Running head: AUTOMATION SAFETY

Uncorrected, accepted preprint (11.19.18) version of:
Nees, M.A. Safer than the average human driver (who is less safe than me)? Examining a popular safety benchmark for self-driving cars. Journal of Safety Research, 69, 61-68.

The version of record is available at: https://doi.org/10.1016/j.jsr.2019.02.002

Safer Than the Average Human Driver (Who is Less Safe than Me)? Examining a Popular Safety Benchmark for Self-Driving Cars

Michael A. Nees

Lafayette College

Submitted for consideration for publication as Full Length Article in *Journal of Safety Research*

Acknowledgments: Portions of this research were funded by a Richard King Mellon Summer Research Fellowship awarded to the author by the Lafayette College Academic Research Committee.

Corresponding author:
Michael A. Nees
Lafayette College
Department of Psychology
Oechsle Hall
350 Hamilton Street
Easton, PA 18042
Ph: (610) 330 5290
neesm@lafayette.edu
nees.michael@gmail.com

Abstract

Although the level of safety required before drivers will accept self-driving cars is not clear, the criterion of being safer than a human driver has become pervasive in the discourse on vehicle automation. This criterion actually means "safer than *the average* human driver," because it is necessarily defined with respect to population-level data. At the level of individual risk assessment, a body of research has shown that most drivers perceive themselves to be safer than the average driver (the *better-than-average effect*). Using an online sample of U.S. drivers, this study replicated the better than average effect and showed that most drivers stated a desire for self-driving cars that are safer than their own perceived ability to drive safely before they would: (1) feel reasonably safe riding in a self-driving vehicle; (2) buy a self-driving vehicle, all other things (cost, etc.) being equal; and (3) allow self-driving vehicles on public roads. Since most drivers believe they are better than average drivers, the benchmark of achieving automation that is safer than a human driver (on average) may not represent acceptably safe performance of self-driving cars for most drivers.

Key words: human-automation interaction, trust in automation, self-driving vehicles, autonomous driving, vehicle automation

Safer Than the Average Human Driver (Who is Less Safe than Me)? Examining a Popular Safety Benchmark for Self-Driving Cars

Advances in engineering and technology have made the prospect of mass-marketed, self-driving vehicles the subject of increasing public discussion. User acceptance of automation is an important determinant of whether the technology succeeds or fails. The extent to which the public and consumers will accept self-driving cars has yet to be determined, but trust—"the attitude that an agent [in this case a self-driving car] will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability" (Lee & See, 2004, p. 51)—will be an important factor (Choi & Ji, 2015; also see Kaur & Rampersad, 2018; König & Neumayr, 2017). Perceived risk influences trust in automation, which in turn influences the extent to which people will rely on automated systems (Hoff & Bashir, 2015). A study of perceptions of self-driving cars on Twitter found that risks were mentioned three times more often than benefits in social media discourse (Kohl, Mostafa, Böhm, & Krcmar, 2017). Further, surveys consistently have indicated that people have skepticism and apprehensions about vehicle automation that are related to safety (e.g., Nielsen & Haustein, 2018; Piao et al., 2016; Schoettle & Sivak, 2014; Zmud, Sener, & Wagner, 2016), with a recent survey (American Automobile Association, 2018) reporting that over 70% of U.S. drivers fear riding in a fully automated vehicle. Clearly, safety will be an important factor that will affect acceptance of self-driving cars, but the criterion for acceptable safety in vehicle automation for the general public is currently unknown.

One potential safety benchmark that has emerged in the discourse on vehicle automation is to compare the performance of self-driving cars to human drivers to establish whether the automation is safer than a human driver. This *safer than a human driver criterion* (SHDC) has become ubiquitous in the discourse surrounding vehicle automation. For instance, Google News (i.e., news-only) web searches conducted on November 17, 2018 for the phrases "safer than a human driver" and "safer than human drivers" (both searches in quotation marks) returned 711 and 1540 respective results—nearly all of which reported news and analysis on vehicle automation. These reports and commentaries contain claims that vehicle automation already has met (e.g., by Elon Musk, as reported in McGoogan, 2016), has not met (e.g., McArdle, 2018), and/or eventually will meet (e.g., Hetherington, 2018) the SHDC. One survey (Schoettle & Sivak, 2014) showed that around 75% of participants were moderately to highly concerned about "self-driving vehicles not driving as well as human drivers in general," whereas another (Piao et al., 2016) indicated that only 25% of participants believed that automated vehicles will be "safer than human driven vehicles." Indeed, much of the discussion of acceptable levels of safety for self-driving cars seems to hinge upon whether they meet the SHDC (e.g., Teoh & Kidd, 2017), perhaps because this criterion presents a stark, binary delineation between outcomes superior or inferior to the current status quo.

The SHDC defines safety relative to population-level data parameters, which means the criterion is actually "safer than *the average* human driver." Indeed, Kalra and Groves (2017) estimated that widespread deployment of highly automated vehicles that are even somewhat (i.e., 10%) safer than the average human driver would save many lives (up to half a million, depending on various factors) in the decades following their introduction. As such, the normative, rational decision for minimizing loss of life in the long-term would be for all drivers to use highly automated vehicles as soon as the automation has become marginally safer than the average human driver.

At the level of individual decision-making, however, it is not certain that vehicle automation that is safer than the average driver will compel widespread acceptance, adoption, and purchase of vehicles with self-driving capabilities. Human decision-making does not follow normative probabilistic processes (for a review, see Beach & Lipshitz, 1993). Perceived risk may be influenced by a number of cognitive biases that lead individuals to believe their own personal risk is different from normative probabilities based on population-level data. Across a wide variety of performance and trait domains, individuals tend to view themselves as better than average--a phenomenon called *the better-than-average effect* (for a review, see Alicke & Govorun, 2005).

In the context of driving, research consistently has shown that most drivers believe themselves to be a safer driver than both the average human driver and the drivers in their own peer groups (Finn & Bragg, 1986; Harré, Foster, & O'Neill, 2005; Marottoli & Richardson, 1998; McCormick, Walkey, & Green, 1986). Svenson (1981) showed that 88% of a sample of U.S. drivers and 77% of a sample of Swedish drivers rated themselves as safer than the median driver. McKenna, Stanier, and Lewis, (1991) showed that participants rated themselves as more skillful than the average driver across a number of driving tasks that affect safety (e.g., paying attention to other vehicles, judging distances required to stop, and minding appropriate speeds for driving conditions). In a sample of U.K. drivers, Horswill, Waylen, and Tofield (2004) showed that participants rated themselves as more safe, more skillful, and less accident prone than both their demographically-matched peers and the average driver.

