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## Cognitive Underpinnings of Beliefs and Confidence in Beliefs about Fully Automated Vehicles

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# Cognitive Underpinnings of Beliefs and Confidence in Beliefs about Fully Automated Vehicles

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## Disclaimer

# EXECUTIVE SUMMARY

We received grant #467 from MPC to conduct a study on the self-regulation of distracted driving. This study examined actual traffic and weather conditions under which drivers use cell phones. We hypothesized that drivers attempt to reduce the risk of an accident by regulating the use of cell phones. Specifically, many drivers limit cell phone usage in adverse driving conditions characterized by slick roads, limited visibility, or heavy traffic. A second major aim of the proposed research was to demonstrate that even in the most adverse driving environments, a significant proportion of individuals use a cell phone while operating their vehicles with predictable negative effects on driving safety. The study that we designed to test these ideas involved videotaping driving behavior at various intersections in Salt Lake City, UT. The goal was to videotape characteristics of the driver (e.g., gender), driver behavior (e.g., cell phone use, eating), and driving errors (e.g., rolling stops, failures to stop) under various weather and traffic conditions.

Unfortunately, we encountered a number of problems in the videotaping. After months of testing, we learned that no matter what sort of lenses, filters, camera angles and locations we used, we could not reliably record characteristics and activities of drivers with a camera. Consequently, we resorted to having an observer code driver attributes and distracting behaviors. We used a camera to record movements of the vehicles at intersections including failures to stop and any other dangerous maneuvers. The data were disappointing. We did not find that vehicular movements and driving behavior differed when drivers were engaged in distracting activities. We also could not show that the likelihood of cell phone use and other behaviors were affected by driver attributes, the time of day, traffic conditions, or the weather. Part of the problem is that, regardless of the conditions, the base rate levels of cell phone use were very low on the roads where the observations were made.

While conducting the naturalistic study of the self-regulation of driving, we also conducted an investigation of consumer attitudes toward fully automated vehicles using the funding from MPC. That study is presented in this report. Findings of the research were presented at a national conference (Yu, Z., Sanbonmatsu, D. M., Strayer, D. L., Biondi, F., & Cooper, J. M. (2018). *Cognitive Underpinnings of Beliefs and Confidence in Beliefs about Fully Automated Vehicles.* Poster presented at the Annual Meeting of the American Psychological Science Association. San Francisco, CA.) and published in a transportation journal last year (Sanbonmatsu, D. M., Strayer, D. L., Yu, Z., Biondi, F., & Cooper, J. M. (2018). Cognitive underpinnings of beliefs and confidence in beliefs about fully automated vehicles, *Transportation Research Part F: Traffic Psychology and Behaviour, 55(May),* 114–122. https://doi.org/10.1016/j.trf.2018.02.029.) The generous grant support from MPC and the U.S. Department of Transportation were acknowledged in the published paper.

## ABSTRACT

A study investigated the cognitive underpinnings of consumers' beliefs and confidence in their beliefs about fully automated vehicles. Following previous research, opinions about self-driving cars tended to be mixed. The most negative views were held by consumers who had the least knowledge of self-driving cars. Low trust in technology was also associated with more negative views. Although consumers were generally confident in their views of self-driving cars, many were uninformed about them. Consumers' confidence in their beliefs about self-driving cars was more strongly correlated with perceived knowledge and general confidence than real expertise. Thus, consumers' confidence in their opinions about fully automated vehicles appears to be driven by largely superfluous cognitions. A mediation analysis suggests that general self-confidence influences judgmental confidence by affecting perceived judgment relevant knowledge. Participants' confidence in negative beliefs about fully automated vehicles suggests their opinions will not be easily influenced via persuasion.

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# 1. INTRODUCTION

Self-driving vehicles are an emerging technology that will radically reshape transportation on roads and highways. Fully automated, level 5 vehicles will be able to perform all aspects of driving under all roadway and environmental conditions without human control of the vehicle (SAE International, 2014). Unlike semi-automated vehicles (levels 2 and 3), which require drivers to monitor and take back operational control of the vehicle whenever system failure occurs, fully-automated driving systems will not require manual intervention. These vehicles are expected to be safer and more energy efficient than current automobiles and will reduce traffic congestion and insurance rates. Moreover, people will be better able to socialize, work, and relax as they travel because they will be freed of the task of driving. Finally, self-driving vehicles will increase the mobility of persons who are physically and visually impaired.

The views currently being formed of fully automated vehicles and the confidence with which these views are held are important because they will affect consumers' willingness to adopt these vehicles. Consumer opinions will also determine support for the legal and physical infrastructure needed to put the technology on our roads.

