CYBERSECURITY CONCERNS WITH SELF-DRIVING AND CONVENTIONAL VEHICLES

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SUSTAINABLE WORLDWIDE TRANSPORTATION

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16. Abstract

This study was an online survey of American adults about their level of concern with cybersecurity of personally owned self-driving vehicles (with and without driver controls) and current conventional vehicles.

Of interest in this survey were both vehicle security and data privacy. Within vehicle security, the issues examined were hacking vehicles to cause crashes, hacking by terrorists to use the vehicle as a weapon, disabling many vehicles simultaneously, and disabling the main traffic-management system. Within data privacy, the issues examined were gaining access to data on personal travel patterns and gaining access to personal information not related to travel. The survey also asked about the safe and appropriate minimum age to operate self-driving vehicles with and without controls. Completed surveys were received from 519 respondents.

The main findings are as follows:

(1) Hacking of vehicles is of concern even for conventional vehicles.

(2) Hacking of self-driving vehicles with controls is of greater concern than hacking of conventional vehicles.

(3) Hacking of self-driving vehicles without controls is of greater concern than hacking of self-driving vehicles with controls.

(4) The respondents expressed more concern about hacking to gain control of vehicles or the main traffic-management system than hacking of vehicles to get access to personal information.

(5) Females expressed stronger concerns about cybersecurity than did males.

(6) The oldest respondents expressed stronger concerns about cybersecurity than did the youngest respondents.

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Contents

Introduction

In 2014, we performed a multinational survey of consumer expectations and concerns related to self-driving vehicles (Schoettle and Sivak, 2014). That survey, which was performed in the U.S., the U.K., Australia, China, India, and Japan, included three general questions concerning cybersecurity for self-driving vehicles. The results of that study indicated that there is substantial concern about cybersecurity in each of the six countries surveyed. For example, 40% of U.S. respondents were "very concerned" about vehicle security from hackers. (The corresponding percentages for the other five examined countries ranged from 57% in India to 19% in Japan.)

The present study was designed to build upon our 2014 study. The main new element was a comparison of cybersecurity concerns related to current conventional vehicles to those related to self-driving vehicles with and without driver controls (brake pedal, gas pedal, and steering wheel). Also, the present study examined additional cybersecurity aspects, and the survey instrument used a finer response scale than our 2014 study. Finally, the survey examined opinions about the safe and appropriate minimum age to operate self-driving vehicles with and without driver controls.

Method

Survey instrument

An online survey was conducted using SurveyMonkey, a web-based survey company. The text of the questionnaire is included in the appendix. The survey was performed in January 2017.

Respondents

SurveyMonkey's Audience tool was used to recruit respondents 18 years and older from SurveyMonkey's respondent database in the U.S. Fully completed surveys were received for 519 respondents. The margin of error at the 95% confidence level for the overall results is ±4.3%. Demographic breakdowns for the respondents are presented in Table 1. The age and gender breakdowns are similar to the latest U.S. Census age and gender distributions. Figure 1 shows each U.S. Census region and the corresponding states.

Table 1
Demographic breakdowns for the respondents.

Demographic aspect		Percent
Gender	Female	51.9
	Male	48.1
Age group	18 to 29	21.6
	30 to 44	26.1
	45 to 59	28.0
	60 or older	24.3
Income	$0 to $24,999	15.1
	$25,000 to $49,999	19.5
	$50,000 to $74,999	15.8
	$75,000 to $99,999	13.9
	$100,000 to $124,999	8.9
	$125,000 to $149,999	5.4
	$150,000 to $174,999	1.9
	$175,000 to $199,999	1.5
	$200,000 or more	6.0
	Prefer not to answer	12.0
U.S. Census region	New England	6.9
	Middle Atlantic	14.8
	South Atlantic	18.1
	North Central	23.4
	South Central	14.0
	Mountain	8.3
	Pacific	14.6

