Fleets on the streets: How number, affiliation and purpose of autonomous vehicle convoys influence public acceptance and blame

Anonymized

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Abstract

Autonomous vehicles (AVs) may have broad uses in society, but some applications may be more acceptable than others. Determining contexts in which AVs can acceptably operate is a substantial challenge for policy makers. In an online YouGov survey ($N = 1175$) with text-and-image vignettes of a one- or three-lane road section, AV convoys led to lower acceptance and greater blame toward their owning institutions than lone AVs. AVs affiliated with a private commercial company were less accepted than those affiliated with a public transit agency. AVs used to regulate traffic of the vehicles behind them were blamed more than AVs used to navigate through traffic to reach a destination. These results suggest that numerical balance, vehicle affiliation and intended purpose are aspects of future AV policies that will influence people's impressions of autonomous vehicles on public roads.

1 Introduction

Research on public acceptance of autonomous vehicles has largely focused on surveys which directly or indirectly assume a model of private vehicle ownership. For example, such surveys frequently ask participants whether they would personally want to purchase an autonomous vehicle, and how much they would be willing to pay for one, or if they enjoy driving manually. [KHdW15, SS14, PRL+20] (cf. [MM22]). Public opinion surveys that have included specific behaviors or use cases of autonomous vehicles (e.g., [KR18, KNJ19, BSR16, LZC+16, PRL+20]) have focused on situations involving single, privately owned AVs (e.g., daily commute, congested traffic, accidents) rather than situations that broadly transform traffic experiences of other road users. However, due to the high cost of autonomous vehicle technology, the way that most people will first encounter highly autonomous vehicles (Level 4 and above, by the SAE J3016 Standard [oAE21]) will be as observers rather than direct users [LJN15] (cf. ([Rog62]), and the vehicles they are likely to encounter will be owned by fleets rather than private individuals [Mar21]. Fleets of autonomous vehicles are likely to be owned by larger corporate or governmental entities, and may be controlled to dynamically coordinate their behavior for traffic regulation of human-driven (non-autonomous) vehicles (e.g., see [CWW+21, WKVB17]). People's everyday driving experiences—the daily commute, for example—will be more directly impacted, sooner, by their experience of other vehicles and those vehicles' behavior: the purpose/application of the autonomous vehicles, how many of them are on the road or their affiliation [VPK+18, GDZL22]. For practical issues about how to deploy autonomous vehicles onto roads in the future—and who should do that—understanding public opinion about the context about which autonomous vehicles are present on public roads in the first place is paramount.

The current work offers an initial exploration of how three policy-related factors—the number of vehicles, the affiliated institution and the purpose of the autonomous vehicle(s) on the road—influence public acceptance and responsibility allocation of the vehicles. We present the design and results of a (N= 1175) survey study[1] performed online to understand how these factors affect the public acceptance of autonomous vehicles and blame attribution for accidents involving these vehicles. This

[1] Although past AV surveys have used one survey per independent variable of interest (e.g., [BSR16] used separate studies for number of sacrificed lives and type of family members), the current work uses one study to explore all variables to account for interaction effects, which are not expected (based on prior work) but are considered for completeness.

study is the first of its kind, looking at public acceptance and blame attribution of autonomous vehicle fleets in specific scenarios. Given the importance of public acceptance of autonomous vehicles to vehicle adoption and responsibility attribution to vehicle manufacturers, this work may aid the development of policy decisions related to the presence, purpose and affiliation of single autonomous vehicles and coordinated platoons[2] of autonomous vehicles on public roads.

2 Literature review

2.1 Acceptance and responsibility with groups of vehicles

A large literature has explored public acceptance as a key measure of public opinion for autonomous vehicles (e.g., [CRH+19, CLR18, KHdW15, SS14]. Past public opinion surveys of autonomous vehicles have predominantly evaluated public perception of singleton autonomous vehicles or have assessed general attitudes towards the concept of autonomous vehicles (e.g., [HXG18]). However, allowing groups of coordinated autonomous vehicles on public roadways is a key policy consideration, since coordinated autonomous passenger vehicles can improve throughput and relieve traffic congestion by regulating normal vehicle traffic behind them (based on simulation and small scale road tests; cf. [VPK+18]). Groups of autonomous trucks are likely to replace many long-distance drivers, while groups of autonomous passenger vehicles are being proposed in the U.S. [Vis18, Ric19] How will the presence of groups of autonomous vehicles on public roadways affect people's acceptance of AVs?