Many national and local surveys have assessed public attitudes toward fully automated vehicles. Studies have revealed a wide range of opinion about the technology (e.g., Bazilinskyy, Kyriakidis, & de Winter, 2015). While most consumers are willing to ride in a driverless car (e.g., Autoblog, 2013), they are not ready to buy one (Konig & Neumayr, 2017). Moreover, while the majority of consumers believe fully automated vehicles will increase driving safety, more than one-third believe roadways will be safer if vehicles continue to be operated by people (Kelley Blue Book, 2016). Many consumers are reluctant to relinquish control of their cars (Kelley Blue Book, 2016; Konig & Neumayr, 2017). Concerns about the expense of driverless vehicles and fears about software failure and security are also commonplace (Fagnant & Kockelman, 2015; Konig & Neumayr, 2017; Kyriakidis, Happee, & De Winter, 2015; Schoettle and Sivak, 2014).

While many studies have examined consumer beliefs about automated vehicles, studies have not examined consumers' confidence in their beliefs. As discussed here, confidence or certainty is important because it determines willingness of people to act on their beliefs and the extent to which their beliefs are susceptible to influence. There has also been little work on the cognitive underpinnings of consumer opinions about fully automated vehicles. In this study, we investigated how knowledge of self-driving vehicles, perceived knowledge of self-driving vehicles, general beliefs about the self, and beliefs about technology are shaping attitudes toward self-driving cars and the confidence with which these attitudes are held. As we shall see, consumers are generally confident in their opinions about fully automated vehicles. That is, they tend to be relatively certain that their beliefs about driverless cars are accurate or correct. However, their confidence is commonly grounded in cognitions that are irrelevant to their judgments. Negative views of fully automated vehicles, while confidently held, do not appear to be based on real knowledge of the technology.

## 1.1 Why Judgmental Confidence Matters

Confidence is important because it affects a willingness to act on an attitude or belief. Studies have shown that attitudes are more likely to guide decision making and behavior when certainty is high (e.g., Fazio & Zanna, 1978a; 1978b; Glasman & Albarracin, 2006). Judgments that are confidently expressed are also more likely to influence others (e.g., Cramer et al., 2011; Tenney et al., 2011). More importantly, confidence or certainty affects the extent to which attitudes and beliefs are susceptible to influence and change (Babad, Ariav, Rosen, & Salomon, 1987; Krosnick & Abelson, 1992; Swann, Pelham, &

Chidester, 1988; see also Brinol & Petty, 2009). Finally, confident views are often extreme. Evaluations that are confidently held or those perceived to be based on a large amount of information tend to be more polarized, that is, more positive or negative versus moderate (e.g., Sanbonmatsu, Kardes, Posavac, & Houghton, 1997). Thus, the confidence with which beliefs about fully automated vehicles are held is important because it will affect the adoption of and support for the technology. Confidence or certainty may also determine the extremity of opinions about fully automated vehicles and the degree to which these opinions can be influenced.

Research has shown that there is only a moderate to weak positive relation between confidence and accuracy in important judgmental domains such as eye witness identification (e.g., Bothwell, Deffenbacher, & Brigham, 1987; Sporer, Penrod, Read, & Cutler, 1995), clinical assessment (e.g., Miller, Spengler, & Spengler, 2015), and impression formation (e.g., Ames, Kammrath, Suppes, and Bolger, 2010). People are generally overconfident about the accuracy of their beliefs and judgments (e.g., Lichtenstein, Fischhoff, and Phillips 1982; Vallone, Griffin, Lin, & Ross, 1990). Although the relation between expertise and calibration is modest, individuals who are low in knowledge tend to be the most overconfident (Lichtenstein and Fischhoff 1977). Related work has shown that individuals lacking in competency are most likely to overestimate their ability and performance (Dunning, Johnson, Ehrlinger, & Kruger, 2003; Kruger & Dunning, 1999). These findings suggest that consumers may be confident in their beliefs about fully automated vehicles even when they know little about the technology.

Another important factor affecting judgmental confidence or certainty about driverless vehicles may be general self-confidence. General confidence is often conceived to be the sum of a person's confidence in specific domains (Shrauger & Schohn, 1995). General belief in the self is associated with the tendency to overestimate the favorableness of past and future performance (Morrison, Thomas, & Weaver, 1973; Shrauger, 1972). Hence, it may be associated with overconfidence in the accuracy or correctness of one's specific judgments. While general confidence may be unrelated to actual domain specific knowledge, it may contribute to greater perceived knowledge which may heighten estimations of judgmental accuracy (Trafimow & Sniezek, 1994).

