Back to the Future: Opinions of Autonomous Cars Over Time

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ABSTRACT

The aim of this research was to investigate whether preferences of U.S. adults regarding autonomous vehicles have changed in the past decade. We believe this to be indicative of the effect of cultural shifts over time in preferences regarding robots, similar to the effect of cultural and national differences on preferences regarding robots (e.g. [9, 14]). By replicating a 2009 survey regarding autonomous vehicle parking, we found that participants ranked four out of six parking and transportation options significantly differently now particularly for an autonomous vehicle with no override, a taxi, driving a standard vehicle, and being next to a vehicle driven by another person. Additionally, we found partial support that participants who were more informed about autonomous vehicle technology showed an increase in preferences for autonomous vehicles.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in interaction design**; • **Computer systems organization** → **Robotics**; **Robotic autonomy**; • **General and reference** → **Metrics**.

KEYWORDS

study replication, attitudes towards robots, autonomous cars, impact of time on HRI

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1 INTRODUCTION

In the decade since Desai et al. (2009) surveyed people about their comfort with autonomous vehicles (AVs) [8], technological advances have flourished. Before 2009, AVs were strictly research projects [2, 4, 11, 12]. Now, the transportation industry is full of vehicle manufacturers and transportation companies that offer a variety of automated options ranging anywhere from fully autonomous fleets and ride-hailing, logistics and trucking, to personal in-vehicle Advanced Driver Assistance Systems (ADAS) [6]. The aim of the research outlined in this paper is to examine changes in attitudes towards AVs over time by replicating the seminal work by Desai et al. in 2009. Ultimately this work can modernize our understanding of public perceptions of AVs and also inform how people's attitudes towards robots of all types might vary over time, especially in sectors in which autonomous technologies have quickly sprawled out of research labs and into the hands of businesses and individual consumers alike. In 2019, 36 companies reported autonomous car testing in California for a total of 2,855,739 miles driven. These reports became required by law only in 2015 [1], highlighting that these innovations are only recently becoming available to the public eye. Given these changes in the last decade, we hypothesized that participant attitudes towards AVs surveyed in 2020 would be significantly different than those attitudes surveyed in 2009.

In 1995, Carnegie Mellon University's Navlab 5 AV steered for over 98% of a 2,800+ mile journey with researchers controlling the speed of the vehicle [13]. AV research continued both in this lab and in others, with approaches including the modification of highway infrastructure [4, 11]. In 2009, AV commercialization began with the self driving car project at Google [12], now Waymo. By 2016, the world saw its first AV fatality [23]. In parallel to advances in AVs, transportation also saw changes in ride-hailing. In 2010, the Uber app launched, followed by the Lyft app in 2013. In 2017, the National Household Travel Survey showed that ride-hailing use doubled relative to 2009 [5]. Additionally, ride-hailing companies have invested in research and development of AVs for their fleets.

Since 2009, many surveys about AVs of all types have been published [7, 10, 15, 24], as well as studies of driver behavior when using AVs [3, 19, 20]. In particular, researchers have used autonomous parking to study not only attitudes towards AVs, but also user behavior with AVs, due to a combination of commercial availability, and the complexity of behaviors involved in engaging, monitoring, and intervening in autonomous parking and their relationships to (dis)trust in autonomous systems [19–21]. Regardless of someone's amount of driving experience, they will likely have had to park a car. Thus, the survey by Desai et al. [8] was selected for replication because it is the earliest relevant survey of public attitudes towards AVs, including automated parking which has become more common for everyday drivers, thus increasing the likelihood of reflecting changes in perceptions over time. Because AV technology has seen tremendous growth since 2009, we hypothesized the following:

***Hypothesis 1 (H1)*:** Participant preferences of autonomous parking options between 2009 and 2020 will be significantly different.

***Hypothesis 2 (H2)*:** Differences between participant preferences in 2009 and 2020 will be impacted by participants' familiarity with technology; scores from those with low technology familiarity will

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be more similar to scores from participants surveyed in 2009 than those with high technology familiarity.

***Hypothesis 3 (H3)*:** For participants surveyed in 2020, those who report they are more informed about AV technology will show greater preferences for AVs than those who report they are less informed about AV technology.

