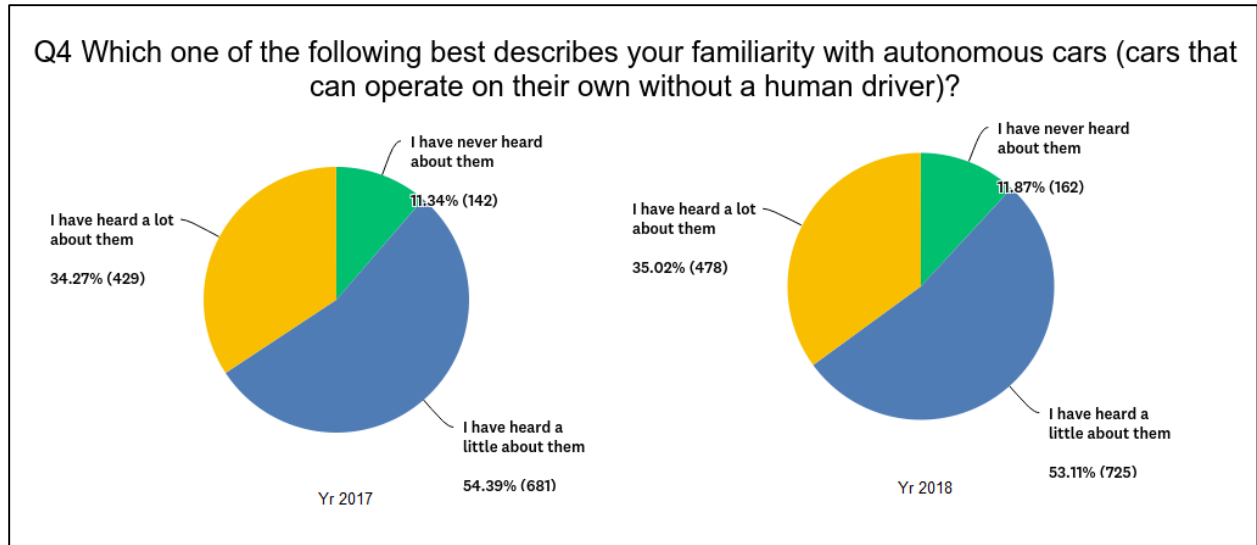
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**Q4 Which one of the following best describes your familiarity with autonomous cars (cars that can operate on their own without a human driver)?**

Yr 2017
- I have never heard about them: 11.34% (142)
- I have heard a lot about them: 34.27% (429)
- I have heard a little about them: 54.39% (681)

Yr 2018
- I have never heard about them: 11.87% (162)
- I have heard a lot about them: 35.02% (478)
- I have heard a little about them: 53.11% (725)

**Figure 1** Results from 2017 and 2018 on participant familiarity with autonomous cars. In both years, the majority of our participants declared having heard about autonomous cars at least a little, while approximately a third of them declared having heard a lot about them.

## INTERNAL SENSORS IN MANUALLY-DRIVEN VS. SEMI-AUTONOMOUS CARS: TYPES OF SENSORS

The first two questions (Q8 and Q9) were accompanied by a paragraph to set the context of what risky driving behaviours for a manually-driven car (MD) and a semi-autonomous car (SA) look like. In the SA condition, a short description of SA was provided. In both paragraphs, it was emphasized that "*sensors can be installed **inside a car** to detect risky driving behaviours*", and that "*With such sensors, the car can alert the driver and reduce the number of risky driving behaviours on the road.*" Then, given the following choice, the participants were asked to select all of the sensors that they would be comfortable having inside the car:

- A touch-based sensor that detects whether you have your hands on the steering wheel
- A video camera that detects whether you are paying attention to the road
- An alcohol level measuring sensor that detects whether you have been drinking
- A video camera that detects whether you are under the influence of drugs or alcohol
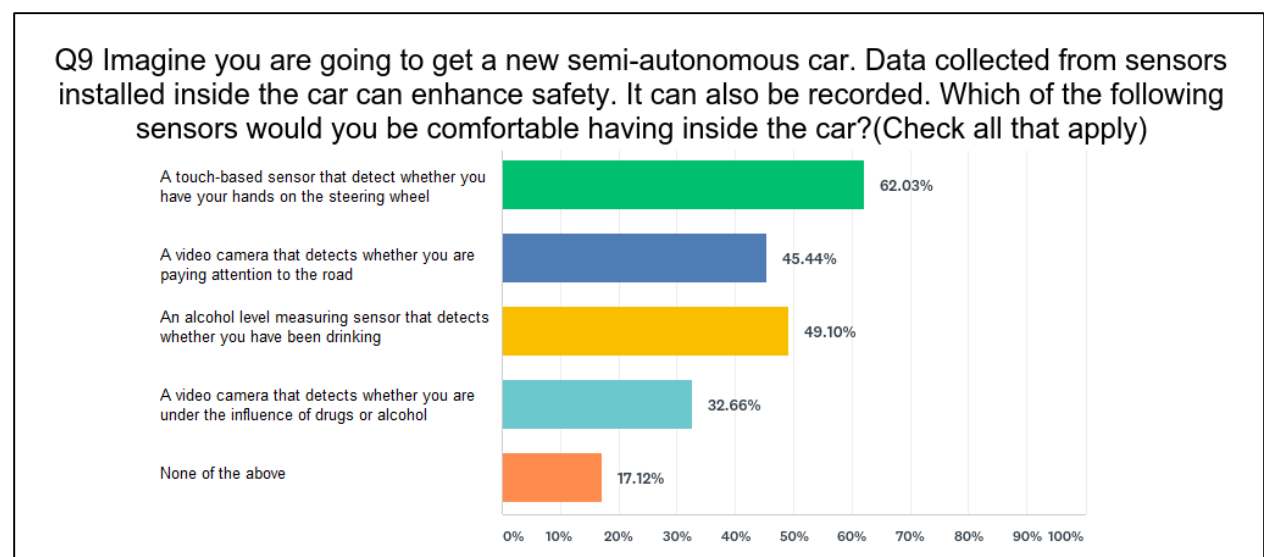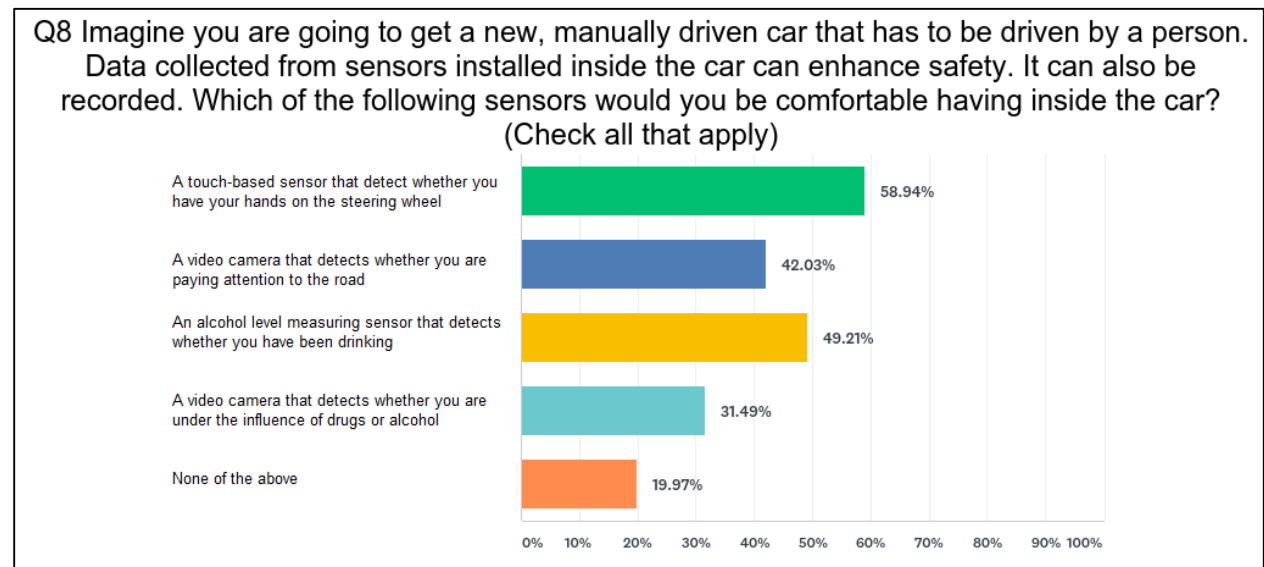- None of the above

The sensor types were provided to contrast the two risky driving conditions that a set of sensors could detect (distracted driving, and driving under the influence of alcohol), and a video-based and non-video-based sensors (Video vs. Non-Video). The order of Q8 and Q9 was randomized in order to account for possible order effects.