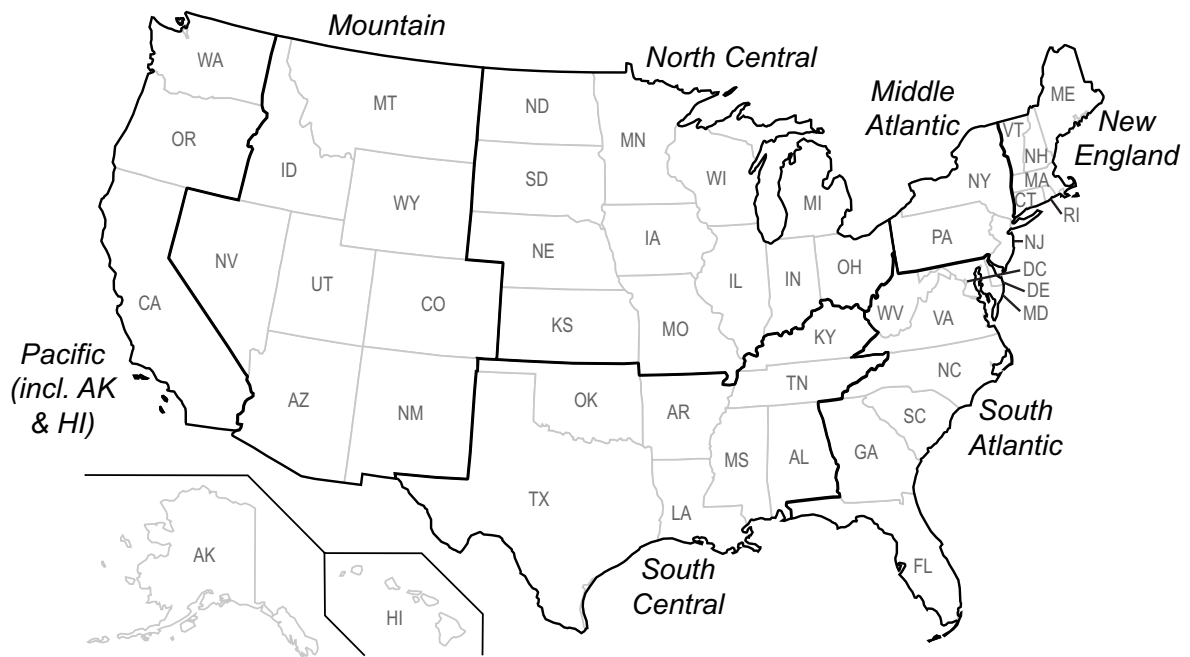Figure 1. U.S. Census regions.

Results

All respondents combined

Table 2 presents the distributions of the responses for all respondents combined. The entries in Table 2 are presented in decreasing order of percentage indicating "extremely concerned" about a particular cybersecurity aspect for self-driving vehicles without controls.

The main findings are as follows:

(1) Hacking of vehicles is of concern even for conventional vehicles, with the percentage of those who expressed some concern ranging from 49.0% to 68.1%, depending on the cybersecurity aspect.

(2) Hacking of self-driving vehicles with driver controls is of greater concern than hacking of conventional vehicles, with the proportional increase in the percentage of those who are extremely concerned ranging from 1.5 to 1.7.

(3) Hacking of self-driving vehicles without driver controls is of greater concern than hacking of self-driving vehicles with controls, with the proportional increase in the percentage of those who are extremely concerned ranging from 1.5 to 2.0.

(4) The greatest level of concern for conventional vehicles and self-driving vehicles with driver controls was hacking or disabling the main traffic-management system, with 12.4% and 19.9%, respectively, indicating they were extremely concerned.

(5) The greatest concern for self-driving vehicles without driver controls was hacking of vehicles to cause crashes or other malicious intent, with 33.4% indicating they were extremely concerned.

(6) Fewer respondents were extremely concerned about hacking of vehicles to get access to personal information than hacking to gain control of vehicles or the main traffic-management system. This applies for conventional vehicles, as well as self-driving vehicles with or without driver controls.

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Table 2
Distributions of the responses for all respondents combined. The entries are percentages.