## 1.2 A Study of the Cognitive Underpinnings of Beliefs about Autonomous Vehicles

A survey was conducted to measure consumers' beliefs about fully automated vehicles and their confidence in their beliefs. Consumers also expressed their intentions to purchase a driverless vehicle, and their support for legislation and policies to put these driving systems on our roadways. Additionally, consumers completed a measure of their perceived knowledge and a test of their actual knowledge of fully automated vehicles. They also filled out the general self-confidence scale developed by Shrauger and Schohn (1995). Finally, participants were asked to complete the trust in technology scale (McKnight, Carter, Thatcher, & Clay, 2011; McKnight, Choudhury, & Kacmar, 2002). Trust in technology is composed of two constructs — faith in general technology, which refers to the belief that technology is usually reliable, functional, and helpful, and trusting stance, which refers to the belief that positive outcomes will result from relying on technology. Participants completed a scale of both constructs.
The predictions of the study were grounded in previous research on automated vehicles and theory on attitudes and human judgment. They were also derived from an unpublished survey we had conducted earlier in the year examining consumer attitudes toward advance driving assistance systems and fully automated vehicles. The survey of 200 consumers revealed mixed evaluations of self-driving cars. However, consumers were confident in their opinions regardless of their levels of expertise or knowledge. Most consumers were not well informed about fully automated vehicles. Those who were lacking in knowledge tended to express the most negative views.

Although these data were intriguing, the findings were not publishable because the questions were embedded in a larger survey of advanced driving assistance systems that proved to be uninteresting. We did not want to selectively report data on fully automated vehicles. In addition, the unpublished survey helped us to develop some novel hypotheses about the possible determinants of judgmental confidence that we sought to investigate in this follow-up. In many respects, though, the present study was an effort to replicate our prior findings.

Following our previous research, we predicted that consumers would generally be confident in their opinions about fully automated vehicles. However, they were not expected to be highly knowledgeable about them. It was anticipated that consumers' confidence would be more strongly associated with perceived knowledge of self-driving vehicles and general confidence than with actual knowledge. Consumers with the least expertise were expected to have the most negative opinions about self-driving cars. Finally, beliefs about fully automated driving systems were expected to be much more favorable when consumers generally trust technology.

# 2. METHOD

## 2.1 Participants

One hundred fourteen (47 female, 66 male, and one unidentified) Amazon Mechanical Turk workers were paid three dollars to complete the survey. Participation was limited to workers in the United States who were "Masters" ("who have demonstrated excellence across a wide range of HITs" or human intelligence tasks). The ages of the participants were as follows: two were 16 to 24 years old, 62 were 25 to 34 years old, 28 were 35 to 44 years old, and 22 were 45 or older. All but three of the participants reported that they had a driver's license.

## 2.2 Procedure

The survey was administered on Qualtrics. A consent cover letter was presented to inform participants of the aims and procedures of the study, and their rights as participants. They were told: "The purpose of this research is to investigate peoples' attitudes toward emerging driving technologies. You will complete a survey of your opinions and beliefs about fully autonomous (self-driving) vehicles." The survey items were administered in 10 sections or blocks. Participants were allowed to skip questions. However, they were not allowed to return to questions in a previous block after moving to a new block. Afterwards, they were thanked for their participation and debriefed.

## 2.3 Measures

On the first measures of the survey, participants indicated their age, gender, and whether they had a driving license.

*General confidence.* Participants then completed the seven items of the general self-confidence sub-scale of the Personal Evaluation Inventory (PEI; Shrauger & Schohn, 1995). They indicated their agreement with statements such as "I lack some important capabilities that may keep me from being successful" and "when things are going poorly, I am usually confident that I can successfully deal with them." The PEI has been shown to have high level of internal consistency and reliability (Shrauger & Schohn, 1995).

*Beliefs and Evaluation.* In the next section of the survey, participants were informed: "you will be asked about your views of fully autonomous (self-driving) vehicles. These are the vehicles of the near future that are currently in development which will be completely autonomous and not require a human driver." They were asked to indicate their agreement or disagreement with the following statements: "The first generation of fully autonomous (self-driving) vehicles on our roads will be unsafe for many years because of problems with the technology"; "Fully autonomous (self-driving) vehicles will reduce traffic congestion and help to diminish energy consumption"; "Fully autonomous (self-driving) vehicles will be a threat to public safety because many drivers will not know how to operate them properly". Participants responded on a seven-point scale anchored by 1 = *strongly agree* and 7 = *strongly disagree*, with a midpoint of 4 = *neither agree nor disagree*. They also expressed their overall evaluation of autonomous vehicles on a 7-point scale anchored by 1 = *highly positive* and 7 = *highly negative*, with a midpoint of 3 = *neither positive nor negative*. Finally, participants indicated "How confident are you about your assessment of fully autonomous (self-driving) vehicles? That is, how confident are you that your assessments are correct?" on a 4-point scale where 1 = *not at all confident*, 2 = *a little confident*, 3 = *confident*, and 4 = *highly confident*. They also indicated "How certain are you about your judgments of fully autonomous (self-driving) vehicles? That is, how certain are you that your judgments are right?" on a 4-point scale where 1 = *not at all certain*, 2 = *a little certain*, 3 = *somewhat certain*, and 4 = *highly certain*.