Relevant literature in human-robot interaction (HRI) has identified differences in public opinion toward single versus groups of robots. Masjutin *et al.* [MLM22] found that Germans age 16 or older changed their decision about which candidate to hire to conform to a majority opinion held by either a group of robot evaluators, human evaluators or a mix of robot and human evaluators. Moreover, with a majority group of robot evaluators, people attributed their change to the robots knowing the answer better, while with a majority group of human evaluators, they changed because of social pressure. This suggests that people may find a road behavior more acceptable when it is performed by a majority of both the "robot" and human-driven cars on the road. Fraune *et al.* [FSS+17] found that U.S. and Japanese students rated groups of robots as more intelligent and having more "mind" than a single robot. This may suggest that groups of autonomous vehicles—as "robotic" cars—will be also perceived as more competent and therefore, more acceptable to have on public roadways. In another study, Fraune *et al.* [FOS+20] found people were more willing to interact with and were more positive in their attitudes about groups of robots that they rated as cohesive versus non-cohesive groups of robots. This may mean that autonomous vehicles that are "entitative" [DBA99] (i.e., act together and look similar) in groups would be more acceptable in the context of roadways as well. However, Fraune *et al.* [FSSS15] found that people were less accepting of non-humanoid robots that were in groups rather than alone. One possible reason is that groups or "swarms" of robots affect people's physiology: Podevijn1 *et al.* [POM+16] found that groups of robots moving around a person caused the person to have a higher heart rate, skin conductance (a physiological measure of arousal) and self-reported arousal than did singleton robots. We therefore test whether groups of AVs are perceived more positively or negatively than lone AVs.

> Research Question 1 (Acceptance of Convoys): Will people rate the presence of autonomous vehicle convoys as more or less acceptable than the presence of a lone autonomous vehicle?

Responsibility allocation (or "blame attribution") is a second key consideration in people's opinion of autonomous vehicles. Assigning responsibility for AV accidents has both moral implications (cf. [Eli19]) and is influenced by design considerations (e.g., [BWAG19]). Empirical surveys have evaluated how the public assigns blame to various parties (e.g., manufacturers, owners, drivers, the government), primarily comparing levels of automation (e.g., [PRL+20, BCMP20]) or comparing blame assigned to human drivers versus autonomous vehicles (e.g., [LD21, CCK21]). While level of automation is an important technical consideration in AVs, people's perceptions of blame may also be influenced by policy decisions such as groups versus singleton AVs.

Although no past work to our knowledge has looked at the effect of number of vehicles on blame assignment, past work in sexual assault cases found that as the number of perpetrators increases,

[2]we use the terms "convoy" and "platoon" interchangeably to refer to autonomous vehicles that are proximate to each other

greater blame is assigned to the victim (i.e., victims of offenses with multiple perpetrators are blamed more than victims of a single perpetrator) [Lim18]; similarly, groups are less likely to be assigned blame than individuals for organizational failures [GS03]. We explore whether this effect may be present with assigning blame to parties involved in accidents with varying numbers of AVs.

> Research Question 2 (Responsibility of Convoys): Will people assign responsibility differently for accidents involving autonomous vehicle convoys compared to a lone autonomous vehicle?

2.2 Acceptance and responsibility with government or corporate automated transit systems

Autonomous vehicles have been proposed for operation by organizations with public affiliation as well as those with private affiliation. Government-affiliated platoons that coordinate vehicles in order to improve efficiency have been proposed to solve many public problems related to the future of transportation [WKS21, SG20, WKVB17], including the use of fleets of AVs as "public urban vehicles" in France, Singapore and other countries as easy as the 1990s [DP97]. Commercial (private company) affiliated platoons of heavy duty vehicles have also been proposed, such as autonomous trucks affiliated with different commercial companies or platooning services that may coordinate with one another (cf. [FSJ17, Nis09]). Past work about either government affiliated or commercial affiliated automated transit systems have typically addressed public opinion of one or the other but not both. Government-affiliated autonomous vehicles' comfort and speed have been compared to existing public transportation modes [NXL+19], assessed for traffic control and energy consumption [SLB+19] and have been investigated using focus groups that identify concerns about how pedestrians and platoon pods would interact, including whether or how people would be prevented from crossing between them [WLH+19]. However, these works did not experimentally compare how people's perceptions of autonomous vehicles would change depending on the public/governmental versus private/commercial affiliation of the vehicles. Thus, a major unanswered question is how people's perceptions of the acceptance of the vehicles on public roads is influenced when the vehicles are designed or managed by public/governmental versus private/commercial companies.