McKenna (1993) asked people to rate their likelihood of being involved in an accident while riding in a vehicle as a passenger versus while driving the vehicle. People believed that they had an average chance of being involved in an accident as a passenger, but they reported that they had a less than average chance of being involved in an accident as the driver of a car. In other words, people seemed to believe that population-level statistics about accidents applied to other drivers, but not to themselves. McKenna concluded that the mechanism for this bias is the illusion of control (rather than alternative explanations such as unrealistic optimism). Related findings reported by DeJoy (1989) suggested that unrealistic optimism stems from the tendency for people to overestimate the extent to which they have control over circumstance which could lead to an accident while driving. Correspondingly, risk denial (believing one's own risk is less than that of the general population) increases as perceived control over risk increases (Sjöberg, 2000).

A bias toward inflated perceptions of safety while one is in control of a vehicle could be problematic for acceptance of self-driving cars. Research has suggested that people have a strong desire to be able to take control back from automated systems (König & Neumayr, 2017; Nees, 2016; Schoettle & Sivak, 2016), likely because they feel safer when they are in control of the vehicle (e.g., DeJoy, 1989; Sjöberg, 2000) rather than riding as a passive passenger (see (McKenna, 1993). Although the normative, rational decision at a population level may be for all drivers to relinquish control to self-driving cars as soon as automation is safer than the average human driver (see Kalra and Groves, 2017), the realization of population-level benefits (e.g., reduced traffic fatalities) will require that individuals accept and use or buy self-driving cars. If most individuals believe they are above-average drivers with respect to safety due to biases related to the illusion of control over risks, then they may require self-driving cars to meet a higher benchmark than the SHDC before they will accept this new technology. Specifically, it seems that people will want self-driving cars to be safer than they believe themselves to be. For example, a recent study (Liu, Yang, & Xu, in press) modeled risk acceptability for self-driving vehicles in a sample of responses from Chinese participants. Their results suggested that the minimum acceptable safety criterion may be 4-5 times safer than human drivers.

The Current Study

In the current study, an online sample of U.S. drivers made ratings regarding their own perceived ability to drive safely. They also made ratings of their perceptions of the ability of current vehicles with automation to drive safely. Finally, they rated their desired level of safety before they would accept self-driving cars. In this study, desired safety was measured with three outcomes: (1) participants' desired safety level of self-driving vehicles before the vehicles are allowed on public roads; (2) participants' desired safety level of self-driving vehicles before participants would feel reasonably safe riding in the vehicles; and (3) participants' desired safety level of self-driving vehicles before participants would buy a self driving vehicle, all other things (cost, etc.) being equal. All ratings (self-ratings, current automation ratings, and the three desired safety ratings) were made on a scale of percentiles from 1-99, where the 50^{th} percentile represented the average human driver. Participants were told that, for the purposes of this study, a "self-driving" car corresponds to a vehicle with full automation (i.e., that functions at SAE levels 4/5, see SAE On-road Automated Vehicles Standards Committee, 2016), which recent research showed is approximately what people interpret the term "self-driving" to mean (Nees, 2018).

Hypotheses

Hypothesis 1. My first hypothesis was that this study would replicate the better-than-average effect for self-ratings of safe driving ability; specifically, I expected that most participants would view themselves as above the 50^{th} percentile with respect to their ability to drive safely.

Hypothesis 2. My second hypothesis was that most drivers would perceive their own ability to drive safely as better than the current ability of vehicles with automation to drive safely.

Hypothesis 3. My third hypothesis was that most people would use their own perceived driving ability—rather than the safer-than-the-average-driver benchmark, as a criterion for acceptable safety. Specifically, I expected that most participants would indicate that self-driving cars need to be safer than their own perceived safety ability before they would ride in, purchase, or endorse public roadway use of self-driving cars.

Method

Participants

Participants (*N* = 504) were recruited online via Amazon Mechanical Turk (AMT). AMT workers were required to be located in the United States, to have a task approval rating of greater than 95%, and to have at least 1000 previously approved tasks. The study description also indicated that the research was only open to licensed drivers. Participants were paid $0.50 for their time. Thirty-two participants failed screening questions (described below), so the final sample analyzed was *N* = 472 (*M* age = 37.25, *SD* = 10.98 years; 205 females, 266 males, and 1 person who chose “other/prefer not to respond”). Self-reported racial/ethnic backgrounds were white (*n* = 383), Asian (*n* = 42), black or African American (*n* = 35), Hispanic or Latino (*n* = 29), American Indian or Alaska Native (*n* = 1), and Native Hawaiian or Pacific Islander (*n* = 1), other (*n* = 3), and “prefer not to answer” (*n* = 3). Some participants (*n* = 23) selected more than one category, so the sum of these numbers is greater than the sample size. Participants reported holding a bachelor’s or 4-year degree (*n* = 196), some college with no degree (*n* = 107), an associates degree or 2-year degree (*n* = 70), a high school diploma or GED (*n* = 47), a master’s degree or post-bachelor professional degrees (*n* = 47), a doctoral degree (*n* = 4), and no high school diploma (*n* = 1). Participants reported *M* = 19.31 years of driving experience (*SD* = 11.55, *mdn* = 17.00, minimum = 1.00, maximum = 56.00). Participants reported driving *M* = 8.10 hours per week (*SD* = 8.18, *mdn* = 6.00, minimum = 0.00, maximum = 80.00). Participants reported the scenario that best described where they drive most often as urban/city driving (*n* = 285), rural/small town driving (*n* = 129), distance/interstate/freeway driving (*n* = 54), and other (*n* = 4). On a scale from 1 (“not familiar at all”) to 7 (“extremely familiar”), participants rated their familiarity with the current state of technology related to vehicle automation and self-driving cars as $M = 3.96$ ($SD = 1.48$, $mdn = 4.00$) and their familiarity with news stories about recent Uber and Tesla fatal accidents involving automation as $M = 4.54$ ($SD = 1.93$, $mdn = 5$). Participants reported having read $M = 7.74$ articles about self-driving cars in print or online ($SD = 47.00$, $mdn = 2.00$, minimum = 0.00, maximum = 999.00). Regarding owning or using a vehicle that had automated features, participants reported 200 instances of cruise control, 21 instances of automatic braking, 15 instances of automatic lane keeping or lane keeping assist, 11 instances of adaptive cruise control, 2 instances of Autopilot, and 1 instance of automatic blind spot warning; 258 participants reported owning or using vehicles with none of these features. Participants were allowed to select more than one feature, so these instances sum to greater than the sample size.

Instructions and Survey Questions

After accepting the recruitment posting on AMT, participants were directed to a survey hosted on Qualtrics. Following informed consent, participants were instructed that the study questions were about self-driving cars, "defined as a vehicle in which computers and automated systems perform driving tasks including steering, accelerating/braking, and monitoring the driving scenario without help from the human driver." Participants also received a brief explanation of percentiles, including instructions that said, "The average human driver is at the 50th percentile, which means that 50% of all humans drive more safely than the average driver, and 50% of all humans drive less safely than the average driver." Verbatim instructions are shown in Appendix A.