With Q8 and Q9, we hypothesized that people would be less comfortable having a video camera inside the cars compared to the alternatives that gather less identifying information to detect and alert drivers of risky driving behaviours (H1). We did find support for H1 in our results. Overall, people were more comfortable with non-video sensors over video-based sensors by 34.9% in MD and 33.31% in SA conditions.

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In addition, we found that more people are supportive of sensors that detect driver distractions compared to sensors that detect whether a driver is under the influence of alcohol in both SA (by 20.14%) and MD (25.74%) conditions.

We also hypothesized that more people would be supportive of the sensors (regardless of which) being installed inside SA than MD (H2). For MD, internals sensors received an accumulated percentage of 181.5%, whereas SA received 189.19%. This was also reflected in the number of people who didn't find any of the sensors comfortable (20.0% in MD condition and 17.1% in SA).

We also found a significant difference in participant responses across age groups. Participants older than 60 years of age were the most supportive of video cameras that detect whether you are paying attention to the road in an MD and SA than any other age group. Significantly lower number of participants aged 18-29 said none of the suggested sensors are appropriate inside a car for both MD and SA than participants aged 45 and older. More participants aged 45-60 said they would not be comfortable with any of the suggested sensors inside an MD or SA.
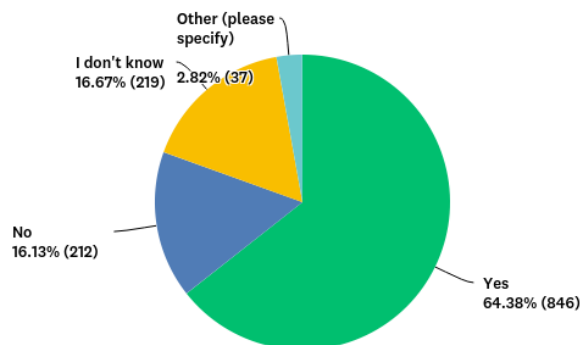


Q8 Imagine you are going to get a new, manually driven car that has to be driven by a person. Data collected from sensors installed inside the car can enhance safety. It can also be recorded. Which of the following sensors would you be comfortable having inside the car? (Check all that apply)

- A touch-based sensor that detect whether you have your hands on the steering wheel — 58.94%
- A video camera that detects whether you are paying attention to the road — 42.03%
- An alcohol level measuring sensor that detects whether you have been drinking — 49.21%
- A video camera that detects whether you are under the influence of drugs or alcohol — 31.49%
- None of the above — 19.97%



Q9 Imagine you are going to get a new semi-autonomous car. Data collected from sensors installed inside the car can enhance safety. It can also be recorded. Which of the following sensors would you be comfortable having inside the car?(Check all that apply)

- A touch-based sensor that detect whether you have your hands on the steering wheel — 62.03%
- A video camera that detects whether you are paying attention to the road — 45.44%
- An alcohol level measuring sensor that detects whether you have been drinking — 49.10%
- A video camera that detects whether you are under the influence of drugs or alcohol — 32.66%
- None of the above — 17.12%

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Questions 10 and 11 were designed to better understand whether installation of internal sensors, in general, are supported for SA vs. MD for the purposes of safety. Our participant response to Q10 (SA) and Q11 (MD) is well aligned with our findings of H2 discussed above. The participants were given traffic accident scenarios involving a distracted driver riding in SA and MD and asked whether it should be mandatory to for the cars to always have sensors inside the cars. The order of these two questions was also randomized to account for possible order effects. While 64% of the participants shows support for mandatory installation of internal sensors in SA, only 49% showed support in MD.

We also found that male participants said 'No' to whether it should be mandatory for MD to have sensors installed inside the cars significantly more than female participants (p<.05). There was no significant difference across gender when the analogous question was posed for SA (Q10).

In addition, participants in 60+ age group said 'Yes' significantly more in SA condition than those in the age group 45-60. In MD condition, participants in 45-60 age group said 'Yes' significantly LESS than those in any other age groups.



Q10 Tommy was riding in his semi-autonomous car when it failed to detect a pedestrian crossing the street. Tommy had been on the road for a while, and his car was doing most of the driving, safely. When Tommy's car hit the pedestrian, Tommy was busy texting his friend out of boredom of driving. His hands were off the steering wheel, and his eyes were on his cellphone.There are no sensors inside his car to detect when Tommy is distracted and to remind him to pay attention to the road.Should it be mandatory for semi-autonomous cars to always have sensors inside the cars?

Other (please specify)
I don't know 16.67% (219)  2.82% (37)
No 16.13% (212)
Yes 64.38% (846)

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Q11 Jamie was driving his manually-driven car when he failed to detect a pedestrian crossing the street. When Jamie's car hit the pedestrian, he was distracted and took his eyes off the road for a minute to text his friend. His hands were off the wheel while texting. There were no sensors inside his car to detect that Jaimie was distracted and to remind him to pay attention to the road. In the future, should it be mandatory for manually driven cars to have sensors installed inside the cars?

Other (please specify)

I don't know
19.03% (250) 2.59% (34)

Yes
49.47% (650)

No
28.92% (380)

## FOOLING INTERNAL SENSORS OF SEMI-AUTONOMOUS CARS

Q12 (Video) and Q13 (Pressure) sought to delve deeper into sensors in different privacy spectrum installed in SAs: a video camera and a pressure sensor that can be used to detect driver inattention. We hypothesized that more people would support making it illegal to fool a non-video-based (Non-Video) sensors than a video-based sensor (Video) in order to provide more room for the drivers to create private space inside their car as they wish. In both questions, our participants were presented with a scenario of a driver who is annoyed by alerts from a car and decides to fool either a video camera or a pressure sensor. They were asked whether it should be illegal for a driver to fool such sensors inside an SA. The order of these two questions was also randomized to account for possible order effects.

We found that our participants are generally supportive of making it illegal to fool such sensors regardless of the sensor type -- 66% of the participants said yes in the video camera and 67% said yes in the pressure sensor conditions.
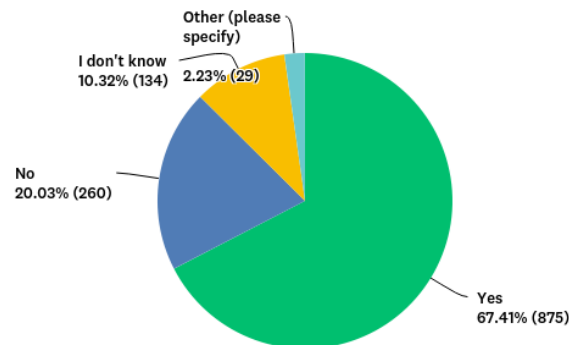
In both Q12 and Q13, male participants were significantly more opposed to the idea (answered 'No') than female participants ($p<.05$). We also found effects of age in the response. In both Video and Non-Video conditions, participants aged 60+ were the most supportive of making it illegal to fool the sensors[1].

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[1] In the Video condition, participants aged 60+ said 'No' (it should NOT be illegal) significantly less and said 'Yes' (it should be illegal) significantly more than those aged 30-44. In the Non-Video condition, participants aged 60+ said 'No' significantly less than any other age group, and said 'Yes' significantly more than age groups 30-44 and 34-60.

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Q12 Jane's semi-autonomous car comes with a suite of sensors inside her car, including a video camera to detect whether she is paying attention to the road. When the car detects that she is distracted, it makes an annoying beeping noise until she pays attention to the road again.Jane is tired of hearing the beeping noise. She decides to fool the system by having a photo of her where the video camera can see it.Should it be illegal for people like Jane to fool the sensors inside a car?

Other (please specify)
2.23% (29)

I don't know
11.94% (155)

No
19.57% (254)

Yes
66.26% (860)

Q13 Kate's semi-autonomous car comes with a suite of sensors inside her car, including a pressure sensor that detects whether her hands are on the wheel when necessary. When the car detects that her hands are off the wheel, it makes an annoying beeping noise until she takes control of the wheel.Kate is tired of hearing the beeping noise. She decides to fool the system by using a clamp that puts the right amount of pressure on the wheel to turn off the noise.Should it be illegal for people like Kate to fool the sensors inside a car?