In a related public opinion survey on artificial intelligence (AI) algorithms that explored public versus private affiliation, 2000 U.S. YouGov respondents did not have high confidence in any type of organization to develop and manage AI [ZD20]. University researchers and the U.S. military were the most trusted groups to *develop* AI in the public interest, followed by large tech companies (e.g. Google, Microsoft, Facebook) [ZD20]; non-government organizations and companies were the most trusted to *manage* AI; and the U.S. state and federal government were the least trusted (note that trust was generally low). To extend such research into public opinion of autonomous vehicles' management, we filter the key categories used in [ZD20] to only include affiliated organizations that are actively developing autonomous vehicle platoons based on the literature reviewed (i.e., public transport authorities and private companies).

> Research Question 3 (Acceptance of Affiliations): Will people rate autonomous vehicles affiliated with a public transit agency as more or less acceptable than those affiliated with a private commercial company?

Among work that has looked at the effect of affiliation on responsibility attribution, Copp *et al.* found that larger companies were blamed less than smaller companies in an AV accident [CCK21]. We therefore also explore how two main affiliations of autonomous vehicles affect responsibility allocation for accidents.

> Research Question 4 (Responsibility of Affiliations): Will people assign responsibility differently for accidents involving autonomous vehicle(s) affiliated with a public transit agency versus a private commercial company?

2.3 Autonomous Vehicle Purpose

Past research has investigated various purposes and application domains of autonomous vehicles. Researchers are increasingly studying the public opinion on AVs for different destination-transporting applications (i.e., applications in which the AV transports people or items), including private AVs [ZLV22], public transportation [PB17], automated shuttle services [BMC20] and automated trucking [KBvdBAC21]. Researchers have used survey studies to examine public expectations and concerns about automated public transportation in different countries, including the US, the UK, Australia, New Zealand, Singapore, and China [CC20, CLR18, CRH+19, SS14, ZCZ20].

While most research focuses on various destination-transporting applications, simulated results from the intelligent transportation systems literature have shown that as automated vehicle fleets increase in scale and capacity, they will become capable of another function: traffic regulation (i.e., setting the pace of traffic) [ČJ18, ZYQ19]. This role may be passive, as human drivers and other road users learn to adjust their driving as the fleet's style becomes prevalent on public roads [Gil21]. It may instead be active, if automated vehicles intentionally nudge other drivers in order to control either local interactions or the citywide flow of traffic [FBS+19, WKVB17]. Either way, the role of traffic regulation may be traced back to design choices overseen by automated vehicle developers, raising new problems at the intersection between the specification of fleet behavior and public policy [GDZL22]. An open question is how the perception of automated vehicles depends on their purpose of *accommodating* traffic flow (as is the case when AVs transport to a destination and drives around other vehicles) vs. *regulating* overall traffic flow (as is the case when AVs purposely control the speed of human-driven vehicles behind them). Past public surveys that have looked at vehicle purpose have found that, in crash situations, participants significantly prefer "selfish" automated vehicles over those that try to minimize collective harm in a utilitarian sense [LL21]. And a qualitative study found that respondents, after riding in an autonomous shuttle, were more open to automated vehicle fleets as an alternative rather than substitutive means of transportation [HG20]. There is a pressing need to fill gaps in past work that have not explicitly included traffic regulation as an emerging purpose of AVs.

> Research Question 5 (Acceptance of Traffic Regulation): Will people rate autonomous vehicles whose purpose is traffic regulation as more or less acceptable than those whose purpose is destination transport?