Sundstrom (2008) suggested that self-ratings of driving skill relative to the average driver can be improved by providing additional reference points on the rating scale (e.g, by referencing "a very good driver" in addition to the "the average driver"). Following instructions, participants rated each of the following five items on a scale representing percentiles from 1 to 99, where "the worst human drivers are at the 1st percentile, the average human driver is at the 50th percentile, and the best human drivers are at the 99th percentile": (1) their own ability to drive safely; (2) the ability of self-driving cars to drive safely currently ("right now at this moment")[1]; (3) the desired safety percentile that should be achieved before self-driving cars are allowed on public roads; (4) the desired safety percentile that should be achieved before the participant would feel "reasonably safe" riding in a self-driving car; and (5) the desired safety percentile that should be achieved before the participant would buy a self-driving car, "all other things (price, etc.) being equal." These five questions were presented in a random order for each participant. The verbatim text of each question is provided in Appendix B. Participants then completed the demographics and driving experience questions.

Four participants were excluded from all analyses for reporting that they did not understand the tutorial about percentiles. In the demographics section of the Qualtrics survey, participants gave responses to the statement "I read and answered all questions in this survey to the best of my ability" on a scale from 1 ("strongly disagree") to 7 ("strongly agree"). Twenty participants were excluded from all analyses for giving a response lower than six on the scale. Six participants were excluded from all analyses for self-reporting that they were not licensed drivers. Two additional participants were excluded for failing more than one of these criteria.

[1] To be clear, vehicles that meet the definition of "self-driving" used in this study do not currently exist on the consumer market. Still, misunderstandings about the current functional capabilities of vehicles with automation and confusion surrounding the terminology used to describe vehicle automation appear to be widespread (see Abraham, Seppelt, Mehler, & Reimer, 2017; McDonald, Carney, & McGehee, 2018; Nees, 2018). The wording of this question in the study was meant to reflect (and assess), rather than contribute to, these misunderstandings.

Results

The distributions of self-ratings and ratings of perceived current safety of self-driving cars are shown in Figure 1. The self-rating for driving safety percentile was M = 74.29 (SD = 19.01, 95% CI [72.58, 76.01], mdn = 80), with 80.9% of the sample rating themselves as more safe than average (i.e., higher the 50^{th} percentile). A single sample t-test showed that this mean was significantly higher than the 50^{th} percentile, $t(471) = 27.76$, $p < .001$, $d = 1.28$. These results provided evidence in support of Hypothesis 1.

To examine if people believe they are safer than current self-driving cars, the difference between the self-rating and the current automation rating was calculated, where scores greater than zero indicated higher perceived safety ability for one's self as compared to current automation. The difference was M = 18.99 (SD = 31.09, 95% CI [16.17, 21.80], mdn = 15), with 66.1% of the sample rating themselves as more safe than current self-driving cars. A single sample t-test showed that this mean was significantly higher than 0, $t(471) = 13.27$, $p < .001$, $d = 0.61$. These results provided evidence in support of Hypothesis 2.

The distributions of ratings of desired safety percentiles for self-driving cars are shown in Figure 2. To examine whether people desire self-driving cars that are safer than they believe themselves to be, the differences between the three desired safety ratings and the self-rating were calculated, where scores greater than zero indicated that people desired automation that is safer than their own perceived ability to drive safely. The distributions of the difference scores are shown in Figure 3. People who indicated that they would never accept self-driving cars were excluded from these analyses, but their responses are also shown in Figure 3. For the safety rating desired before self-driving cars are allowed on public roads (n = 417, 55 "never" responses), the difference was M = 8.69 (SD = 22.26, 95% CI [6.54, 10.83], mdn = 10), with 68.1% of the sample desiring self-driving cars that are safer than they perceives themselves to be. A single sample *t*-test showed that this mean difference was significantly higher than 0, $t(416) = 7.97$, $p < .001$, $d = 0.39$. For the safety rating desired before a participant would feel reasonably safe riding in a self-driving car ($n = 406$, 66 “never” responses), the difference was $M = 9.00$ (*SD* =

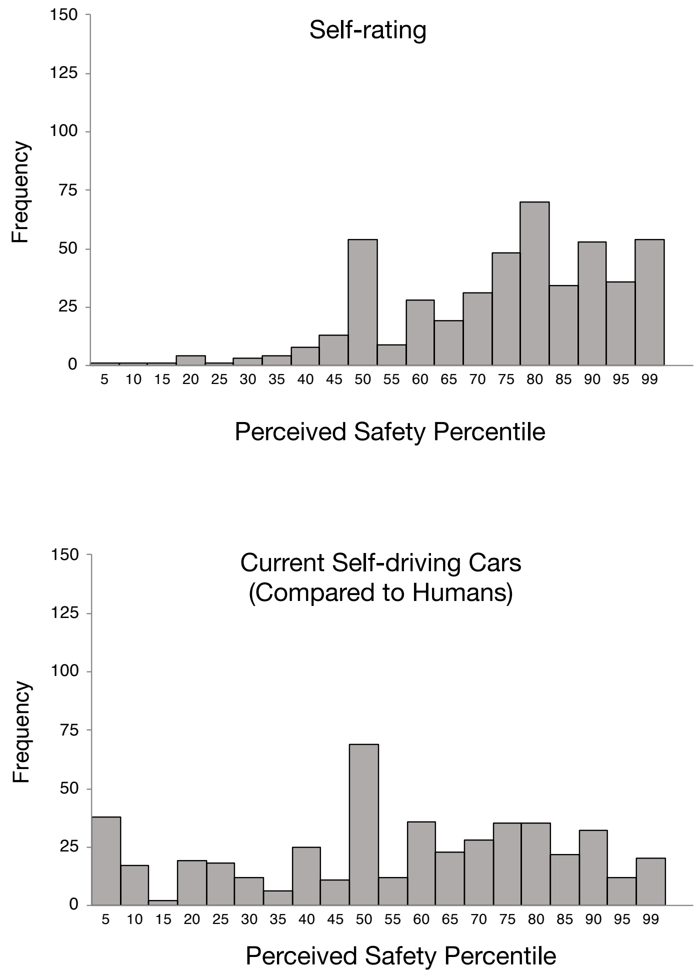

Figure 1. Distributions of the ratings of perceived safety percentiles. The top panel represents drivers’ perceptions of their own percentile for safety. The bottom panel represents drivers’ perceptions of the percentile for safety of current self-driving cars. Both ratings were made relative to other human drivers (with the average human driver representing the 50^{th} percentile)

21.48, 95% CI [6.91, 11.10], *mdn* = 10), with 66.3% of the sample desiring self-driving cars that are safer than they perceives themselves to be. A single sample *t*-test showed that this mean difference was significantly higher than 0, $t(405) = 8.45$, $p < .001$, $d = 0.42$. For the safety rating desired before a participant would buy a self-driving car ($n = 388$, 84 “never” responses), the difference was $M = 10.38$ ($SD = 23.22$, 95% CI [8.07, 12.70], *mdn* = 10), with 71.4% of the sample desiring self-driving cars that are safer than they perceive themselves to be. A single sample *t*-test showed that this mean difference was significantly higher than 0, $t(387) = 8.81$, $p < .001$, $d = 0.45$. For each metric of desired safety, the results provided evidence in support of Hypothesis 3.