*Intentions and policy beliefs*. Participants were asked to indicate their agreement with the following statements about their intentions and policy beliefs: "I am going to try to purchase or lease a fully autonomous (self-driving) vehicle as soon as they become available to consumers"; "I think that policy makers should begin planning and laying the groundwork for fully autonomous (self-driving) vehicles on our roadways"; "States should hold off on legalizing fully autonomous (self-driving) vehicles until they are more completely developed and tested." They again responded on a seven-point scale anchored by 1 = *strongly agree* and 7 = *strongly disagree*.

*Perceived knowledge of automated vehicles*. Participants indicated "How much do you know about fully autonomous (self-driving) vehicles?" on a 5-point scale on which 1 = a *great deal*, 2= *a lot*, 3 = *a moderate amount*, 4 = *a little,* and 5 = *nothing at all*.

*Measure of knowledge of automated vehicles*. Participants were asked to assess the truth or falsity of eight statements about driverless vehicles. They were reminded in the instructions that "fully autonomous (self-driving) vehicles… are the vehicles of the near future that are currently in development which will be completely autonomous and not require a human driver." The questions measured knowledge of fully automated vehicles as they are currently being designed. Obviously, exact knowledge of the driverless cars that will be on roads in the future cannot be measured because of the uncertainty of the precise technology that will be implemented.

*Propensity to trust technology*. Participants completed the four-item "faith in general technology" and the three-item "trusting stance" subscales constituting the propensity to trust technology (McKnight, Carter, Thatcher, & Clay, 2011). They indicated their agreement with items such as "I believe that most technologies are effective at what they are designed to do" that reflect the degree to which technology is assumed to be reliable and helpful, and statements such as "I usually trust a technology until it gives me a reason not to trust it" that measure the expectation that positive outcomes will result from relying on technology. For the sake of brevity, the mean responses to the trusting stance and faith in general technology scales were averaged to create a single index of trust in technology.

# 3. RESULTS

## 3.1 Mean Responses to Survey Questions

*Favorableness of beliefs and evaluations***.** Table 3.1 presents the mean responses to questions about fully automated vehicles. The means tended to be moderate while the standard deviations were fairly high. For example, the mean belief that self-driving vehicles will be unsafe because of problems with the technology was 3.93 on a 1 to 7 scale with a midpoint of 4 while the standard deviation was 1.71. The moderate means and sizeable standard deviations suggest that participants' views about fully automated vehicles were highly variable.

Nevertheless, on average, participants' opinions about fully automated vehicles tended to be positive. Judgments of the safeness of the technology, impact of autonomous vehicles on traffic congestion and energy use, and safeness of drivers' operation of the vehicles, and evaluations of fully automated vehicles (the first 4 items in Table 1) were averaged (with the first and third items reverse scored) to create an overall index of the favorableness of beliefs about automated vehicles. The mean assessment of self-driving cars was 3.38 on a 7-point scale where a lower score indicated more favorable beliefs. This mean was significantly less than the midpoint of 4, $t(113) = 4.54$, $p < .001$.

*Intentions and policy beliefs*. Most participants reported that they do not intend to lease or purchase a self-driving car when they first become available. While most favored planning and building the groundwork needed for fully automated vehicles, many tended to believe that "states should hold off on legalizing fully automated (self-driving) vehicles until they are more completely developed and tested."

*Confidence and certainty***.** Although there were a broad range of opinions about fully automated vehicles, participants tended to be confident about their views. The mean levels of confidence and certainty both approached 3 on a four-point scale. 65.8% of participants indicated that they were "confident" or "highly confident" and 72.0% indicated they were "somewhat certain" or "highly certain" about their views of fully automated vehicles. Only 8% of respondents indicated they were "not at all confident" and only 7% indicated they were "not at all certain". The measures of confidence and certainty were highly correlated $r(113) = .77$, $p < .001$. Consequently, the measures were averaged to create a single index of confidence and certainty that was used in the correlation analyses.

*Knowledge and perceived knowledge*. Participants' knowledge of autonomous vehicles was assessed by eight questions. Because the items were true or false, there was a .50 chance of guessing the correct answer to any question. Thus, the chance score was 4 out of 8. Overall, participants were not highly knowledgeable of fully automated systems. For example, only 32.5% knew that self-driving vehicles may not offer a steering wheel, and 44.7% believed that human control of fully automated vehicles will be necessary in inclement weather or bumper to bumper traffic. 42.1% of participants scored 5 (slightly above chance) or worse.

Participants reported modest levels of knowledge of fully automated vehicles; 47.4% indicated that they had "a moderate amount" of knowledge of self-driving vehicles while 36.8% indicated they knew "a little". The correlation between actual knowledge and perceived knowledge was significant, $r(113) = -.266$, $p = .004$, as participants who reported knowledge generally knew more about fully automated vehicles.