Other (please specify)
2.23% (29)

I don't know
10.32% (134)

No
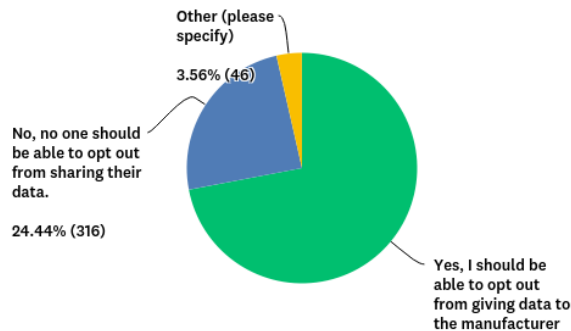20.03% (260)

Yes
67.41% (875)

### REQUIREMENT TO AN INFORMED CONSENT UPON PURCHASING A SEMI-AUTONOMOUS CAR

Finally, Question 14 sought to highlight the foreseeable issue of manufacturers requiring informed consent from the consumer in sharing data collected from the car. While an informed consent process is not an issue, having a requirement to consent in order to purchase a car can become an issue.

In Q14, participants were given a scenario where they are purchasing an SA. In the process, they come across an informed consent form that requires the consumer to agree that all the data collected from the car will be stored and used by the manufacturer to improve safety-critical features of the cars. The participants were

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asked whether there should be an option to refuse to provide data to the car manufacturer? A clear majority of our participants (72%) said 'Yes' to this question. There was no significant difference in the response to this question across age groups or gender.

Q14 You have decided that you want to buy a semi-autonomous vehicle. As you are completing the paperwork to purchase the car, you come across an informed consent form. In order to purchase the car, it requires that you to agree that all the data collected from the car will be stored and used by the manufacturer to improve safety-critical features of their cars.Should there be an option to refuse to provide the data to the car manufacturer?

Other (please specify)
3.56% (46)

No, no one should be able to opt out from sharing their data.
24.44% (316)

Yes, I should be able to opt out from giving data to the manufacturer

## DISCUSSION & CONCLUSION

In this study, we investigated the public's perception on the tradeoff internal sensors pose on semi-autonomous cars. While these sensors were presented as a means to increase road safety from dangerous driver behaviours, they also set a different set of privacy expectations inside a vehicle. Results from our participants suggest that the public in the United States already have a different set of privacy expectations for semi-autonomous cars compared to traditional, manually-driven cars and semi-autonomous cars.

There were some notable details about the type of sensors that people are more comfortable having inside a car. The participants were less comfortable with video-based sensors, regardless of whether it is used to sense your distracted or drunk driving behaviours. The participants were also less comfortable with sensors used to detect drunk driving in comparison to distracted driving. It is tempting to take this result at face value. However, understandably, the idea of having video cameras inside a car or a sensor that detect whether the driver is under the influence of alcohol are less familiar to the public than other alternatives provided to the participants. Therefore, unfamiliarity with these types of sensors may be a factor. Our participant response also suggests that the public is weary of sharing of data collected from the sensors, even if the data is to be used to improve safety features of a car.

Despite the varying comfort level across different types of sensors, the participants showed support for making installation of sensors in semi-autonomous cars not only mandatory, but illegal for the drivers to override. On the other hand, less number of participants showed support for mandatory installation of similar sensors in manually-driven cars. This is a curious phenomenon. If we accept the fact that manually driven cars are less safe on our roads than semi-autonomous cars, then there should be more reasons to mandate installation of internal sensors that reduce dangerous driving behaviours. However, the results from our participants suggest that the public may already have a different privacy expectation inside semi-autonomous cars than in traditional cars.
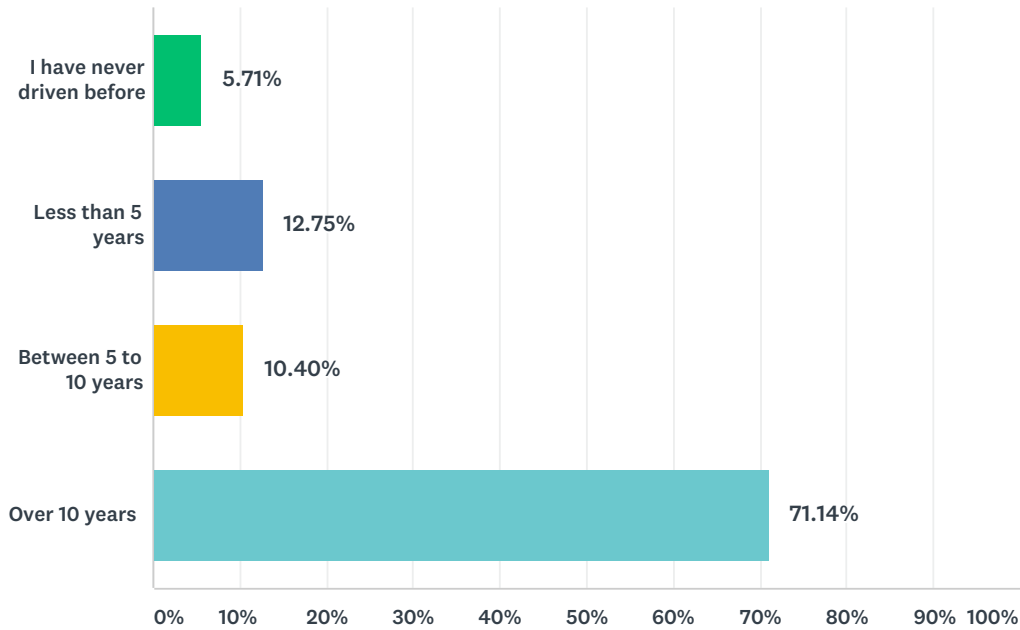
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# Q1 Do you consent to participate in this study?

Answered: 1,374    Skipped: 0
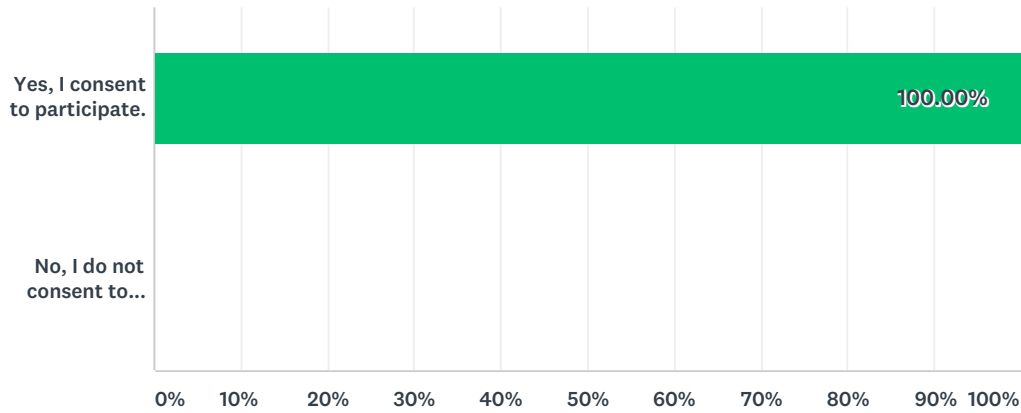


| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Yes, I consent to participate. | 100.00% | 1,374 |
| No, I do not consent to participate. | 0.00% | 0 |
| TOTAL | | 1,374 |

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# Q2 How much driving experience do you have?

Answered: 1,365    Skipped: 9



| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| I have never driven before | 5.71% | 78 |
| Less than 5 years | 12.75% | 174 |
| Between 5 to 10 years | 10.40% | 142 |
| Over 10 years | 71.14% | 971 |
| TOTAL | | 1,365 |

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# Q3 Do you currently own a car?