As shown in Figure 2, however, the modal participant indicated that they desired a level of safety in the bin containing the 95^{th}-99^{th} percentile. This suggested that perhaps participants were not using their own perceived safety percentile as a criterion, but instead were reporting that only self-driving cars as safe as the best human drivers would be acceptable to them. These competing explanations are somewhat difficult to differentiate in these data, because more than a third of the sample rated themselves as higher than the 80^{th} percentile for safety (37.5%; see Figure 2). However, Figure 3, which plots the distributions of the differences between the self-rating and the safety percentile ratings for the three desired safety dimensions, suggests that the self-rating indeed served as a benchmark. For all three dimensions, there are marked increases in frequencies in the first bin for which the difference is greater than zero (indicating a preference for automation more safe than one perceives one’s self to be), with the modal participant indicating that a level of safety between 10 and 20 percentile points higher than their own perceived ability to drive safely would be acceptable.

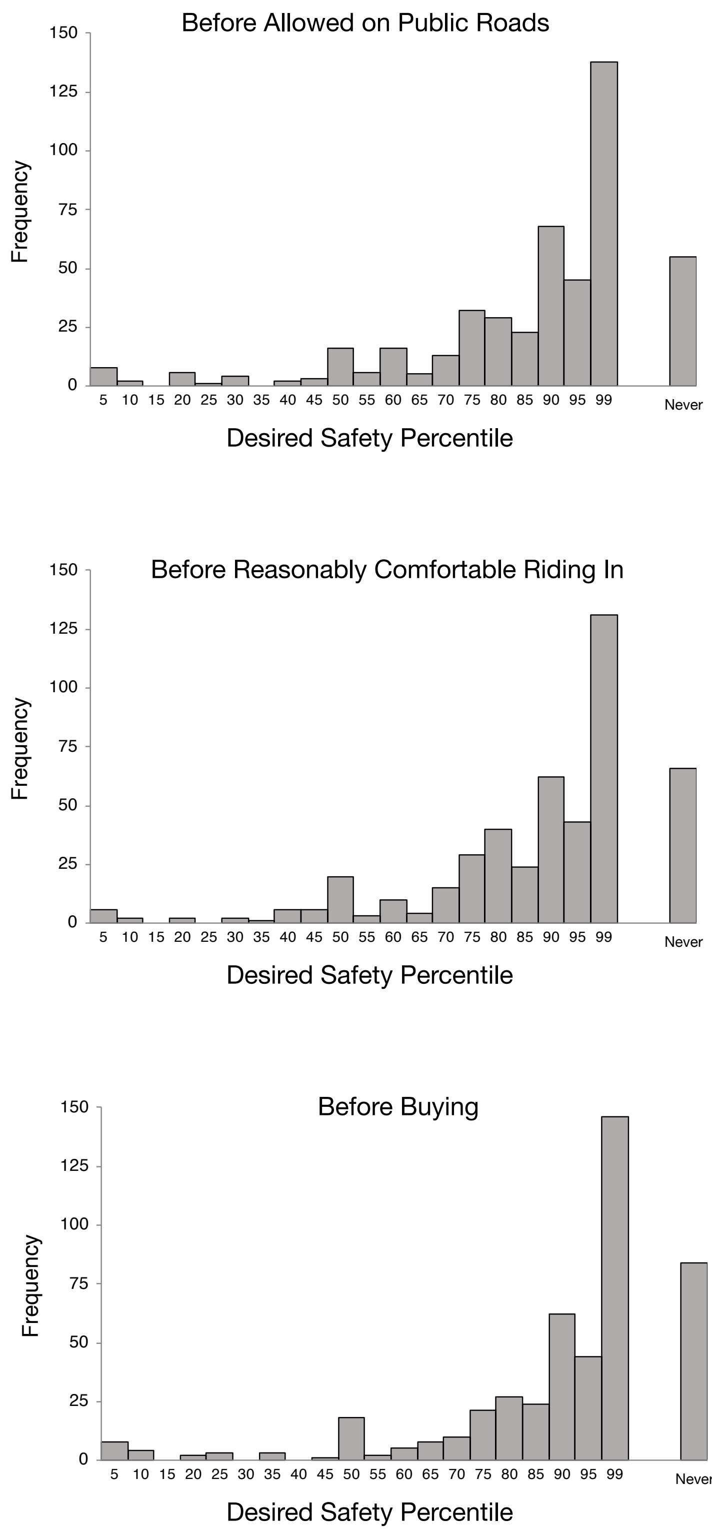

Figure 2 Safety percentile (as compared to a human driver) desired by drivers before self-driving cars are allowed on public roads (top panel), before they would feel reasonably safe riding in a self-driving car (middle panel), and before they would buy a self-driving car (bottom panel). "Never" response indicated the participant would never support the proposition.