Aspect	Response	Conventional vehicles	Self-driving vehicles with controls	Self-driving vehicles without controls
Hacking personally owned vehicles to cause crashes or other malicious intent	Not at all concerned	46.5	15.1	13.5
	Slightly concerned	20.8	22.6	13.5
	Somewhat concerned	9.3	17.0	12.4
	Moderately concerned	6.4	14.9	12.5
	Very concerned	6.8	13.9	14.7
	Extremely concerned	10.2	16.6	33.4
Hacking or disabling many vehicles simultaneously	Not at all concerned	44.6	14.3	13.1
	Slightly concerned	22.6	23.0	14.7
	Somewhat concerned	8.5	15.1	14.7
	Moderately concerned	5.6	16.4	13.3
	Very concerned	7.3	12.0	13.3
	Extremely concerned	11.4	19.3	30.9
Hacking or disabling the main traffic-management system (or large portions of it)	Not at all concerned	31.9	13.7	12.2
	Slightly concerned	24.5	18.1	13.1
	Somewhat concerned	12.5	17.8	14.7
	Moderately concerned	10.4	16.4	16.0
	Very concerned	8.3	14.1	14.3
	Extremely concerned	12.4	19.9	29.7
Hacking personally owned vehicles by terrorists to use as a weapon	Not at all concerned	51.0	22.8	16.8
	Slightly concerned	18.7	19.7	17.0
	Somewhat concerned	7.9	14.1	12.7
	Moderately concerned	7.3	13.5	10.8
	Very concerned	5.2	13.5	13.1
	Extremely concerned	9.8	16.4	29.5
Hacking personally owned vehicles to gain access to data on personal travel patterns	Not at all concerned	45.4	23.6	23.6
	Slightly concerned	19.1	21.0	15.6
	Somewhat concerned	11.4	16.0	13.7
	Moderately concerned	8.3	14.3	10.8
	Very concerned	8.1	12.2	14.7
	Extremely concerned	7.7	12.9	21.6
Hacking personally owned vehicles to gain access to personal information not related to travel*	Not at all concerned	44.0	23.9	22.8
	Slightly concerned	18.9	18.5	14.7
	Somewhat concerned	13.1	15.6	14.1
	Moderately concerned	7.1	12.5	11.0
	Very concerned	7.9	15.6	16.4
	Extremely concerned	8.9	13.7	21.0

*Such as financial information while shopping online in a vehicle.

Gender effects

Table 3 presents the distributions of the two most extreme responses by gender. The main finding here is that more females were extremely concerned about all cybersecurity aspects than were males. This applies to conventional vehicles as well as self-driving vehicles with and without driver controls. For example, 15.2% of females were extremely concerned about hacking many conventional vehicles simultaneously, compared with 7.2% of males.

Table 3
Distributions of the two most extreme responses, by gender. The entries are percentages.

Aspect	Response	Conventional vehicles		Self-driving vehicles with controls		Self-driving vehicles without controls	
		Females	Males	Females	Males	Females	Males
Hacking personally owned vehicles to cause crashes or other malicious intent	Not at all concerned	40.9	52.6	14.5	15.7	11.9	15.3
	Extremely concerned	10.4	10.0	19.7	13.3	36.1	30.5
Hacking or disabling many vehicles simultaneously	Not at all concerned	39.0	50.6	11.5	17.3	10.4	16.1
	Extremely concerned	15.2	7.2	22.7	15.7	33.8	27.7
Hacking or disabling the main traffic-management system (or large portions of it)	Not at all concerned	29.7	34.1	13.0	14.5	11.9	12.4
	Extremely concerned	14.9	9.6	23.4	16.1	32.3	26.9
Hacking personally owned vehicles by terrorists to use as a weapon	Not at all concerned	47.6	54.6	22.7	22.9	16.0	17.7
	Extremely concerned	11.9	7.6	18.2	14.5	33.1	25.7
Hacking personally owned vehicles to gain access to data on personal travel patterns	Not at all concerned	42.0	49.0	23.0	24.1	20.1	27.3
	Extremely concerned	9.3	6.0	15.6	10.0	24.2	18.9
Hacking personally owned vehicles to gain access to personal information not related to travel	Not at all concerned	40.9	47.4	24.2	23.7	22.7	22.9
	Extremely concerned	10.4	7.2	16.4	10.8	22.7	19.3

Age effects

Table 4 presents the distributions of the two most extreme responses by age group. The main findings are as follows:

(1) For all aspects and all vehicle types, the oldest respondents (≥60 years) were more likely to be extremely concerned than were the youngest respondents (18-29 years).

(2) The relative concern of the two middle-age groups depended on the combination of the cybersecurity aspect and the vehicle type. For some combinations, the percentage of those who were extremely concerned increased with age (e.g., for hacking or disabling the main traffic-management system for self-driving vehicles with controls), while for other combinations, the effect of age was non-monotonic.

Table 4
Distributions of the two most extreme responses, by age group. The entries are percentages.