2 METHODOLOGY

2.1 Participants

In 2009, 176 participants were recruited through Amazon's Mechanical Turk (MTurk) [8]. Following similar procedures, in April 2020, we recruited 209 participants also through MTurk. In 2020, participants were required to have an approval rating greater than 95%, be located in the U.S., and be approved for more than 1000 tasks; MTurk participant restrictions were not reported in 2009. Twenty-two participants from 2020 were excluded from data analyses: 15 due to incorrect answers to 2 or more attention check questions, 4 due to providing incorrect rankings (using numbers outside the possible range), and 3 participants due to typing numerical responses where text was expected. After exclusion, 187 participants in 2020 were considered for subsequent data analyses.

In 2009, of the 176 respondents, 69.3% self-reported as female, 30.1% as male, and 0.6% did not provide information. Since 2009, inclusion efforts in research practices have increased, and we thus modified our question asking about gender [16]. In 2020, of the 187 respondents, 39.0% were women, 57.2% were men, 1.6% were non-binary, 1.1% selected both man and woman, and 1.1% preferred not to answer. Figure 1 shows the distribution of participant ages across the two studies. 97.7% of respondents in 2009 and 98.4% of respondents in 2020 reported prior driving experience.

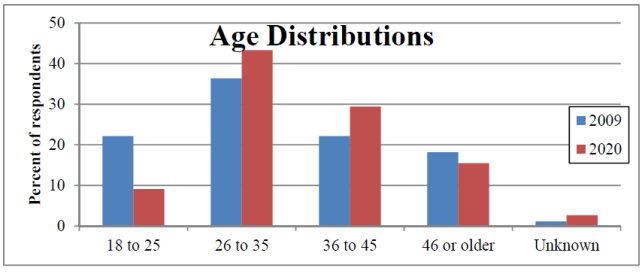

Figure 1: Comparison of respondent ages between years. There was not a statistically significant difference in the distribution of participant ages between the two years.

2.2 Design, materials and procedure

The study followed a between-subjects design with participants split into two groups: one that completed the survey in 2009 and another in 2020. For the current study, participants entered through a link to the survey prepared in Qualtrics posted on MTurk. After reading informed consent information and agreeing to participate, participants were presented with demographic questions (age, gender, prior driving experience). If participants responded that they had driven a car, they were asked how many hours they drive per week, and how many hours they drive with at least one other person in the car per week. All participants were asked how many hours they ride in a car as a passenger per week.

Participants were then provided with the following instructions: "Imagine that you are travelling to the grocery store. We want you to think about each of the following situations which involve parking at the store. Rank the following situations from 1 to 6 in terms of how comfortable you would feel in each situation,where 1 = Most comfortable and 6 = Least comfortable. Since you are ranking these six situations, you will use each number (1 through 6) exactly once." Participants then rank ordered the parking options listed below:

- You park your car manually (Self:Manual)
- You take a taxi and the taxi driver parks the taxi (Taxi)
- Your car automatically parks itself (but you can manually override it) (Self:Auto:Override)
- Your car automatically parks itself (and you cannot manually override it) (Self:Auto:No Override)
- Another driver parks their car next to your car (Other:Manual)
- An automatic car parks itself next to your car (Other:Auto)

To align with Web Content Accessibility Guidelines 2.0, the parking ranking question presented a textbox next to each parking option. Participants were instructed to type into each textbox a number from 1 to 6 representing their rank ordering of each parking option as opposed to physically arranging the order of options in a drag-and-drop interface [17], which could be difficult for persons with mobility impairments. This allowed participants to create ties in their rankings, although they were discouraged them from doing so; ties were not possible in the 2009 survey.

We also asked participants to report their familiarity with AV technology by indicating (Yes or No) whether they have seen videos of an autonomous cars, whether they have seen an autonomous car in person, whether they have been in an autonomous car, which companies they know have been developing autonomous cars, which companies they think might be developing autonomous cars, and what three words come to mind when they think about autonomous cars. Participants were asked if they had experience with robotic systems, and if yes, they were asked to describe it. Three multiple-choice attention-check questions were asked at the end and used to screen for potentially careless participant responses.