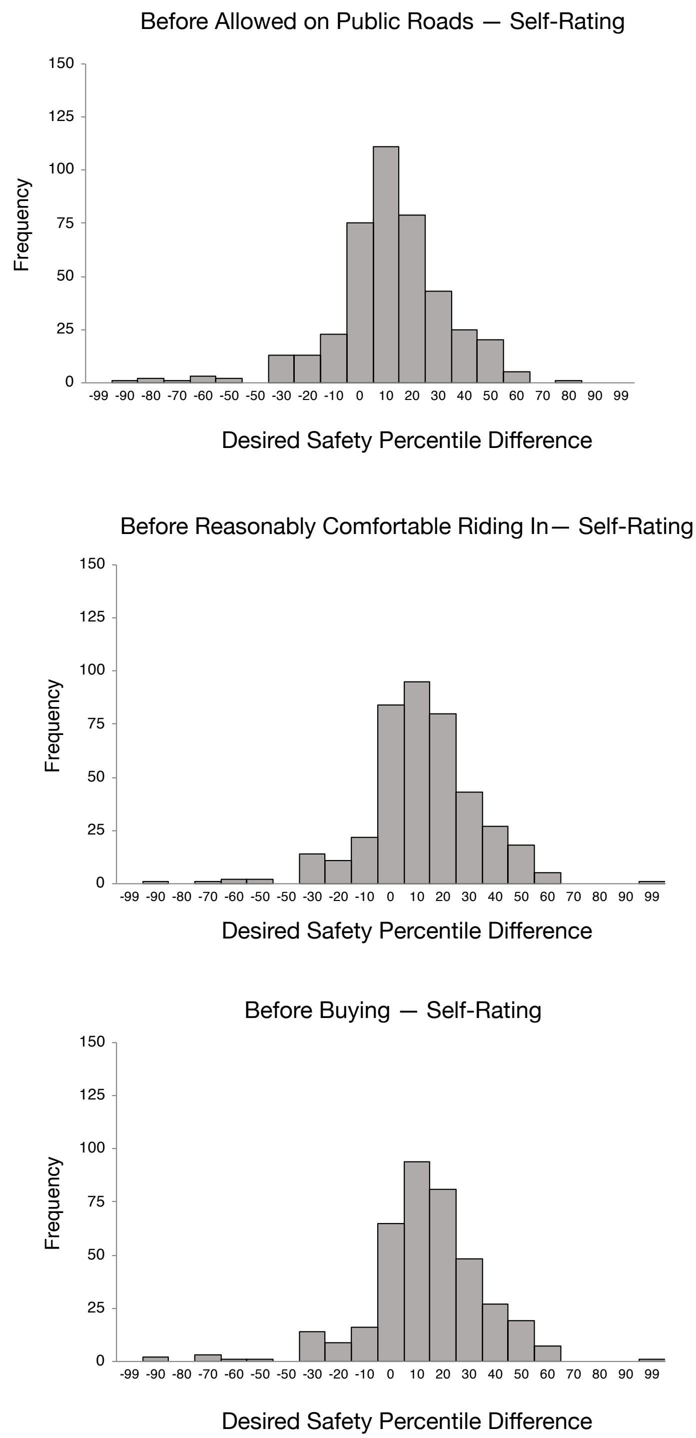

Figure 3. Differences in safety percentiles (as compared to a human driver) subtracting the perceived self-ratings from the desired ratings by drivers before self-driving cars are allowed on public roads (top panel), before they would feel reasonably safe riding in a self-driving car (middle panel), and before they would buy a self-driving car (bottom panel). Positive responses indicate that participants prefer self-driving cars that are safer than their own perceived ability to drive safely.

Exploratory Analyses

Two additional *t*-tests explored whether participants had different desired safety criteria for the different safety measures. To examine whether people desired a higher criterion of safety for riding in a self-driving car themselves versus generally allowing self-driving cars on public roads, the difference between these two ratings was examined (again excluding participants whose response was "never"). The difference was $M = 0.18$ ($SD = 13.99$, 95% CI [-1.20, 1.55], $mdn = 0$). A single sample *t*-test showed that this mean difference was not significantly different from 0, $t(399) = 0.25$, $p = .80$. To examine whether people desired a higher criterion of safety for buying versus riding in a self-driving car, the difference between these two ratings was examined. The difference was $M = 1.35$ ($SD = 14.64$, 95% CI [-0.13, 2.83], $mdn = 0$). A single sample *t*-test showed that this mean difference was not significantly different from 0, $t(378) = 1.80$, $p = .07$. Finally, safety percentile ratings were correlated with each other and with demographic and driving questions to explore relationships that might be of interest for future research. The results of those analyses are shown in Table 1. For the desired safety questions, these correlations necessarily excluded "never" responses for which participants gave no percentile ratings.

Table 1. Correlations

	Self	Cur	Pub	Ride	Buy	Age	YrDr	HrWk	SDArt	SDFa	FatFa
Self	--										
Cur	.15**	--									
	(472)										
Pub	.40**	.32**	--								
	(417)	(417)									
Ride	.40**	.29**	.77**	--							
	(406)	(406)	(400)								
Buy	.35**	.30**	.72**	.75**	--						
	(388)	(388)	(380)	(379)							
Age	.17**	-.05	.15**	.19**	.21**	--					
	(472)	(472)	(417)	(406)	(388)						
YrDr	.21**	-.05	.15**	.20**	.22**	.93**					
	(472)	(472)	(417)	(406)	(388)	(472)	--				
HrWk	.09*	.05	-.10*	-.09	-.11*	-.03	-.01	--			
	(472)	(472)	(417)	(406)	(388)	(472)	(472)				
SDArt	-.04	-.07	.10*	.05	.05	.10*	-.003	-.04	--		
	(472)	(472)	(417)	(406)	(388)	(472)	(472	(472)			
SDFa	.03	.08	-.06	-.06	-.11*	.002	.02	.20**	.11*	--	
	(472)	(472)	(417)	(406)	(388)	(472)	(472)	(472)	(472)		
FatFa	.06	-.03	-.02	.01	-.01	.09	.11*	.14**	.10*	.45**	--
	(472)	(472)	(417)	(406)	(388)	(472)	(472)	(472)	(472)	(472)	

	Self	Cur	Pub	Ride	Buy	Age	YrDr	HrWk	SDArt	SDFa	FatFa
M	74.29	55.31	82.73	83.04	84.47	37.25	19.31	8.10	7.74	3.96	4.54
SD	19.01	27.69	21.47	20.16	21.34	10.98	11.55	8.18	47.00	1.48	1.93

Self = Self-rated safety percentile; **Cur** = Perceived current safety percentile of self-driving cars; **Pub** = Desired safety percentile before self-driving cars are allowed on public roads; **Ride** = desired safety percentile before reasonably safe riding in self-driving cars; **Buy** = Desired safety percentile before would buy a self-driving car; **YrDr** = Years driving experience; **HrWk** = Hours per week driving; **SDArt** = Number of articles read about self-driving cars; **SDFa** = Self-reported familiarity with self-driving technology; **FatFa** = Self-reported familiarity with fatal automation accidents. *N*s are shown in parentheses below each correlation.

* = $p < .05$

** = $p < .01$

Discussion

This study replicated the better-than-average effect for perceived ability to drive safely, as most drivers reported that they believe they are safer than the average driver. This study also showed that most drivers believe they drive more safely than current vehicles with automation are capable of driving. Perceptions of the current safety level of vehicle automation showed high variability; the modal participant perceived that current technology is about as safe as the average human driver. Finally, using three criteria to measure acceptable levels of safety for self-driving cars, this study showed that people desire self-driving cars that are safer than their own perceived ability to drive safely. As such, the benchmark of safer than a human driver that is pervasive in the discourse on vehicle automation seems unlikely to be persuasive at the individual level of decision-making. Most individual drivers believe they are personally safer than the average human driver, and the results of this study suggested that they will use their own perceived ability to drive safely as the benchmark for acceptability of self-driving cars. Other recent research has indicated that acceptable safety for self-driving cars may require that the technology meets benchmarks for safety that are several times better than the average human driver (Liu et al., in press); indeed, the modal participant in this study indicated that they desire self-driving cars that are safer than the best—not average—human drivers.