Aspect	Response	Conventional vehicles				Self-driving vehicles with controls				Self-driving vehicles without controls			
		18-29	30-44	45-59	≥60	18-29	30-44	45-59	≥60	18-29	30-44	45-59	≥60
Hacking personally owned vehicles to cause crashes or other malicious intent	Not at all concerned	50.9	51.1	46.2	38.1	16.1	21.5	12.4	10.3	17.0	17.0	11.7	8.7
	Extremely concerned	10.7	10.4	8.3	11.9	15.2	16.3	16.6	18.3	34.8	31.1	29.0	39.7
Hacking or disabling many vehicles simultaneously	Not at all concerned	58.0	48.9	43.4	29.4	19.6	16.3	13.1	8.7	16.1	16.3	11.7	8.7
	Extremely concerned	6.3	9.6	11.7	17.5	16.1	19.3	18.6	23.0	30.4	32.6	23.4	38.1
Hacking or disabling the main traffic-management system (or large portions of it)	Not at all concerned	42.0	37.0	29.0	20.6	21.4	11.9	14.5	7.9	17.0	11.1	12.4	8.7
	Extremely concerned	6.3	9.6	13.8	19.0	15.2	18.5	20.7	24.6	26.8	31.1	25.5	35.7
Hacking personally owned vehicles by terrorists to use as a weapon	Not at all concerned	59.8	54.1	49.7	41.3	27.7	23.0	22.1	19.0	17.9	16.3	19.3	13.5
	Extremely concerned	6.3	10.4	11.0	11.1	12.5	14.8	20.0	17.5	26.8	30.4	25.5	35.7
Hacking personally owned vehicles to gain access to data on personal travel patterns	Not at all concerned	41.1	45.2	50.3	43.7	19.6	25.9	23.4	24.6	22.3	24.4	23.4	23.8
	Extremely concerned	8.0	6.7	7.6	8.7	10.7	16.3	11.0	13.5	23.2	20.7	18.6	24.6
Hacking personally owned vehicles to gain access to personal information not related to travel	Not at all concerned	51.8	47.4	39.3	38.9	25.9	26.7	22.8	20.6	21.4	25.2	23.4	20.6
	Extremely concerned	6.3	7.4	8.3	13.5	10.7	14.1	13.1	16.7	20.5	20.0	19.3	24.6

Minimum age to operate a self-driving vehicle

Table 5 presents the results concerning the safe and appropriate minimum age to operate a self-driving vehicle without adult supervision. Tables 6 and 7 present the analogous data by gender and age group, respectively.

Table 5
Minimum age to operate a self-driving vehicle without adult supervision.
The entries are percentages.

Minimum age	Self-driving vehicles with controls	Self-driving vehicles without controls
17	47.7	52.5
16	33.0	20.8
15	4.1	4.2
≤14	15.2	22.5

Table 6
Minimum age to operate a self-driving vehicle without adult supervision, by gender.
The entries are percentages.

Minimum age	Self-driving vehicles with controls		Self-driving vehicles without controls	
	Females	Males	Females	Males
17	52.0	43.0	58.7	45.8
16	31.2	34.9	19.7	22.1
15	4.5	3.6	3.7	4.8
≤14	12.3	18.5	17.9	27.3

Table 7
Minimum age to operate a self-driving vehicle without adult supervision, by age group.
The entries are percentages.

Minimum age	Self-driving vehicles with controls				Self-driving vehicles without controls			
	18-29	30-44	45-59	≥60	18-29	30-44	45-59	≥60
17	32.1	37.8	57.2	61.1	39.3	45.2	57.2	66.7
16	42.0	37.8	28.3	25.4	25.9	23.7	24.1	9.5
15	1.8	6.7	5.5	1.6	4.5	5.2	4.8	2.4
≤14	24.1	17.7	9.0	11.9	30.3	25.9	13.9	21.4

The main findings are as follows:

(1) The most frequent minimum age given as being safe and appropriate to operate self-driving vehicles of either type without adult supervision was 17. This was the case for all respondents in general, as well as for all demographic groups except for the youngest respondents (18-29 year olds), who most frequently indicated 16.

(2) More respondents believed that the minimum age should be 17 for self-driving vehicles without controls (52.5%) than for self-driving vehicles with controls (47.7%).

(3) More females than males believed that the minimum age should be 17. This was the case for both self-driving vehicles with controls (52.0% vs. 43.0%) and self-driving vehicles without controls (58.7% vs. 45.8%).

(4) The percentage of those who believed that the minimum age should be 17 increased monotonically with age for both self-driving vehicles with controls (from 32.1% for those 18-29 year olds to 61.1% for those 60 years and older) and self-driving vehicles without controls (from 39.3% for those 18-29 year olds to 66.7% for those 60 years and older).

Summary

This study was an online survey of American adults about their level of concern with cybersecurity of personally owned self-driving vehicles (with and without driver controls) and current conventional vehicles.