Answered: 1,365    Skipped: 9
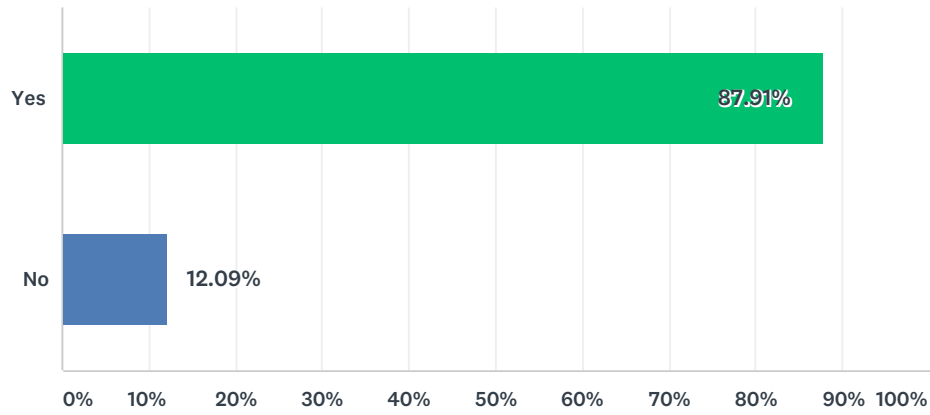


| ANSWER CHOICES | RESPONSES | |
| --- | --- | --- |
| Yes | 87.91% | 1,200 |
| No | 12.09% | 165 |
| TOTAL | | 1,365 |

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# Q4 Which one of the following best describes your familiarity with autonomous cars (cars that can operate on their own without a human driver)?

Answered: 1,365    Skipped: 9



**I have never heard about them**

11.87% (162)

**I have heard a lot about them**

35.02% (478)

**I have heard a little about them**
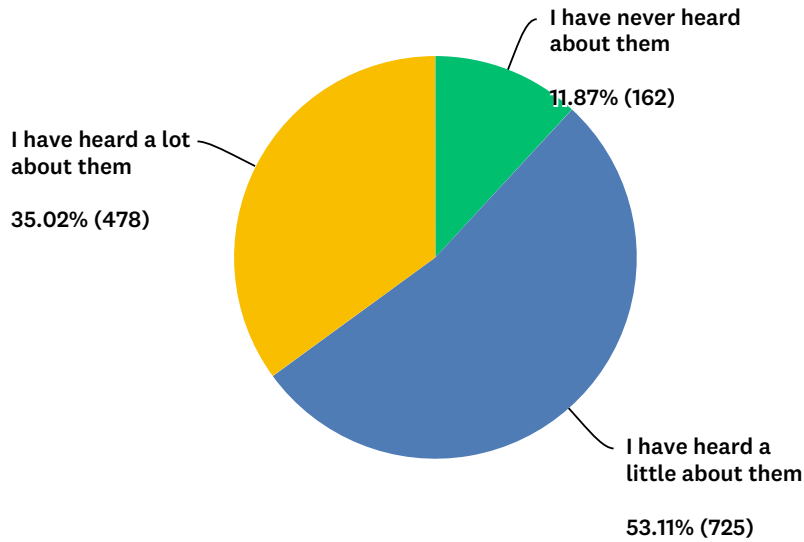
53.11% (725)

| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| I have never heard about them | 11.87% | 162 |
| I have heard a little about them | 53.11% | 725 |
| I have heard a lot about them | 35.02% | 478 |
| TOTAL | | 1,365 |

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# Q5 Have you been in a car accident within the last 5 years?

Answered: 1,365    Skipped: 9
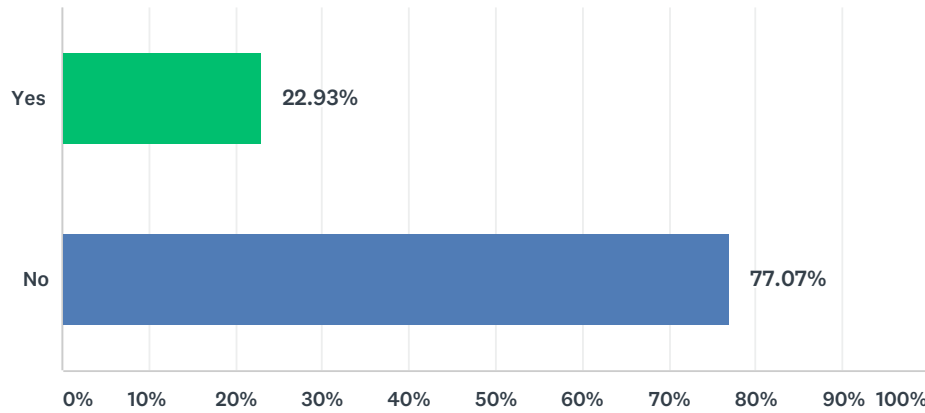


| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Yes | 22.93% | 313 |
| No | 77.07% | 1,052 |
| TOTAL | | 1,365 |

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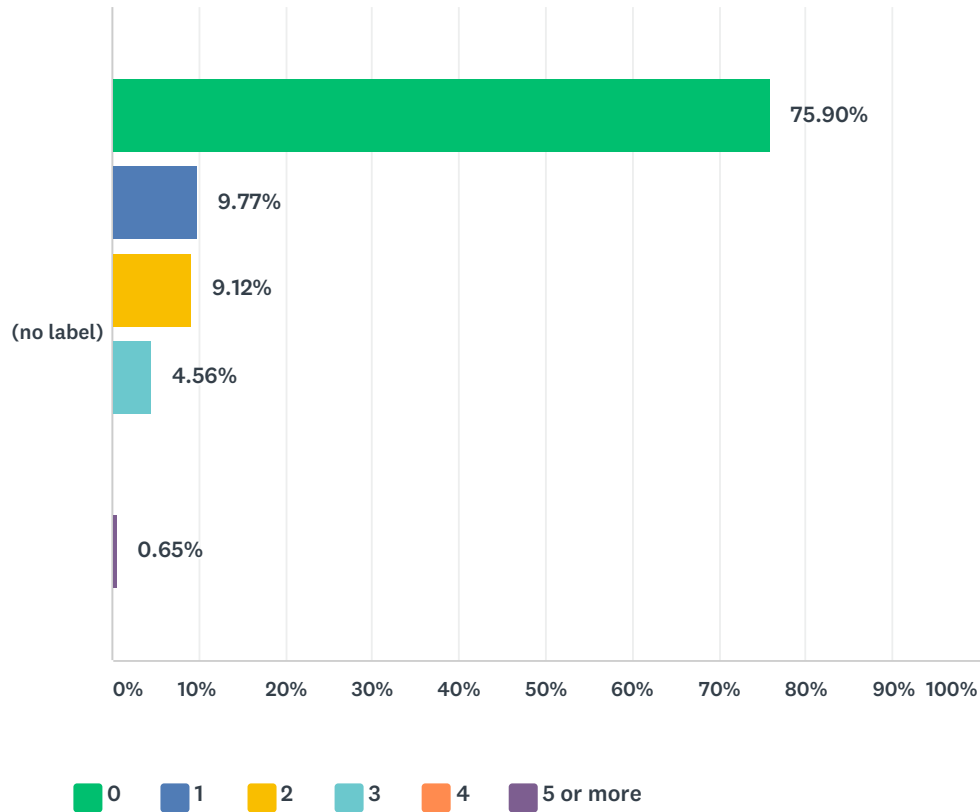# Q6 How many of the car accidents were minor accidents (only some damages to the car and no one was seriously hurt)?