**Table 3.1** Mean responses to survey questions and standard deviations

| | Mean | SD |
|---|---|---|
| "The first generation of fully autonomous (self-driving) vehicles on our roads will be unsafe for many years because of problems with the technology" (1 = *strongly agree* and 7 = *strongly disagree*) | 3.93 | 1.718 |
| "Fully autonomous (self-driving) vehicles will reduce traffic congestion and help to diminish energy consumption" (1 = *strongly agree* and 7 = *strongly disagree*) | 2.73 | 1.604 |
| "Fully autonomous (self-driving) vehicles will be a threat to public safety because many drivers will not know how to operate them properly" (1 = *strongly agree* and 7 = *strongly disagree*) | 4.20 | 1.896 |
| Evaluation of fully autonomous (self-driving) vehicles (1 = *highly positive* and 7 = *highly negative*) | 2.92 | 1.630 |
| Confidence in assessments of fully autonomous (self-driving) vehicles (1 = *not at all confident* and 4 = *highly confident*) | 2.75 | 0.807 |
| Certainty of judgments of fully autonomous (self-driving) vehicles (1 = *not at all certain* and 4 = *highly certain*) | 2.87 | 0.815 |
| "I am going to try to purchase or lease a fully autonomous (self-driving) vehicle as soon as they become available to consumers" (1 = *strongly agree* and 7 = *strongly disagree*) | 5.04 | 1.752 |
| "I think that policy makers should begin planning and laying the groundwork for fully autonomous (self-driving) vehicles on our roadways" (1 = *strongly agree* and 7 = *strongly disagree*) | 2.46 | 1.608 |
| "States should hold off on legalizing fully autonomous (self-driving) vehicles until they are more completely developed and tested" (1 = *strongly agree* and 7 = *strongly disagree*) | 3.53 | 1.878 |
| Perceived knowledge of fully autonomous (self-driving) vehicles (1 = a *great deal* and 5 = *nothing at all*) | 3.30 | 0.775 |
| Actual knowledge of fully autonomous (self-driving) vehicles (maximum possible score = 8) | 5.70 | 1.20 |

Notes: N = 114

## 3.2 Presumed Determinants of Beliefs about Autonomous Vehicles

Correlational analyses were performed to examine the cognitive factors that may shape consumers' beliefs about driverless cars. The correlations between participants' knowledge and perceived knowledge of autonomous vehicles, and their trust in technology, and their beliefs about autonomous vehicles are presented in Table 3.2.

As actual knowledge of fully automated vehicles increased, beliefs about the technology were more positive. For example, the mean favorableness (index) of beliefs about driverless cars was significantly positively correlated with expertise. Thus, participants who had the most negative views of fully automated vehicles tended to have the least actual knowledge of them.

The pattern was identical for perceived knowledge of fully automated vehicles. As self-ratings of expertise increased, assessments were more positive. Thus, participants who reported the lowest levels of perceived knowledge tended to evaluate self-driving vehicles most negatively. Perceived knowledge was also significantly correlated with intentions and policy beliefs; as self-ratings of expertise increased, the endorsement of legal and political support for the technology, and the intention to lease or purchase a self-driving vehicle also increased.

Finally, trust in technology was positively correlated with beliefs about fully automated vehicles. Participants who trust technology tended to judge driverless cars more favorably. For example, they were more likely to believe that fully automated vehicles will reduce traffic congestion and energy consumption. They also were more likely to convey legal and political support for autonomous vehicles and express the intention to lease or purchase a driverless car.

## 3.3 Confidence in Beliefs about Autonomous Vehicles

*The relation between confidence and beliefs.* Table 3.2 presents the correlations between belief favorableness and confidence. As beliefs about driverless cars became more positive, confidence and certainty tended to be higher. For example, participants who believed that fully automated vehicles will reduce congestion and energy consumption expressed high levels of confidence in their views. However, a closer examination of the data revealed that the levels of confidence of participants who expressed negative views about fully automated driving systems were also relatively high. In fact, on average, their confidence was almost identical to that of participants reporting positive views. For example, participants who evaluated self-driving cars negatively were not less confident than participants who expressed neutral or positive evaluations, $M = 2.78$ vs. $M = 2.93$, $t(112) = .853$, $p = .395$. A regression analysis indicated there was a quadratic trend characterizing the relation between the mean favorableness of the index of beliefs about automated vehicles and confidence, $F(2,111) = 3.96$, $p = .022$, in which confidence was higher for participants whose evaluations were more positive and more negative as opposed to near the midpoint.

This pattern was more directly captured by the analysis of the relation between judgmental confidence and extremity. The extremity of the favorableness of the index of beliefs about fully automated vehicles was calculated by subtracting the index from the midpoint (4) and calculating the absolute value. As expected confidence and certainty was highly correlated with extremity, $r(113) = .445$, $p < .0001$; participants who were confident about their beliefs tended to express greater positivity or greater negativity about self-driving systems.