Although another study (König & Neumayr, 2017) showed different results for willingness to ride in versus buy a self-driving car, exploratory analyses here provided no evidence that participants rated the three criteria differently for acceptable levels of safety, which suggested that they desired the same level of safety before self-driving cars are allowed on public roads, before they would feel reasonably safe riding in a self-driving car, and before they would buy (all other things being equal) a self-driving car. Research has shown that people to tend to perceive less risk when their own personal exposure is the target of the rating. Perceived risk has been shown to increase as the proximity to the person rating the risk decreases—as the target moves from the individual, to family and friends of the individual, to the general public, the risk to the target is rated as higher (Sjöberg, 2000). My data suggested, however, that drivers might perceive the presence of self-driving cars on public roads to be as much of a personal risk (or benefit) as riding in a self-driving car, but more research is needed to understand this finding.

Exploratory correlational analyses also yielded some findings that warrant follow-up in future research. Self-ratings were moderately positively related to all ratings of desired levels of safety, which corroborated the primary finding of the study (i.e., people to tended to rate themselves highly and desire automation that is safer than their own perceived ability). Self-ratings were also weakly positively correlated with age and variables related to driving experience, as well as the perceived safety level of current automation The latter relationship suggested that as drivers' perceptions of their own ability to drive safely increased, so did their perceptions of the current abilities of automation. Ratings of the current perceived safety level were moderately positively correlated with all desired safety ratings, which suggested that drivers who believe current automated systems are safer tended to also believe safety levels should be higher for acceptance. Age and years of driving experience were both weakly positively correlated with all three desired safety ratings, which suggested that older drivers showed a tendency to desire higher levels of safety for acceptance (perhaps in part because they believed themselves to be safer; see above). The number of hours spent driving per week had a weak negative correlation with the desired safety rating for allowing self-driving vehicles on public roads and a weak to moderate positive correlation with self-reported familiarity with self-driving technology, which suggested that people who drive high numbers of hours may have a lower bar for desired safety and perhaps may have a greater interest in self-driving vehicles. Finally, there was no evidence that familiarity with the recent Tesla and Uber crashes involving vehicle automation affected desired safety ratings, as none of the desired safety ratings showed any relationship with self-reported familiarity with those incidents.

Limitations and Caveats

The current results should be considered in light of several limitations of the study. The online sample used here cannot be assumed to be representative of the general population. Past research has suggested that Mechanical Turk samples, for example, are younger and more educated than the general population (see Paolacci & Chandler, 2014), and the sample obtained here likely differs from the population of drivers on other potentially important demographic variables. The impact of these differences on the generalizability of the results obtained here is not known, but available evidence has suggested that Mechanical Turk samples can produce results comparable to those obtained using broader sampling strategies (e.g., in political science research, see Clifford, Jewell, & Waggoner, 2015).

Another important caveat is that all analyses of acceptable levels of safety relative to one's own perceived ability in this study excluded people who indicated that they would never accept a self-driving car, regardless of its ability to drive safely. Approximately 12% of participants would never accept self-driving cars on public roads, 14% would never ride in self-driving cars, and 18% would never buy a self-driving car. These findings suggested that a non-trivial number of drivers will remain skeptical and apprehensive of self-driving vehicles, regardless of the level of safety attained by automation (also see Nielsen & Haustein, 2018; Piao et al., 2016; Schoettle & Sivak, 2014; Zmud, Sener, & Wagner, 2016).

This possibility notwithstanding, perceived safety, although important, is not the only factor that will contribute to acceptance of high automation in vehicles. Research on acceptance of automation in vehicles has been studied as a multidimensional construct (see, e.g., Nees, 2016; Nordhoff, de Winter, Kyriakidis, van Arem, & Happee, 2018). Acceptance is expected also to be impacted by factors including (but not limited to) cost, experience with technology, and ease-of-use, and these additional factors may attenuate concerns with perceived safety. Further, perceptions of vehicle automation are likely to change over time as automation becomes more pervasive. As such, the results of the current study represent a snapshot of safety perceptions of a dynamic and evolving new technology. Indeed, current perceptions of vehicle automation seem to be complicated by a variety of misconceptions about the functionality and safety capabilities of current vehicle automation (see, e.g., Abraham, Seppelt, Mehler, & Reimer, 2017; McDonald, Carney, & McGehee, 2018; Nees, 2018), some of which may be alleviated with greater expsoure to vehicle automation.

The current study examined perceived and desired levels of safety for high automation in vehicles; the description given to participants met the criteria for SAE Level 4, in which the vehicle performs longitudinal, lateral, and monitoring functions without human assistance. As such, it is not clear that these results would translate to currently available Level 2 systems that are best characterized as partial automation—the driver maintains responsibility for one or more dynamic driving tasks, including monitoring the driving scenario. Drivers should view current Level 2 automation as driver assistance systems for which the driver and machine must cooperate to achieve safety. As such, safety is an emergent property of the interactions between drivers and automation in current systems rather than a binary choice between the respective safety abilities of the human versus the vehicle. The ratings in this study targeted prospective future "self-driving" systems characterized by high automation; more research is needed to understand desired and acceptable levels of safety for current driver assistance systems charactertized by partial automation.

In this regard, the question that asked participants to rate "current self-driving cars" could have been misleading or confusing, since vehicles with high automation have yet to be brought to market. Still, the question was included to assess the perceived levels of safety of current automation in vehicles, and the modal participant perceived current automation to be about as safe as the average human driver. This seems to show that many participants either overestimated the capabilities of current vehicle automation or held pessimistic views of human drivers, since vehicles are not currently capable of the high level of automation examined in this study. Current systems presumably would necessarily be worse than most humans at accomplishing “self-driving.” Another possibility, however, is that most participants were naïve to the functional capabilities of current automation and simply guessed that current functionality is about as good as the average human driver. Either way, education and training to familiarize drivers with the capabilities and limitations of vehicle automation seem to be imperative as automation is deployed on roads.