Answered: 308   Skipped: 1,066
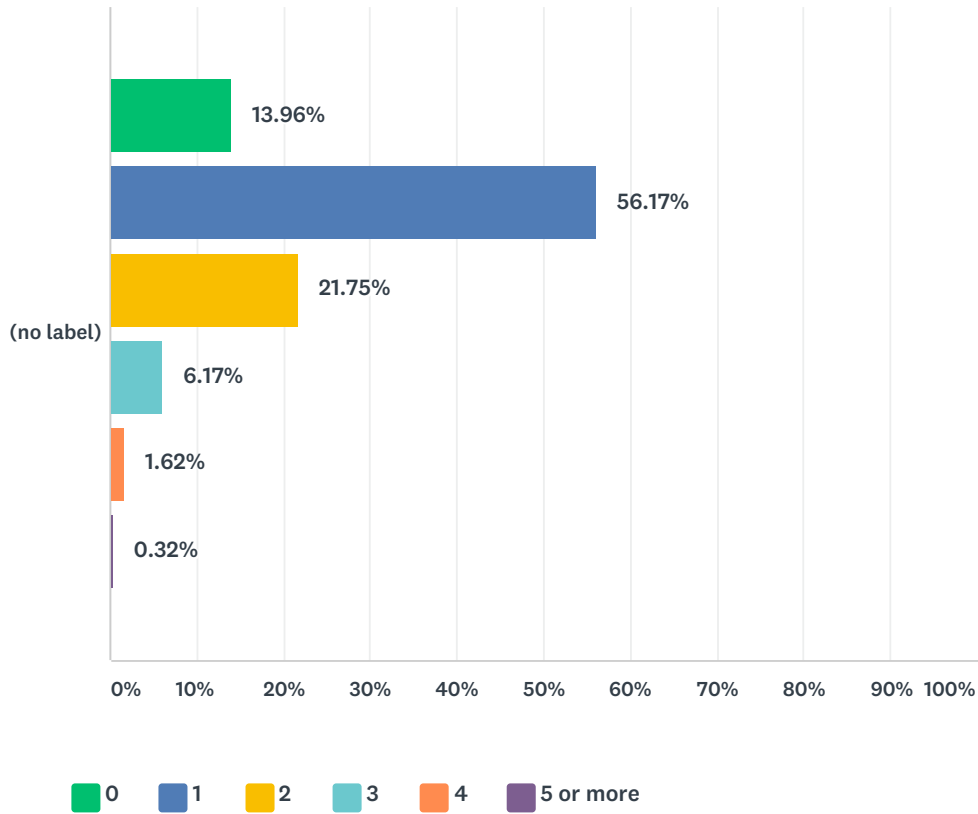


| | 0 | 1 | 2 | 3 | 4 | 5 OR MORE | TOTAL | WEIGHTED AVERAGE |
|---|---|---|---|---|---|---|---|---|
| (no label) | 13.96% 43 | 56.17% 173 | 21.75% 67 | 6.17% 19 | 1.62% 5 | 0.32% 1 | 308 | 1.26 |

# Q7 How many of the car accidents were serious accidents (someone was seriously hurt or killed)?

Answered: 307    Skipped: 1,067



| | 0 | 1 | 2 | 3 | 4 | 5 OR MORE | TOTAL | WEIGHTED AVERAGE |
|---|---|---|---|---|---|---|---|---|
| (no label) | 75.90% 233 | 9.77% 30 | 9.12% 28 | 4.56% 14 | 0.00% 0 | 0.65% 2 | 307 | 0.45 |

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Q8 Imagine you are going to get a new, manually driven car that has to be driven by a person. Data collected from sensors installed inside the car can enhance safety. It can also be recorded. Which of the following sensors would you be comfortable having inside the car?(Check all that apply)
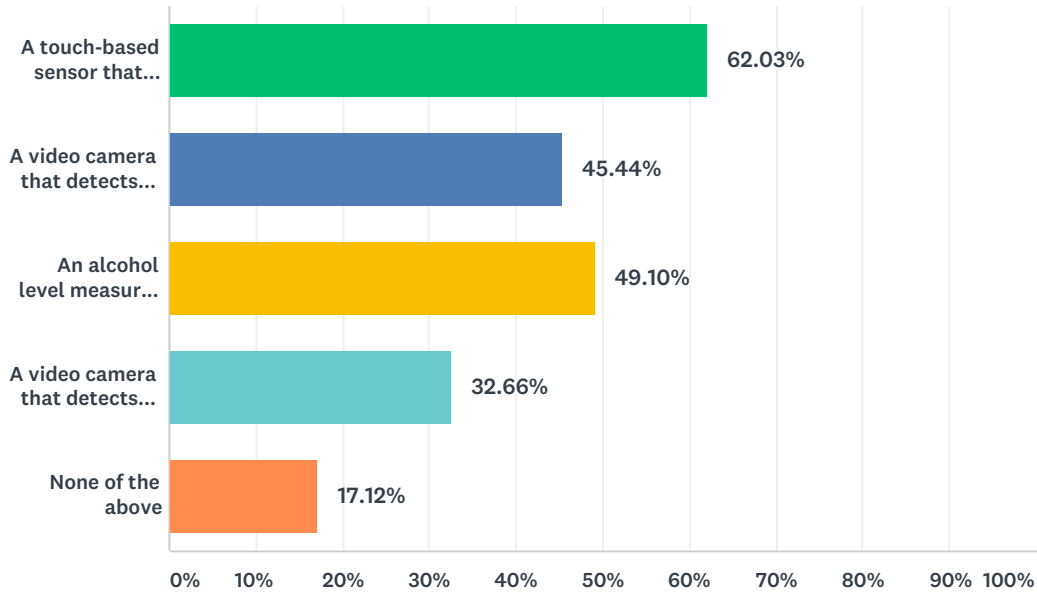
Answered: 1,337     Skipped: 37
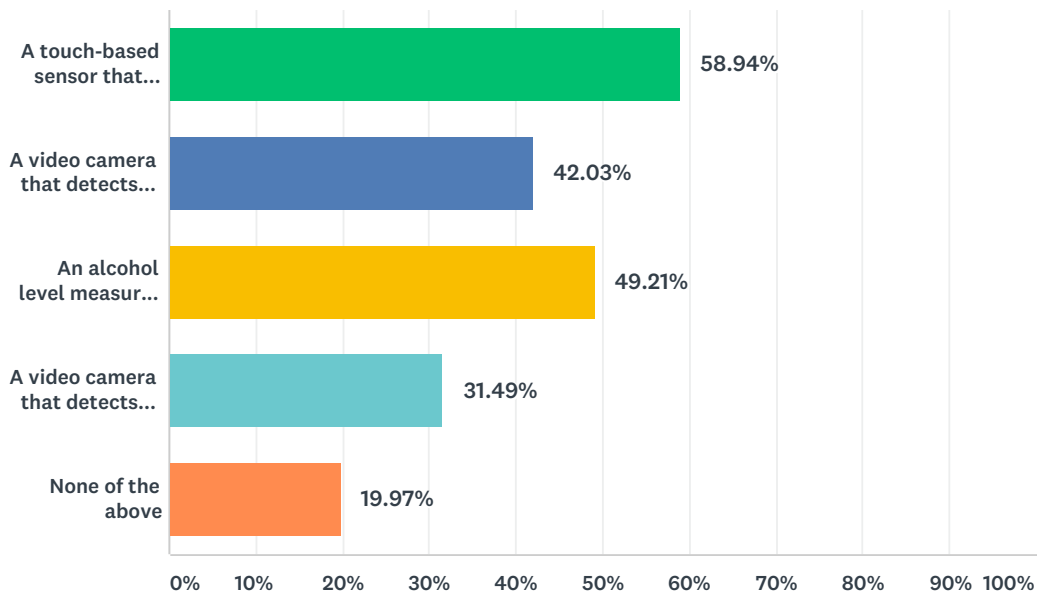


| ANSWER CHOICES | RESPONSES | |
| --- | --- | --- |
| A touch-based sensor that detect whether you have your hands on the steering wheel | 58.94% | 788 |
| A video camera that detects whether you are paying attention to the road | 42.03% | 562 |
| An alcohol level measuring sensor that detects whether you have been drinking | 49.21% | 658 |
| A video camera that detects whether you are under the influence of drugs or alcohol | 31.49% | 421 |
| None of the above | 19.97% | 267 |
| Total Respondents: 1,337 | | |