In 2009, participants were paid $0.50 for their participation [8] and $1.00 in 2020 (increased due to the longer survey and inflation). No time limits for completing the survey were imposed.

3 RESULTS

Data analysis was conducted using the open-source tool JASP [18]. There was not a statistically significant difference in the distribution of participant ages between the two years, (Mann-Whitney $U = 14635.0, p = .056, r_{pointbiserial} = 0.111$). However, there was for the distribution of participant genders between 2009 and 2020, $\chi^2(2, 363) = 34.74, p < .001$.

3.1 H1: Comparison of years

To test for significant differences in participant preferences between 2009 and 2020 (H1), we compared the rank data provided by participants in 2009 to those provided in 2020 using Mann-Whitney U

Table 1: Comparison of Parking Option Median Ranks

Parking option	2009	2020
Self: Manual*	1	2
Another driver: Manual*	3	4
Taxi*	3	2.5
Self: Auto: Override	3	3
Another driver: Auto	5	5
Self: Auto: No override*	6	5

* significant difference in ranks between years, p ≤ .001

tests, the non-parametric equivalent of independent samples t-test for ordinal level data. The median ranks for each parking option in both surveys are shown in Table 1.

See Figure 2 for boxplot comparisons for each parking option between the two surveys. For manual parking, the distributions in 2009 (Median = 1, $M = 1.7, SD = 1.331$) and in 2020 (Median = 1, $M = 2.1, SD = 1.452$) were significantly different, being ranked more negatively in 2020 (Mann-Whitney $U = 13432.0, p < .001, r_{pointbiserial} = -0.184$) than in 2009. Additionally, another driver manually parking was significantly less preferred in 2020 (Median = 4, $M = 3.8, SD = 1.382$) than in 2009 (Median = 3, $M = 3.3, SD = 1.343$) (Mann-Whitney $U = 12962.0, p < .001, r_{pointbiserial} = -0.212$). A Mann-Whitney test also showed that taxis were more preferred in 2020 (Median = 2.5, $M = 2.845, SD = 1.503$) than in 2009 (Median = 3, $M = 3.364, SD = 1.558$), $U = 19629.5, p = .001, r_{pointbiserial} = 0.193$. For a car autonomously parking with override, from 2009 (Median = 3, $M = 3.193, SD = 1.421$) to 2020 (Median = 3, $M = 3.168, SD = 1.465$), there was no significant change in preference (Mann-Whitney $U = 16685.5, p = .815, r_{pointbiserial} = 0.014$). For an autonomous car parking next to the respondent's car, there was no significant change in preference from 2009 (Median = 5, $M = 4.358, SD = 1.148$) to 2020 (Median = 5, $M = 4.489, SD = 1.337$), (Mann-Whitney $U = 14972.5, p = .127, r_{pointbiserial} = -0.090$). For AVs without override, there was a significant increase in preference from 2009 (Median = 6, $M = 5.040, SD = 1.366$) to 2020 (Median = 5, $M = 4.586, SD = 1.484$), (Mann-Whitney $U = 19797.0, p < .001, r_{pointbiserial} = 0.203$).

A supplementary analysis was conducted on 31 participants from 2020 who included ties in their rankings of parking options. Some rankings had ties between more than two options for parking. For this analysis, all multi-way ties were treated as combinations of two-way ties. The most-frequently-tied pair was another manual driver and autonomous parking without override (12 ties). The least-frequently-tied pair was another manual driver and another autonomous driver (3 ties). Table 2 shows the frequency of all ties.

3.2 H2 & H3: Impact of technology familiarity

For the analyses of H2 and H3, participants were split into three groups based on technology familiarity. The groups were participants from 2009, participants from 2020 who reported no familiarity with a specific topic, and participants from 2020 who reported familiarity with this topic, for the topics listed in Table 3.

The rankings of these groups were analysed using Kruskal-Wallis H tests, the non-parametric equivalent of a one-way ANOVA. Significant pairwise comparisons in rankings of AVs (not taxi or manual) are reported.