Of interest in this survey were both vehicle security and data privacy. Within vehicle security, the issues examined were hacking vehicles to cause crashes, hacking by terrorists to use the vehicle as a weapon, disabling many vehicles simultaneously, and disabling the main traffic-management system. Within data privacy, the issues examined were gaining access to data on personal travel patterns and gaining access to personal information not related to travel. The survey also asked about the safe and appropriate minimum age to operate self-driving vehicles with and without controls. Completed surveys were received from 519 respondents.

The main findings are as follows:

(1) Hacking of vehicles is of concern even for conventional vehicles.

(2) Hacking of self-driving vehicles with controls is of greater concern than hacking of conventional vehicles.

(3) Hacking of self-driving vehicles without controls is of greater concern than hacking of self-driving vehicles with controls.

(4) The respondents expressed more concern about hacking to gain control of vehicles or the main traffic-management system than hacking of vehicles to get access to personal information.

(5) Females expressed stronger concerns about cybersecurity than did males.

(6) The oldest respondents expressed stronger concerns about cybersecurity than did the youngest respondents.

Reference

Schoettle, B. and Sivak, M. (2014). *Public opinion about self-driving vehicles in China, India, Japan, the U.S., the U.K., and Australia* (Report No. UMTRI-2014-30). Ann Arbor: The University of Michigan Transportation Research Institute. Available at: http://deepblue.lib.umich.edu/bitstream/handle/2027.42/109433/103139.pdf

Appendix: Questionnaire

We are conducting a survey of opinions about vehicle cybersecurity.

We are interested in your level of concern about various cybersecurity issues for current conventional vehicles and for different types of self-driving vehicles that may become available in the near future.

It is not necessary for you to currently drive or own a vehicle to participate.

Q1. How concerned are you about the following issues related to different levels of self-driving vehicle technology **for personally owned passenger vehicles**?

Self-driving vehicles <u>with</u> controls have a brake pedal, a gas pedal, and a steering wheel. The operator would be able to turn off or disable the self-driving system or drive the vehicle manually, like a conventional vehicle.

*Self-driving vehicles <u>without</u> controls **do not** have a brake pedal, a gas pedal, and a steering wheel. The operator would be able to turn off or disable the self-driving system but would NOT be able to drive the vehicle manually, like a conventional vehicle.*

Topic	Current conventional vehicles	Self-driving vehicles WITH controls	Self-driving vehicles WITHOUT controls
Hacking personally owned vehicles to cause crashes or other malicious intent	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned
Hacking personally owned vehicles to gain access to data on personal travel patterns	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned
Hacking personally owned vehicles to gain access to personal information not related to travel (such as financial information while shopping online in a vehicle)	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned
Hacking personally owned vehicles by terrorists to use as a weapon	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned

Q2. How concerned are you about the following issues related to different levels of self-driving vehicle technology **for the traffic system as a whole**?

Self-driving vehicles <u>with</u> controls have a brake pedal, a gas pedal, and a steering wheel. The operator would be able to turn off or disable the self-driving system or drive the vehicle manually, like a conventional vehicle.

*Self-driving vehicles <u>without</u> controls **do not** have a brake pedal, a gas pedal, and a steering wheel. The operator would be able to turn off or disable the self-driving system but would NOT be able to drive the vehicle manually, like a conventional vehicle.*

Topic	Current conventional vehicles	Self-driving vehicles WITH controls	Self-driving vehicles WITHOUT controls
Hacking or disabling many vehicles simultaneously	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned
Hacking or disabling the main traffic-management system (or large portions of it)	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned	☐ Not at all concerned ☐ Slightly concerned ☐ Somewhat concerned ☐ Moderately concerned ☐ Very concerned ☐ Extremely concerned

Q3. What is the minimum age that you feel would be safe or appropriate to allow a child (under the age of 18) to operate a self-driving vehicle on public roads without adult supervision?

Self-driving vehicles <u>with</u> controls have a brake pedal, a gas pedal, and a steering wheel. The operator would be able to turn off or disable the self-driving system or drive the vehicle manually, like a conventional vehicle.

*Self-driving vehicles <u>without</u> controls **do not** have a brake pedal, a gas pedal, and a steering wheel. The operator would be able to turn off or disable the self-driving system but would NOT be able to drive the vehicle manually, like a conventional vehicle.*

	Self-driving vehicles WITH controls	Self-driving vehicles WITHOUT controls
Please select an age for each vehicle type:		

Thank you for taking the time to complete this survey!