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# Q9 Imagine you are going to get a new semi-autonomous car. Data collected from sensors installed inside the car can enhance safety. It can also be recorded. Which of the following sensors would you be comfortable having inside the car?(Check all that apply)
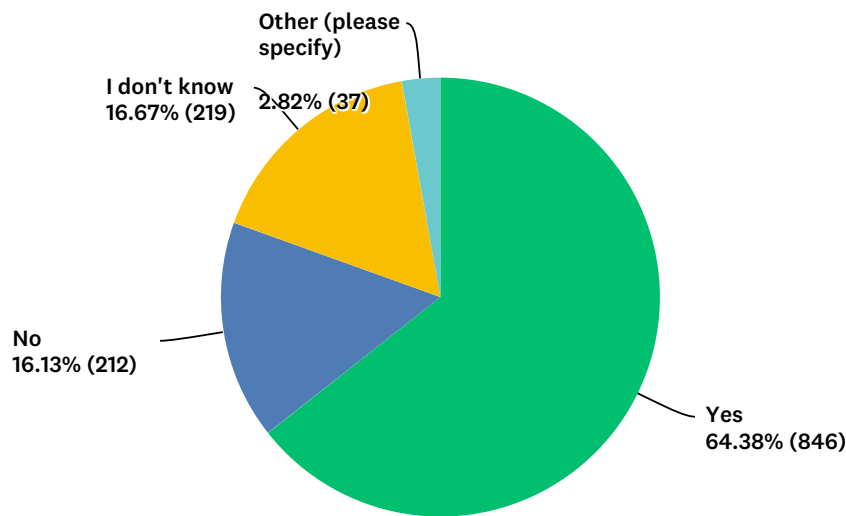
Answered: 1,338     Skipped: 36



| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| A touch-based sensor that detect whether you have your hands on the steering wheel | 62.03% | 830 |
| A video camera that detects whether you are paying attention to the road | 45.44% | 608 |
| An alcohol level measuring sensor that detects whether you have been drinking | 49.10% | 657 |
| A video camera that detects whether you are under the influence of drugs or alcohol | 32.66% | 437 |
| None of the above | 17.12% | 229 |
| Total Respondents: 1,338 | | |

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Q10 Tommy was riding in his semi-autonomous car when it failed to detect a pedestrian crossing the street. Tommy had been on the road for a while, and his car was doing most of the driving, safely. When Tommy's car hit the pedestrian, Tommy was busy texting his friend out of boredom of driving. His hands were off the steering wheel, and his eyes were on his cellphone.There are no sensors inside his car to detect when Tommy is distracted and to remind him to pay attention to the road.Should it be mandatory for semi-autonomous cars to always have sensors inside the cars?

Answered: 1,314     Skipped: 60



| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Yes | 64.38% | 846 |
| No | 16.13% | 212 |
| I don't know | 16.67% | 219 |
| Other (please specify) | 2.82% | 37 |
| TOTAL | | 1,314 |

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# Q11 Jamie was driving his manually-driven car when he failed to detect a pedestrian crossing the street. When Jamie's car hit the pedestrian, he was distracted and took his eyes off the road for a minute to text his friend. His hands were off the wheel while texting. There were no sensors inside his car to detect that Jaimie was distracted and to remind him to pay attention to the road.In the future, should it be mandatory for manually driven cars to have sensors installed inside the cars?

Answered: 1,314    Skipped: 60
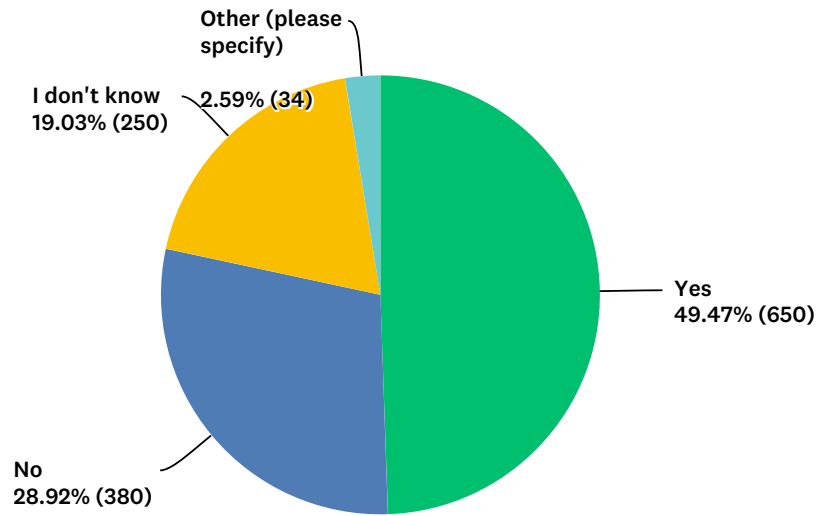


| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Yes | 49.47% | 650 |
| No | 28.92% | 380 |
| I don't know | 19.03% | 250 |
| Other (please specify) | 2.59% | 34 |
| TOTAL | | 1,314 |

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# Q12 Jane's semi-autonomous car comes with a suite of sensors inside her car, including a video camera to detect whether she is paying attention to the road. When the car detects that she is distracted, it makes an annoying beeping noise until she pays attention to the road again.Jane is tired of hearing the beeping noise. She decides to fool the system by having a photo of her where the video camera can see it.Should it be illegal for people like Jane to fool the sensors inside a car?

Answered: 1,298    Skipped: 76
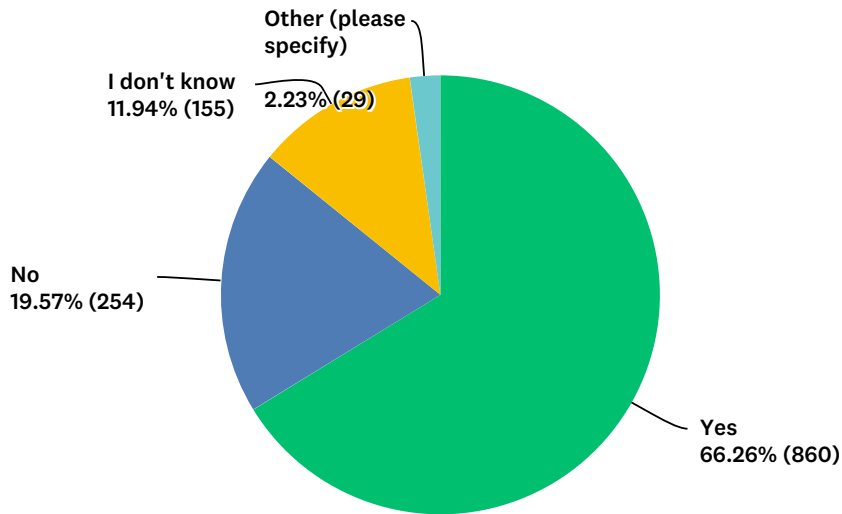


| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Yes | 66.26% | 860 |
| No | 19.57% | 254 |
| I don't know | 11.94% | 155 |
| Other (please specify) | 2.23% | 29 |
| TOTAL | | 1,298 |

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Q13 Kate's semi-autonomous car comes with a suite of sensors inside her car, including a  pressure sensor that detects whether her hands are on the wheel when necessary. When the car detects that her hands are off the wheel, it makes an annoying beeping noise until she takes control of the wheel.Kate is tired of hearing the beeping noise. She decides to fool the system by using a clamp that puts the right amount of pressure on the wheel to turn off the noise.Should it be illegal for people like Kate to fool the sensors inside a car?
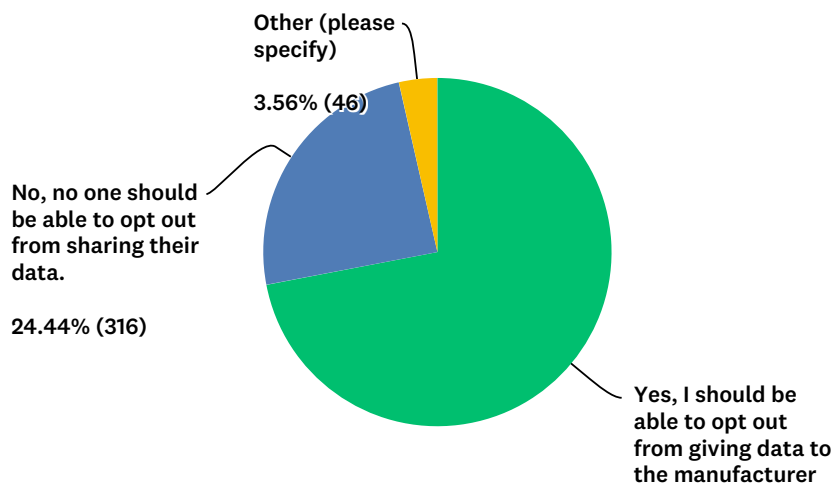
Answered: 1,298     Skipped: 76
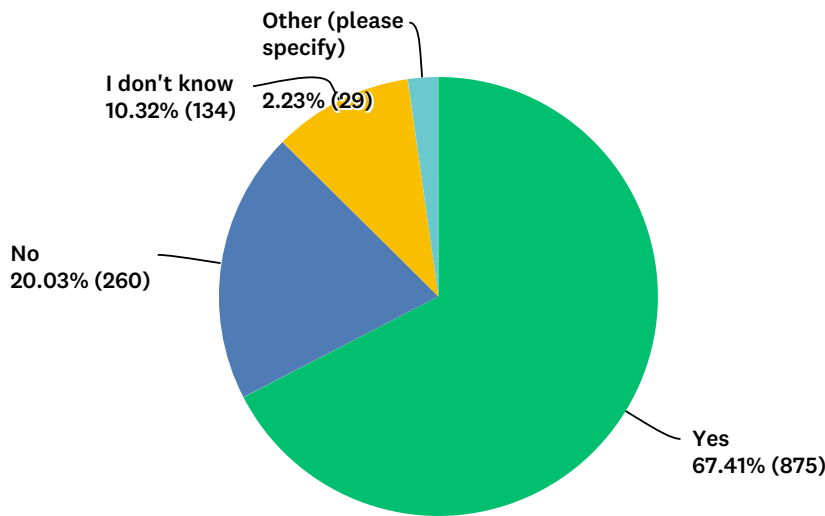


| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Yes | 67.41% | 875 |
| No | 20.03% | 260 |
| I don't know | 10.32% | 134 |
| Other (please specify) | 2.23% | 29 |
| TOTAL | | 1,298 |

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# Q14 You have decided that you want to buy a semi-autonomous vehicle. As you are completing the paperwork to purchase the car, you come across an informed consent form. In order to purchase the car, it requires that you to agree that all the data collected from the car will be stored and used by the manufacturer to improve safety-critical features of their cars.Should there be an option to refuse to provide the data to the car manufacturer?
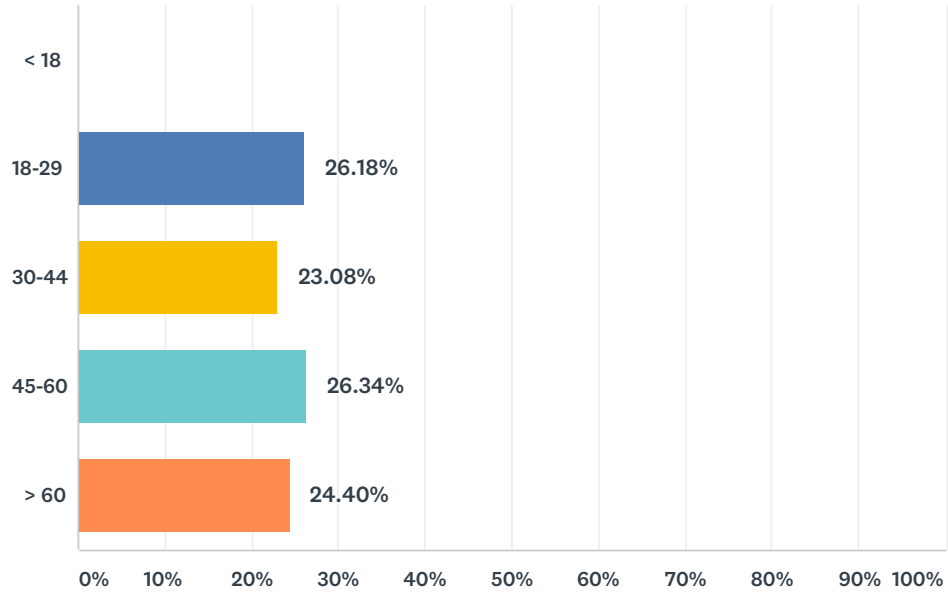
Answered: 1,293     Skipped: 81

**Other (please specify)**

**3.56% (46)**

**No, no one should be able to opt out from sharing their data.**

**24.44% (316)**

**Yes, I should be able to opt out from giving data to the manufacturer**

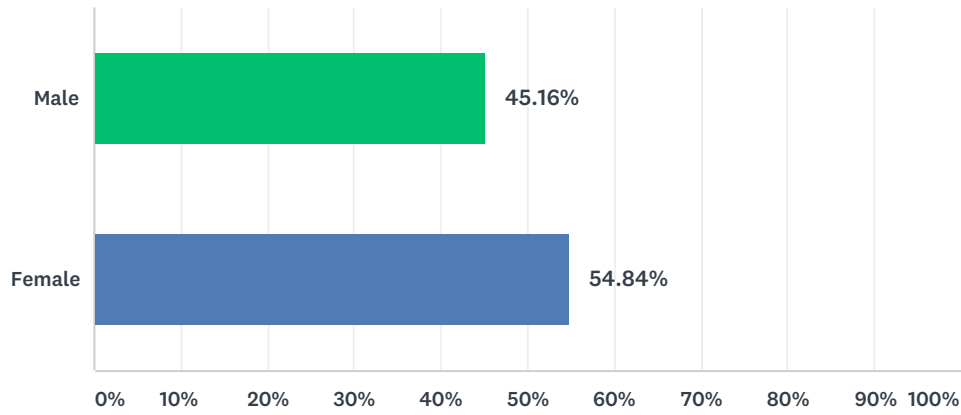| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| Yes, I should be able to opt out from giving data to the manufacturer | 72.00% | 931 |
| No, no one should be able to opt out from sharing their data. | 24.44% | 316 |
| Other (please specify) | 3.56% | 46 |
| TOTAL | | 1,293 |

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# Q15 Age

Answered: 1,291    Skipped: 83



| ANSWER CHOICES | RESPONSES | |
| --- | --- | --- |
| < 18 | 0.00% | 0 |
| 18-29 | 26.18% | 338 |
| 30-44 | 23.08% | 298 |
| 45-60 | 26.34% | 340 |
| > 60 | 24.40% | 315 |
| TOTAL | | 1,291 |

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# Q16 Gender

Answered: 1,291    Skipped: 83



| ANSWER CHOICES | RESPONSES | |
| --- | --- | --- |
| Male | 45.16% | 583 |
| Female | 54.84% | 708 |
| TOTAL | | 1,291 |