Conclusions

This study examined the *safer than a human driver criterion*—a benchmark for safety in self-driving vehicles that has become pervasive in the discourse on vehicle automation. Attempts to statistically benchmark the performance of automated vehicles against human drivers have revealed a number of complications. For example, Kalra and Paddock (2016) estimated that prototype automated vehicles would need to drive 275 million miles to establish with 95% confidence that they perform comparably to human drivers, and Koopman and Wagner (2017) have documented a considerable array of challenges with validating the safety of automated systems in vehicles. Even if these attempts at veridical quantification of the safety of automated systems prove successful, evidence of population-level safety benefits of self-driving cars may be inadequate for compelling widespread public adoption of automated vehicles, because these approaches establish safety levels relative to the average human driver. The results of this study reiterated the body of research showing that most drivers perceive their own ability to drive safely as better than average. The results of this study further suggested that drivers desire self-driving cars that are safer than they perceive themselves to be, which for most drivers is better than average—in many cases considerably above average. Although the SHDC may offer a normative, rational decision-making criterion for the adoption of self-driving cars (Kalra & Groves, 2017), biases related to perceived risks in driving (such as the illusion of control, see McKenna, 1993) are likely to shift the criterion of acceptance for most drivers higher than the SHDC—perhaps much higher (Liu et al., in press).

References

Abraham, H., Seppelt, B., Mehler, B., & Reimer, B. (2017). What's in a Name: Vehicle Technology Branding & Consumer Expectations for Automation. In *Proceedings of the 9th International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (pp. 226–234). New York, NY, USA: ACM. https://doi.org/10.1145/3122986.3123018

Alicke, M. D., & Govorun, O. (2005). The better-than-average effect. In M. D. Alicke, D. A. Dunning, & J. Krueger (Eds.), *The Self in Social Judgment* (pp. 85–106). New York: Psychology Press.

American Automobile Association. (2018). *Vehicle Technology Survey--Phase IIIB*.

Beach, L. R., & Lipshitz, R. (1993). Why classical decision theory is an inappropriate standard for evaluating and aiding most human decision-making. In D. Harris & W.-C. Lee (Eds.), *Decision Making in Aviation* (pp. 85–102). New York: Routledge.

Choi, J. K., & Ji, Y. G. (2015). Investigating the Importance of Trust on Adopting an Autonomous Vehicle. *International Journal of Human–Computer Interaction*, *31*(10), 692–702. https://doi.org/10.1080/10447318.2015.1070549

Clifford, S., Jewell, R. M., & Waggoner, P. D. (2015). Are samples drawn from Mechanical Turk valid for research on political ideology? ,
Are samples drawn from Mechanical Turk valid for research on political ideology? *Research & Politics*, *2*(4), 2053168015622072. https://doi.org/10.1177/2053168015622072

DeJoy, D. M. (1989). The optimism bias and traffic accident risk perception. *Accident Analysis & Prevention*, *21*(4), 333–340. https://doi.org/10.1016/0001-4575(89)90024-9

Finn, P., & Bragg, B. W. E. (1986). Perception of the risk of an accident by young and older drivers. *Accident Analysis & Prevention*, *18*(4), 289–298. https://doi.org/10.1016/0001-4575(86)90043-6

Harré, N., Foster, S., & O'Neill, M. (2005). Self-enhancement, crash-risk optimism and the impact of safety advertisements on young drivers. *British Journal of Psychology*, *96*(2), 215–230. https://doi.org/10.1348/000712605X36019

Hetherington, J. (2018, April 13). Uber Boss Says Self-Driving Cars Are Like Student Drivers. Retrieved May 1, 2018, from http://www.newsweek.com/uber-boss-says-self-driving-cars-are-student-drivers-884421

Hoff, K. A., & Bashir, M. (2015). Trust in automation: Integrating empirical evidence on factors that influence trust. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *57*(3), 407–434. https://doi.org/10.1177/0018720814547570

Horswill, M. S., Waylen, A. E., & Tofield, M. I. (2004). Drivers' ratings of different components of their own driving skill: a greater illusion of superiority for skills that relate to accident involvement. *Journal of Applied Social Psychology*, *34*, 177–195.

Kalra, N., & Groves, D. G. (2017). *The Enemy of Good: Estimating the Cost of Waiting for Nearly Perfect Automated Vehicles*. Rand Corporation.

Kalra, N., & Paddock, S. M. (2016). Driving to safety: How many miles of driving would it take to demonstrate autonomous vehicle reliability? *Transportation Research Part A: Policy and Practice*, *94*, 182–193. https://doi.org/10.1016/j.tra.2016.09.010

Kaur, K., & Rampersad, G. (2018). Trust in driverless cars: Investigating key factors influencing the adoption of driverless cars. *Journal of Engineering and Technology Management*, *48*, 87–96. https://doi.org/10.1016/j.jengtecman.2018.04.006

Kohl, C., Mostafa, D., Böhm, M., & Krcmar, H. (2017). Disruption of Individual Mobility Ahead? A Longitudinal Study of Risk and Benefit Perceptions of Self-Driving Cars on Twitter. *Wirtschaftsinformatik 2017 Proceedings*. Retrieved from http://aisel.aisnet.org/wi2017/track12/paper/11

König, M., & Neumayr, L. (2017). Users' resistance towards radical innovations: The case of the self-driving car. *Transportation Research Part F: Traffic Psychology and Behaviour*, *44*, 42–52. https://doi.org/10.1016/j.trf.2016.10.013

Koopman, P., & Wagner, M. (2017). Autonomous vehicle safety: An interdisciplinary challenge. *IEEE Intelligent Transportation Systems Magazine*, *9*(1), 90–96.

Lee, J. D., & See, K. A. (2004). Trust in automation: Designing for appropriate reliance. *Human Factors*, *46*(1), 50–80.

Liu, P., Yang, R., & Xu, Z. (n.d.). How Safe Is Safe Enough for Self-Driving Vehicles? *Risk Analysis*, *0*(0). https://doi.org/10.1111/risa.13116

Marottoli, R. A., & Richardson, E. D. (1998). Confidence in, and self-rating of, driving ability among older drivers. *Accident Analysis & Prevention*, *30*(3), 331–336. https://doi.org/10.1016/S0001-4575(97)00100-0

McArdle, M. (2018, March 20). No, driverless cars aren't far safer than human drivers. *The Sacramento Bee*. Retrieved from http://www.sacbee.com/opinion/op-ed/article206034149.html

McCormick, I. A., Walkey, F. H., & Green, D. E. (1986). Comparative perceptions of driver ability— A confirmation and expansion. *Accident Analysis & Prevention*, *18*(3), 205–208. https://doi.org/10.1016/0001-4575(86)90004-7

McDonald, A., Carney, C., & McGehee, D. (2018, September 26). Vehicle Owners' Experiences with and Reactions to Advanced Driver Assistance Systems. Retrieved November 17, 2018, from http://aaafoundation.org/vehicle-owners-experiences-reactions-advanced-driver-assistance-systems/

McGoogan, C. (2016, April 25). Elon Musk: Tesla's Autopilot is twice as safe as humans. *The Telegraph*. Retrieved from https://www.telegraph.co.uk/technology/2016/04/25/elon-musk-teslas-autopilot-makes-accidents-50pc-less-likely/

McKenna, F. P. (1993). It won't happen to me: Unrealistic optimism or illusion of control? *British Journal of Psychology*, *84*(1), 39–50. https://doi.org/10.1111/j.2044-8295.1993.tb02461.x

McKenna, F. P., Stanier, R. A., & Lewis, C. (1991). Factors underlying illusory self-assessment of driving skill in males and females. *Accident Analysis & Prevention*, *23*(1), 45–52. https://doi.org/10.1016/0001-4575(91)90034-3

Nees, M. A. (2016). Acceptance of Self-driving Cars: An Examination of Idealized versus Realistic Portrayals with a Self- driving Car Acceptance Scale. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *60*(1), 1449–1453. https://doi.org/10.1177/1541931213601332

Nees, M. A. (2018). Drivers' Perceptions of Functionality Implied by Terms Used to Describe Automation in Vehicles. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. Philadelphia, PA.