**Table 3.2** Correlations between beliefs about fully automated vehicles, and knowledge, perceived knowledge, trust in technology, and confidence and uncertainty (p values in parentheses)

| | Knowledge | Perceived Knowledge | Trust in Tech | Confidence and Certainty |
|---|---|---|---|---|
| Fully autonomous vehicles will be unsafe because of problems with the technology | .222 (.018) | -.237 (.011) | -.285 (.002) | .206 (.028) |
| Fully autonomous vehicles will reduce traffic congestion & energy consumption | -.282 (.002) | .251 (.007) | .370 (.000) | -.192 (.041) |
| Fully autonomous vehicles will be a threat to public safety because drivers will not know how to operate them | .245 (.009) | -.288 (.002) | -.322 (.000) | .275 (.003) |
| Evaluation of fully autonomous vehicles | -.153 (.105) | .236 (.011) | .355 (.000) | -.133 (.157) |
| Mean favorableness of beliefs about and evaluation of self-driving vehicles (index) | -.265 (.004) | .298 (.001) | .389 (.000) | -.240 (.010) |
| Intention to lease or purchase a self-driving vehicle | -.004 (.639) | .297 (.001) | .297 (.001) | -.179 (.057) |
| Policy makers should begin laying the groundwork for self-driving vehicles | -.180 (.055) | .250 (.007) | .269 (.004) | -.236 (.011) |
| States should hold off on legalizing self-driving vehicles | .126 (.183) | -.218 (.020) | -.233 (.013) | .322 (.000) |

Notes: N = 114

*Predictors of confidence.* Correlational analyses were conducted to examine the possible determinants of participants' confidence in their beliefs about automated vehicles. From Table 3, it is apparent that judgmental confidence was predicted by perceived knowledge but not by actual knowledge of self-driving systems. A comparison of the correlation coefficients indicates that perceived judgment relevant knowledge was much more strongly correlated with confidence than actual knowledge, $z = 3.27$, $p = .001$. Judgmental confidence was also significantly correlated with general confidence. The correlation between perceived knowledge and general self-confidence was marginally significant, $r(113) = -.176$, $p = .061$. Finally, participants' confidence in their beliefs about fully automated vehicles was marginally significantly correlated with trust in technology.

We speculated that general confidence may contribute to judgmental confidence by increasing perceived judgment relevant knowledge. An analysis was conducted to test whether the relation between the general self-confidence and judgmental confidence and certainty is mediated by perceived knowledge. Bootstrapping (N=114, 10,000 bootstrap resamples) indicated that perceived knowledge partially mediated this relation (indirect effect = .01, SE = .006, 95% CI = .0007 to .0245). The total effect of general self-confidence on judgmental confidence remained significant when perceived knowledge was included in the model (direct effect = .031, SE = .012, 95% CI = .0073 to .0541).

In sum, participants' confidence in their beliefs about fully automated vehicles does not appear to have been based on actual knowledge. Rather, their confidence or certainty was predicted most strongly by how much they thought they knew and general self-confidence — factors largely irrelevant to certainty about judgments of driverless cars. The mediation analysis suggests that general confidence affects judgmental confidence, in part, by increasing how much consumers think they know.

**Table 3.3** Correlations between confidence and certainty in automated vehicle judgments, and knowledge, perceived knowledge, general confidence, and trust in technology (p values in parentheses)

| | Confidence and Certainty |
|---|---|
| Knowledge | .053<br>(.577) |
| Perceived Knowledge | -.456<br>(.000) |
| General self-confidence | .290<br>(.002 ) |
| Trust in Technology | -.162<br>(.085) |

Notes: N=114

# 4. DISCUSSION

Beliefs about fully automated vehicles tend to be favorable (e.g., Konig & Neumayr, 2017; Schoettle and Sivak, 2014). Nevertheless, a sizeable proportion of consumers minimize benefits of the technology and belief that driverless cars will be unsafe. Our findings indicate that the most unfavorable views of fully automated vehicles are held by the least knowledgeable consumers. Thus, a significant contributor to negativity toward self-driving vehicles appears to be lack of knowledge. The favorableness of beliefs about fully automated vehicles was also related to trust in technology; consumers who do not perceive that technology is helpful and reliable, and who do not believe that positive outcomes result from relying on technology evaluate self-driving cars less positively.

Consumers are generally confident about their views of fully automated vehicles even though many are uninformed about them. Seventy-two percent of our respondents indicated they were "somewhat certain" or "highly certain" about their beliefs, even though 42.1% performed slightly above chance or worse on our measure of knowledge of driverless cars. The findings indicated there is little relation between actual knowledge of fully automated vehicles and judgmental confidence. Nonetheless, confidence appears to contribute to more polarized opinions about self-driving vehicles. Participants who were high in judgmental confidence tended to express much more positive or much more negative views than participants were less certain.