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# Q17 Household Income

Answered: 1,290    Skipped: 84
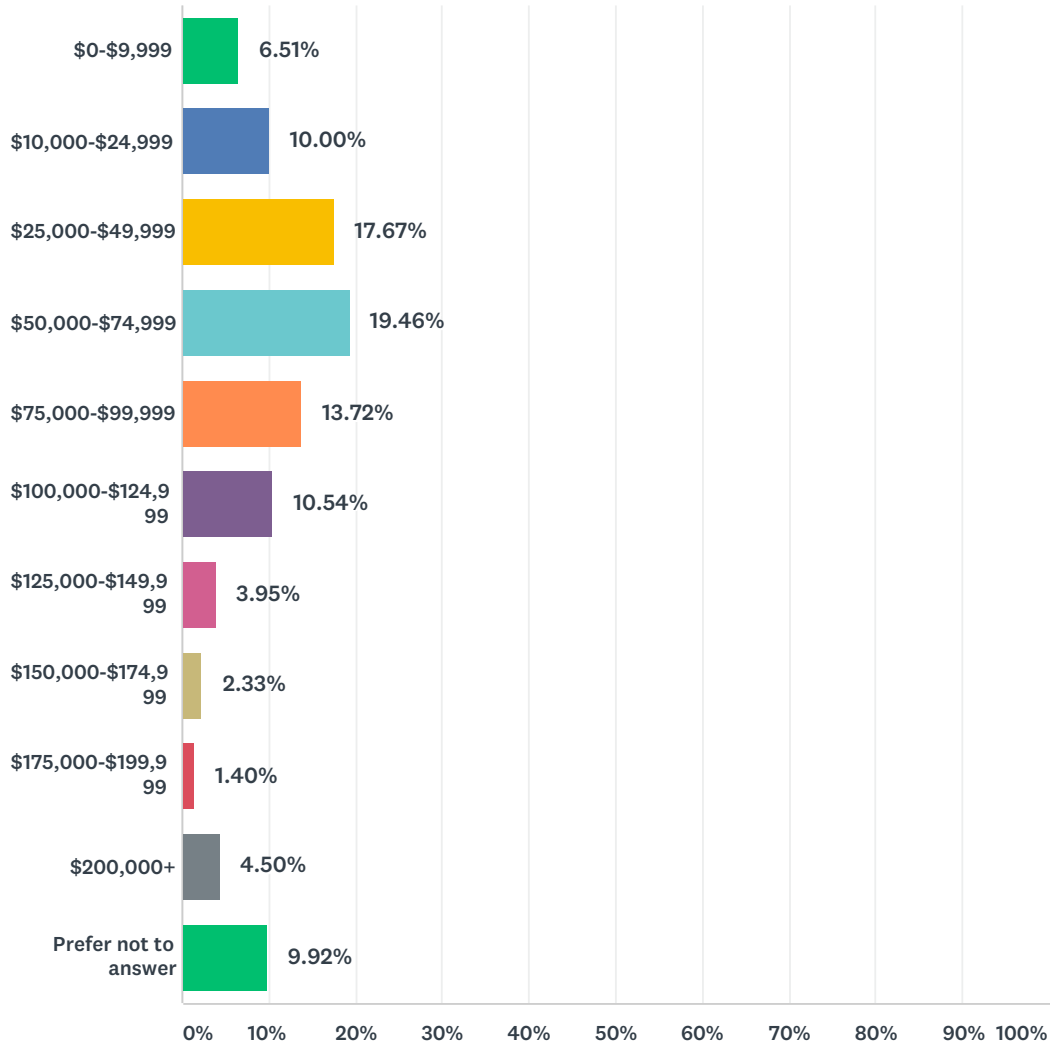


| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| $0-$9,999 | 6.51% | 84 |
| $10,000-$24,999 | 10.00% | 129 |
| $25,000-$49,999 | 17.67% | 228 |
| $50,000-$74,999 | 19.46% | 251 |
| $75,000-$99,999 | 13.72% | 177 |
| $100,000-$124,999 | 10.54% | 136 |
| $125,000-$149,999 | 3.95% | 51 |
| $150,000-$174,999 | 2.33% | 30 |
| $175,000-$199,999 | 1.40% | 18 |
| $200,000+ | 4.50% | 58 |

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| | | |
|---|---|---|
| Prefer not to answer | 9.92% | 128 |
| TOTAL | | 1,290 |

# Q18 Region

Answered: 1,284    Skipped: 90
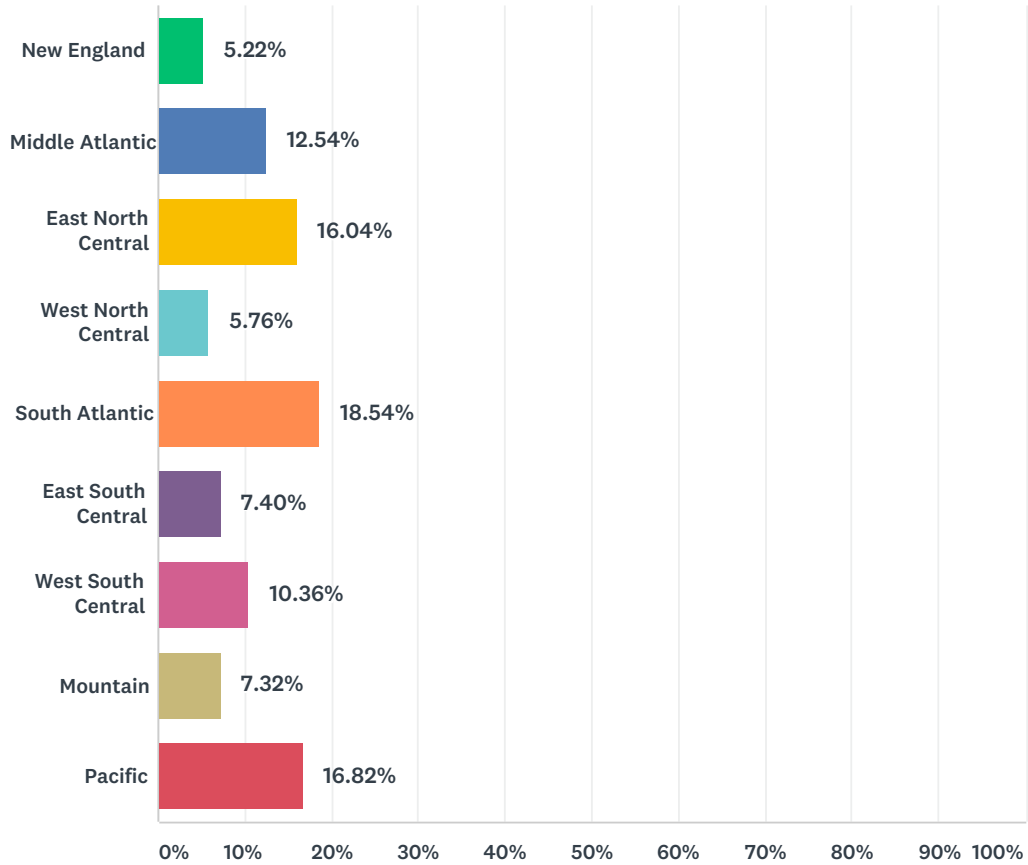


| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| New England | 5.22% | 67 |
| Middle Atlantic | 12.54% | 161 |
| East North Central | 16.04% | 206 |
| West North Central | 5.76% | 74 |
| South Atlantic | 18.54% | 238 |
| East South Central | 7.40% | 95 |
| West South Central | 10.36% | 133 |
| Mountain | 7.32% | 94 |
| Pacific | 16.82% | 216 |
| TOTAL | | 1,284 |

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# Q19 Device Type

Answered: 1,291    Skipped: 83
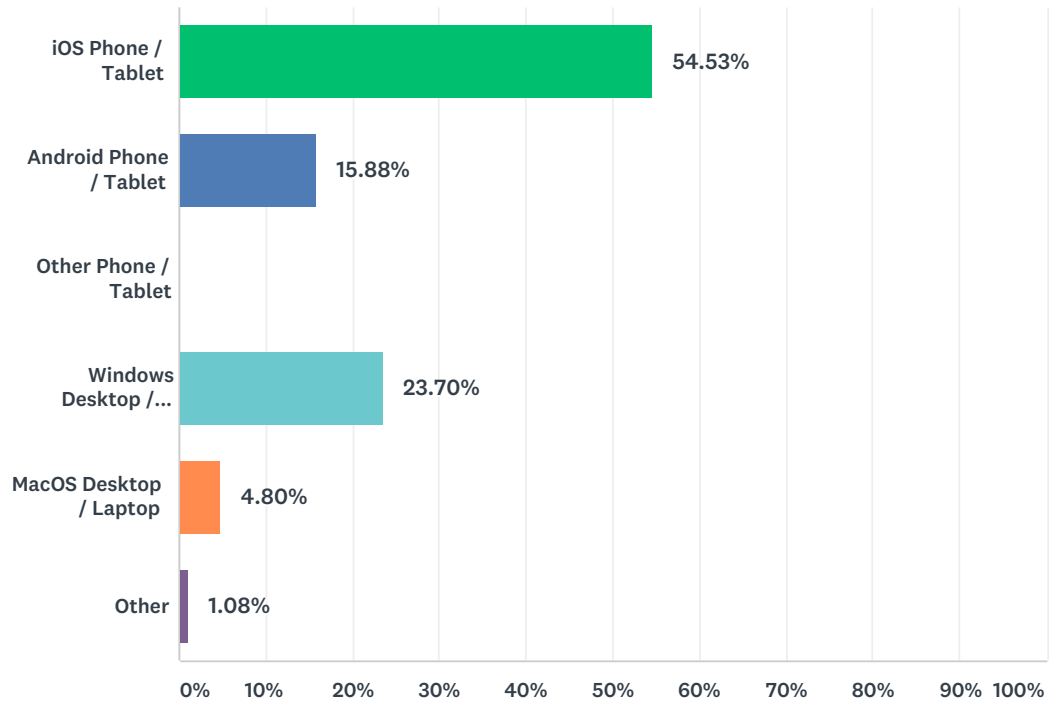


| ANSWER CHOICES | RESPONSES | |
|---|---|---|
| iOS Phone / Tablet | 54.53% | 704 |
| Android Phone / Tablet | 15.88% | 205 |
| Other Phone / Tablet | 0.00% | 0 |
| Windows Desktop / Laptop | 23.70% | 306 |
| MacOS Desktop / Laptop | 4.80% | 62 |
| Other | 1.08% | 14 |
| TOTAL | | 1,291 |

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