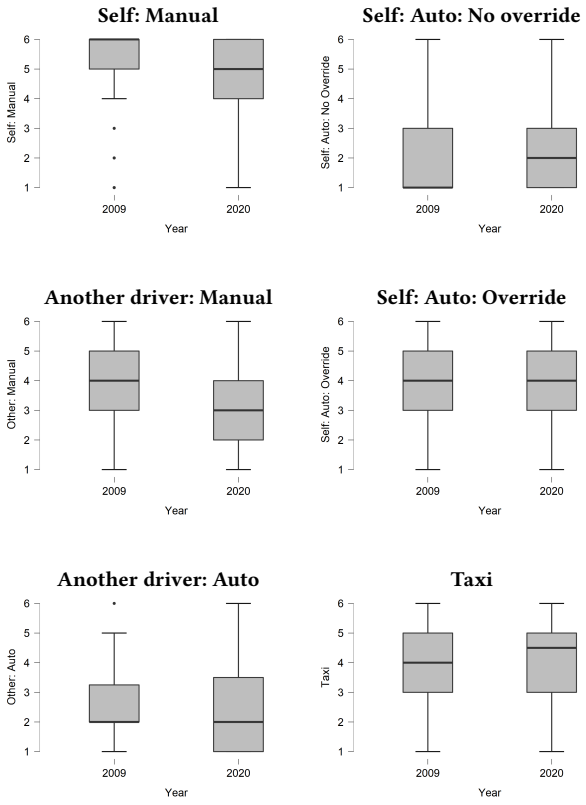

Figure 2: Comparison of preference distributions between years. Note: For ease of interpretation, the vertical axis represents rank preference as reverse-coded, with a high number indicating a high preference.

The results of Kruskal-Wallis tests were significant when groups were split by prior viewing of AV video for the rankings of autonomous parking with no override ($H = 13.723, F(2, 359) = 4.391, p = .001, \eta^2 = 0.024$). Dunn's post-hoc tests with Bonferroni corrections yield significant pairwise differences for autonomous parking with no override between 2009 ($M = 5.040, SD = 1.366$) and no prior viewing of AV video ($M = 4.510, SD = 1.327$) ($p = .003$), and between 2009 ($M = 5.040, SD = 1.366$) and prior viewing of AV video ($M = 4.638, SD = 1.512$) ($p = .009$).

When groups were split by prior viewing of AVs in person, there was a significant difference in rankings of autonomous parking with no override between groups ($H = 17.425, F(2, 360) = 6.716, p < .001, \eta^2 = 0.036$). Dunn's post-hoc tests with Bonferroni corrections yield significant pairwise differences for autonomous parking with no override between 2009 ($M = 5.040, SD = 1.366$) and no prior viewing of AVs in person ($M = 4.700, SD = 1.452$) ($p = .017$), between 2009 ($M = 5.040, SD = 1.366$) and prior viewing of AVs in person ($M = 4.190, SD = 1.542$) ($p < .001$), and between those with ($M = 4.190, SD = 1.542$) and without ($M = 4.700, SD = 1.452$) prior viewing of AVs in person ($p = .039$).

Table 2: Summary of tied rankings in 2020 survey data, *N*=31

Scenario	Self: Manual	Another driver: Manual	Taxi	Self: Auto: Override	Another driver: Auto	Self: Auto: No override
Self: Manual	-	7	10	6	6	6
Another driver: Manual	-	-	7	6	3	5
Taxi	-	-	-	7	8	8
Self: Auto: Override	-	-	-	-	8	8
Another driver: Auto	-	-	-	-	-	
Self: Auto: No override	-	-	-	-	-	-

Table 3: Responses to technology familiarity questions

	2009	2020 - No	2020 - Yes	2020 - No response
prior viewing of AVs in video	N.D.	48	138	1
prior viewing of AVs in person	N.D.	145	42	0
prior experience being in an AV	N.D.	167	20	0
prior experience with robotic systems	N.D.	151	36	0
accidents involving autonomous vehicle	N.D.	95	92	0

For 2009, N.D. means that no data was collected for these questions.