The study strengthened judgment literature by showing relative contributions of knowledge, perceived knowledge, and general self-confidence to judgmental confidence. Confidence expressed by participants was more strongly correlated with perceived judgment relevant knowledge and general self-confidence than real expertise. Thus, consumers' confidence in their opinions about automated vehicles appears to be driven heavily by largely superfluous factors. Prior research has shown that perceived knowledge contributes to judgmental confidence (Trafimow & Sniezek, 1994). The mediation analyses suggest that general confidence affects judgmental confidence by affecting perceived judgment-relevant knowledge. Finally, although the least knowledgeable consumers expressed the most negative opinions about driverless cars, they tended to hold these views with a high degree of confidence.

The development of measures for the timely study of emerging phenomena, such as automated vehicles, does not always permit careful psychometric testing. Our measure of knowledge of self-driving vehicles was not systematically assessed for validity and reliability. However, we believe that the measure has a high level of face validity (see Appendix). Moreover, it was significantly correlated with perceived knowledge, with both measures indicating that beliefs about fully automated vehicles become less positive as knowledge decreases. This convergence, and the consistency of the findings with this conducted pilot study, suggests the findings are valid and reliable.

Why do consumers with lower knowledge of driverless cars tend to have less favorable views? Consumers who are relatively unaware may harbor unwarranted beliefs about the risks of self-driving vehicles. Indeed, low knowledge participants tended to agree with erroneous statements such as "fully autonomous (self-driving) vehicles will require a human driver in inclement (bad) weather conditions, and bumper to bumper traffic." However, interest in and liking of fully automated vehicles may also affect knowledge. Consumers who are drawn to automated systems may be more apt to seek out information about them which may contribute to the positive relation between expertise and the favorableness of beliefs.

Fully automated vehicles are expected to be safer and more energy efficient than current automobiles and are expected to reduce traffic congestion and insurance rates. The adoption of fully automated vehicles and the support for policies to put these vehicles on our roads is heavily dependent on public attitudes toward this emerging technology. Unfortunately, beliefs about driverless cars are mixed. Our study indicates that misconceptions and ignorance are responsible for much of the negativity. Consequently, education and communication about fully automated vehicles could be effective in changing consumer attitudes. However, the high levels of confidence of consumers harboring negative views of driverless vehicles suggest that these opinions may be resistant to persuasion. Direct experience (e.g., Fazio & Zanna, 1978b) with fully automated vehicles, rather than communication, may be necessary to convince skeptical consumers of the merits of the technology.

# REFERENCES


Ames, D. R., Kammrath, L. K., Suppes, A., & Bolger, N. (2010). Not so fast: The (not-quite-complete) dissociation between accuracy and confidence in thin-slice impressions. *Personality and Social Psychology Bulletin*, *36*(2), 264-277. https://doi.org/10.1177/0146167209354519

Autoblog (2013). *Autonomous cars found trustworthy in global study.* Retrieved from https://www.autoblog.com/2013/05/19/autonomous-cars-found-trustworthy-in-global-study/

Babad, E. Y., Ariav, A., Rosen, I., & Salomon, G. (1987). Perseverance of bias as a function of debriefing conditions and subjects' confidence. *Social Behaviour*, *2*(3), 185-193. Retrieved from http://psycnet.apa.org/record/1989-11767-001

Bazilinskyy, P., Kyriakidis, M., & de Winter, J. (2015). An International Crowdsourcing Study into People's Statements on Fully Automated Driving. *Procedia Manufacturing*, *3*, 2534-2542. https://doi.org/10.1016/j.promfg.2015.07.540

Bothwell, R. K., Deffenbacher, K. A., & Brigham, J. C. (1987). Predicting eyewitness accuracy from confidence: the optimality perspective. *Journal of Applied Psychology*, *72*, 691-695.

Briñol, P., & Petty, R. E. (2009). Persuasion: Insights from the self-validation hypothesis. *Advances in experimental social psychology*, *41*, 69-118. https://doi.org/10.1016/S0065-2601(08)00402-4

Cramer, R. J., DeCoster, J., Harris, P. B., Fletcher, L. M., & Brodsky, S. L. (2011). A confidence-credibility model of expert witness persuasion: Mediating effects and implications for trial consultation. *Consulting Psychology Journal: Practice and Research*, *63*(2), 129. http://dx.doi.org/10.1037/a0024591

Dunning, D., Griffin, D. W., Milojkovic, J. D., & Ross, L. (1990). The overconfidence effect in social prediction. *Journal of personality and social psychology*, *58*(4), 568. http://dx.doi.org/10.1037/0022-3514.58.4.568

Glasman, L. R., & Albarracín, D. (2006). Forming attitudes that predict future behavior: a meta-analysis of the attitude-behavior relation. *Psychological bulletin*, *132*(5), 778. 10.1037/0033-2909.132.5.778

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

Fazio, R. H., & Zanna, M. P. (1978a). Attitudinal qualities relating to the strength of the attitude-behavior relationship. *Journal of Experimental Social Psychology*, *14*(4), 398-408. https://doi.org/10.1016/0022-1031(78)90035-5