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., de Winter, J., Kyriakidis, M., van Arem, B., & Happee, R. (2018). Acceptance of Driverless Vehicles: Results from a Large Cross-National Questionnaire Study. *Journal of Advanced Transportation*, *2018*.

Paolacci, G., & Chandler, J. (2014). Inside the turk: Understanding Mechanical Turk as a participant pool. *Current Directions in Psychological Science*, *23*(3), 184–188. https://doi.org/10.1177/0963721414531598

Piao, J., McDonald, M., Hounsell, N., Graindorge, M., Graindorge, T., & Malhene, N. (2016). Public Views towards Implementation of Automated Vehicles in Urban Areas. *Transportation Research Procedia*, *14*, 2168–2177. https://doi.org/10.1016/j.trpro.2016.05.232

SAE On-road Automated Vehicles Standards Committee. (2016). *SAE J3016: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems* (No. SAE J3016) (pp. 1–30).

Schoettle, B., & Sivak, M. (2014). A survey of public opinion about autonomous and self-driving vehicles in the U.S., the U.K., and Australia. Retrieved from http://deepblue.lib.umich.edu/handle/2027.42/108384

Schoettle, B., & Sivak, M. (2016). *Motorists' preferences for different levels of vehicle automation: 2016* (No. SWT-2016-8). Sustainable Worldwide Transportation: The University of Michigan.

Sjöberg, L. (2000). Factors in Risk Perception. *Risk Analysis*, *20*(1), 1–12. https://doi.org/10.1111/0272-4332.00001

Sundström, A. (2008). Self-assessment of driving skill–A review from a measurement perspective. *Transportation Research Part F: Traffic Psychology and Behaviour*, *11*(1), 1–9.

Svenson, O. (1981). Are we all less risky and more skillful than our fellow drivers? *Acta Psychologica*, *47*(2), 143–148. https://doi.org/10.1016/0001-6918(81)90005-6

Teoh, E. R., & Kidd, D. G. (2017). Rage against the machine? Google's self-driving cars versus human drivers. *Journal of Safety Research*, *63*, 57–60. https://doi.org/10.1016/j.jsr.2017.08.008

Zmud, J., Sener, I. N., & Wagner, J. (2016). *Consumer acceptance and travel behavior: impacts of automated vehicles*. Texas A&M Transportation Institute.

Appendix A: Study Instructions

In this survey, you will answer questions about self-driving cars.

For the purposes of this research, a "self-driving car" is defined as a vehicle in which computers and automated systems perform driving tasks including steering, accelerating/braking, and monitoring the driving scenario without help from the human driver.

Some vehicles qualify as "self-driving" in some circumstances or modes, but not others. The questions in this survey are asking you to make ratings about vehicles that are self-driving or are in self-driving modes.

When you see the term "self-driving" in this research, it always refers to periods during which the car is responsible for steering, accelerating/braking, and monitoring the driving scenario without help from the human driver.

Percentile is a concept that describes the percent of people below a given measurement. With respect to the ability to drive safely, percentile describes the percent of people who are worse than a given driver at driving safely.

For example, 99% of all human drivers are worse than a human driver who is at the 99th percentile for driving safely. In other words, a human driver who is at the 99th percentile is a more safe driver than 99% of all other human drivers, so the 99th percentile describes an exceptionally safe driver relative to other people.

A human driver who is at the 1st percentile is a more safe driver than 1% of all other human drivers, so the 1st percentile describes an exceptionally unsafe driver relative to other people.

The average human driver is at the 50th percentile, which means that 50% of all humans drive more safely than the average driver, and 50% of all humans drive less safely than the average driver.

Do you understand this information about percentiles?

Appendix B: Safety Percentile Ratings Questions

1. In terms of percentiles, please rate yourself with respect to your ability to drive safely.

If the worst human drivers are at the 1st percentile, the average human driver is at the 50th percentile, and the best human drivers are at the 99th percentile, **what percentile are you**?

Enter a number between 1 and 99.

2. In terms of percentiles, please rate where you believe self-driving cars are right now at this moment with respect to their ability to drive safely.

If the worst human drivers are at the 1st percentile, the average human driver is at the 50th percentile, and the best human drivers are at the 99th percentile, **what percentile are self-driving cars right now at this moment**?

Enter a number between 1 and 99.

3. In terms of percentiles, please rate where you believe self-driving cars should be with respect to their ability to drive safely before they are allowed on public roads.

If the worst human drivers are at the 1st percentile, the average human driver is at the 50th percentile, and the best human drivers are at the 99th percentile, **what percentile should self-driving cars be before they are allowed on public roads**?

Enter a number between 1 and 99. Or if you think self-driving cars should never be allowed on public roads under any circumstance, type "never" in the box.

4. In terms of percentiles, please rate where self-driving cars would need to be with respect to their ability to drive safely before you would feel reasonably safe riding in a self-driving car.

If the worst human drivers are at the 1st percentile, the average human driver is at the 50th percentile, and the best human drivers are at the 99th percentile, what percentile would self-driving cars need to be with respect to their ability to drive safely **before you would feel reasonably safe riding in** a self-driving car?

Enter a number between 1 and 99. Or if you would never feel reasonably safe under any circumstance, type "never" in the box.

5. In terms of percentiles, please rate where self-driving cars would need to be with respect to their ability to drive safely before you would purchase a self-driving car, all other things (price, etc.) being equal.

If the worst human drivers are at the 1st percentile, the average human driver is at the 50th percentile, and the best human drivers are at the 99th percentile, what percentile would self-driving cars need to be with respect to their ability to drive safely **before you would purchase a self-driving car**, all other things (price, etc.) being equal?

Enter a number between 1 and 99. Or if you would never purchase a self-driving car under any circumstance, type "never" in the box.