When groups were split by prior experience of being in an AV, there was a significant difference in rankings of autonomous parking with no override between groups ($H = 16.749, F(2, 360) = 6.868, p < .001, \eta^2 = 0.037$). Dunn's post-hoc tests with Bonferroni corrections yield significant pairwise differences for autonomous parking with no override between 2009 ($M = 5.040, SD = 1.366$) and no prior experience being in an AV ($M = 4.662, SD = 1.439$) ($p = .005$) and between 2009 ($M = 5.040, SD = 1.366$) and prior experience being in an AV ($M = 3.950, SD = 1.731$) ($p < .001$).

When groups were split by prior knowledge of AV accidents, there was a significant difference in rankings of autonomous parking with no override between groups ($H = 13.709, F(2, 360) = 5.365, p = .001, \eta^2 = 0.029$). Dunn's post-hoc tests with Bonferroni corrections yield significant pairwise differences for autonomous parking with no override between 2009 ($M = 5.040, SD = 1.366$) and no prior knowledge of AV accidents ($M = 4.458, SD = 1.534$) ($p < .001$) and between 2009 ($M = 5.040, SD = 1.366$) and prior knowledge of AV accidents ($M = 4.717, SD = 1.426$) ($p = .038$).

When groups were split by prior experience with robotic systems, there was a significant difference in rankings of autonomous parking with no override between groups ($H = 19.772, F(2, 360) = 7.598, p < .001, \eta^2 = 0.041$). Dunn's post-hoc tests with Bonferroni corrections yield significant pairwise differences for autonomous parking with no override between 2009 ($M = 5.040, SD = 1.366$) and no prior robotic system experience ($M = 4.709, SD = 1.463$) ($p = .020$), between 2009 ($M = 5.040, SD = 1.366$) and prior robotic system experience ($M = 4.069, SD = 1.479$) ($p < .001$), and between those with ($M = 4.069, SD = 1.479$) and without ($M = 4.709, SD = 1.463$) prior robotic system experience ($p = .010$).

4 DISCUSSION

Results supported that rankings of autonomous driving options in a parking scenario were significantly different between 2009 and 2020, particularly for autonomous parking with no override, being parked by a taxi, parking manually, and being parked next to by a manual driver. Regarding hypothesis H1 which stated that rankings would be different across the two years, four out of six options were ranked significantly differently.

The hypothesis that 2009 participants would rank options more similarly to 2020 participants with lower technology familiarity than those with higher technology familiarity (H2) was not supported. When examining the rankings of autonomous parking with no override, regardless of which measure of technology familiarity was used to split 2020 participants into 2 groups, both groups were significantly different than 2009. When split by prior viewing of an AV in person or experience with robotic systems, the 2020 groups were significantly different from each other.

The hypothesis that participants more informed about AV technology will have an increased preference for AV (H3) was partially supported. Participants who had seen an autonomous car in person ranked autonomous parking without override significantly more favorably than participants who had not seen an autonomous car in person. However, participants without robotic system experience ranked autonomous parking without override significantly more favorably than participants with experience, perhaps suggesting that exposure to the robotics domain may lend individuals to better understand the limitations of autonomy in the real world.

There are various theories for the process of acceptance of technology. The Unified Theory of Acceptance and Use of Technology, which systematically combined previous models, is a general-case model [22]. The empirical comparison of existing models conducted before the unification found that (technological) self-efficacy and anxiety, measures of the Social Cognitive Theory Model, significantly impacted the behavioral intention to use the technology at the start of its adoption, but the effect lessened to non-significance as an individual's experience increased. This may partially explain why participants who had seen an autonomous car in person were more comfortable than those who hadn't. Additionally, in future work, we plan to analyze the data to examine age and gender differences between years on participant preferences. Overall, this work strengthens the idea that the willingness to use autonomous vehicles is not a static trait, and that the culture affecting perception of autonomous systems can change with time.

5 CONCLUSIONS

In the survey responses, four out of six options for parking had significantly different distributions in 2020 than in 2009, supporting the hypothesis that autonomous vehicle preferences have changed. HRI researchers need to consider the passing of time – and particularly the evolution of technology – when considering people's attitudes towards robot systems.

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