Fazio, R. H., & Zanna, M. P. (1978b). On the predictive validity of attitudes: The roles of direct experience and confidence. *Journal of Personality*, *46*(2), 228-243. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1467-6494.1978.tb00177.x/abstract

Kelly Blue Book (2016). *Future Autonomous Vehicle Driver Study September 2016.* Retrieved from https://mediaroom.kbb.com/future-autonomous-vehicle-driver-study

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

Krosnick, J. A., & Abelson, R. P. (1992). The case for measuring attitude strength in surveys. *Questions about questions: Inquiries into the cognitive bases of surveys*, 177-203. Retrieved from https://pprg.stanford.edu/wp-content/uploads/1992-the-case-for-measuring-attitude-strength-in-surveys.pdf

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

Kruger, J., & Dunning, D. (1999). Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments. *Journal of personality and social psychology*, *77*(6), 1121. http://dx.doi.org/10.1037/0022-3514.77.6.1121

Lichtenstein, S., & Fischhoff, B. (1977). Do those who know more also know more about how much they know?. *Organizational behavior and human performance*, *20*(2), 159-183. https://doi.org/10.1016/0030-5073(77)90001-0

Lichtenstein, S., Fischhoff, B., & Phillips, L. D. (1977). Calibration of probabilities: The state of the art. In *Decision making and change in human affairs* (pp. 275-324). Springer Netherlands. Retrieved from https://link.springer.com/chapter/10.1007/978-94-010-1276-8_19

McKnight, D. H., Carter, M., Thatcher, J. B., & Clay, P. F. (2011). Trust in a specific technology: An investigation of its components and measures. *ACM Transactions on Management Information Systems (TMIS)*, *2*(2), 12. 10.1145/1985347.1985353

McKnight, D. H., Choudhury, V., & Kacmar, C. (2002). Developing and validating trust measures for e-commerce: An integrative typology. *Information systems research*, *13*(3), 334-359. Retrieved from https://pubsonline.informs.org/doi/abs/10.1287/isre.13.3.334.81

Morrison, T. L., Thomas, M. D., & Weaver, S. J. (1973). Self-esteem and self-estimates of academic performance. *Journal of consulting and clinical psychology*, *41*(3), 412. http://dx.doi.org/10.1037/h0035337

Miller, D. J., Spengler, E. S., & Spengler, P. M. (2015). A meta-analysis of confidence and judgment accuracy in clinical decision making. *Journal of Counseling Psychology, 62*(4), 553-567. http://dx.doi.org/10.1037/cou0000105

SAE. (2014). *Automated Driving. Levels of Driving Automation Are Defined in New SAE Internaional Standsd J3016*. Retrieved from http://www.sae.org/misc/pdfs/automated_driving.pdf

Sanbonmatsu, D. M., Kardes, F. R., Posavac, S. S., and Houghton, D. C. (1997). Contextual Influences on Judgments Based on Limited Information. *Organizational Behavior and Human Decision Processes, 69,* 251-264.

Schoettle, B., & Sivak, M. (2014). *Public opinion about self-driving vehicles in China, India, Japan, the US, the UK, and Australia*. Retrieved from https://deepblue.lib.umich.edu/handle/2027.42/109433

Shrauger, J. S. (1972). Self-esteem and reactions to being observed by others. *Journal of Personality and Social Psychology*, *23*(2), 192. http://dx.doi.org/10.1037/h0033046

Shrauger, J. S., & Schohn, M. (1995). Self-confidence in college students: Conceptualization, measurement, and behavioral implications. *Assessment*, *2*(3), 255-278. https://doi.org/10.1177/1073191195002003006

Sporer, S. L., Penrod, S., Read, D., & Cutler, B. (1995). Choosing, confidence, and accuracy: A meta-analysis of the confidence-accuracy relation in eyewitness identification studies. *Psychological Bulletin*, *118*(3), 315. http://dx.doi.org/10.1037/0033-2909.118.3.315

Swann, W. B., Pelham, B. W., & Chidester, T. R. (1988). Change through paradox: using self-verification to alter beliefs. *Journal of personality and social psychology*, *54*(2), 268. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/3346813

Tenney, E. R., Small, J. E., Kondrad, R. L., Jaswal, V. K., & Spellman, B. A. (2011). Accuracy, confidence, and calibration: How young children and adults assess credibility. *Developmental Psychology*, *47*(4), 1065. 10.1037/a0023273

Trafimow, D., & Sniezek, J. A. (1994). Perceived expertise and its effect on confidence. *Organizational Behavior and Human Decision Processes*, *57*(2), 290-302. https://doi.org/10.1006/obhd.1994.1016

Vallone, R. P., Griffin, D. W., Lin, S., & Ross, L. (1990). Overconfident prediction of future actions and outcomes by self and others. *Journal of Personality and Social Psychology*, *58*(4), 582. http://dx.doi.org/10.1037/0022-3514.58.4.582