Researchers have explored how robot autonomy, behavior and purpose affect responsibility attribution in human-robot interaction. A lab experiment with an assembly robot found that people received the greatest share of blame, but that greater robot autonomy increased blame toward the robot and decreased blame toward oneself and other participants [KH06]. An online survey using text-based vignettes of robots in three application domains also found that robot autonomy increased blame attributed to the robot and decreased blame attributed to the person; moreover, they found that this resulted in the person being blamed more than a non-autonomous robot (but not an autonomous one) when the robot was at fault [FSG21]. Another online questionnaire with text vignettes found that the robot's purpose (pharmacy service provider or food service provider) did not influence blame attribution: across purposes, a robot was consistently blamed less than a human in the same role and this effect was mediated by the perceived "controllability" of the service provider [LH20]. However, the purposes explored did not explicitly vary the perceived control that the robot or human service provider had in the scenario, such as by varying their behavior.

> Research Question 6 (Responsibility of Traffic Regulation): Will people assign responsibility differently for accidents involving autonomous vehicles for traffic regulation compared to destination transport?

3 Materials and Method

3.1 Participants

We recruited 1204 participants from the YouGov survey platform. YouGov is a representative sampling platform that matches a randomly-drawn sampling frame of the U.S. population with members from their opt-in respondents based on a large set of variables (cf. [Iye13, PI21]); the platform has been widely validated (cf. [MCGK21]). Twenty-nine participants (2.4%) who incorrectly answered the attention check question "What technology is this survey about?" (e.g., "virtual reality" instead of "autonomous vehicles") were excluded, leaving 1175 participants total (643 women, 510 men, 9 non-binary, 13 prefer not to answer) ages 19 to 68 (mean $M = 55$, standard deviation $SD = 13$).

Participants' ethnicity was 907 White or Caucasian, 93 Black or African American, 65 Hispanic or Latino, 25 Asian or Pacific Islander, 13 Native American or Alaskan Native, 35 Multiracial or Biracial, 10 A race/ethnicity not listed here, 27 Prefer not to answer. Participants' highest education was 15 Less than a high school diploma, 168 High school degree or equivalent (e.g. GED), 268 Some college, no degree, 138 Associate degree (e.g. AA, AS), 343 Bachelor's degree (e.g. BA, BS), 158 Master's degree (e.g. MA, MS, MEd), 53 Professional degree (e.g. MD, DDS, DVM), 32 Doctorate (e.g. PhD, EdD).

3.2 Study Design

In this study, we conducted a 2 (vehicle number: single versus group) x 2 (vehicle affiliation: private versus public) x 2 (vehicle purpose: traffic regulation or destination arrival) between-participants online experiment. Participants were randomly assigned to read one of eight text-and-image-based vignettes describing either a single or group of autonomous vehicles that were either operated by a private or public organization and that were either being used to regulate traffic or to transport to a destination.

3.3 Stimuli

Text in the vignettes was designed to vary only in the manipulated variables, to mention each variable at least once in each vignette, and was matched for word count and style (please see Table 1). Images used visual depictions of road traffic in one or three lanes (please see Table 1). Images differed only in the number of vehicles manipulation, as past work (e.g., [FOS+20]) suggests that the effect of this variable may require visual prompts. The vignettes were designed to assess initial impressions of the concepts of vehicle purpose, affiliation and number of vehicles, so used general wording and images. To account for contextual effects apart from the ones being analyzed, vignettes were standardized to use a yellow autonomous sedan and blue normal sedan (colors selected for contrast) and road type (i.e., general road with lanes) and the context noted in our descriptions of stimulus samples [CR22] [3]

To assess responsibility attribution, participants viewed a follow-up text-based vignette (see Table 2) that described an accident with a non-autonomous vehicle having a rear-end shunt with the autonomous vehicle (i.e., the AV's rear end is impacted by the human-driven vehicle) due to unpredictable AV behavior. To motivate this accident scenario, past literature has suggested that AVs may navigate common traffic situations in ways that humans cannot [FKRP+20]. Results in simulation show that new techniques like inverse reinforcement learning can lead to AVs that actively take atypically aggressive or defensive actions near human drivers in order to better control traffic situations [SSASDD16]. A range of hybrid modeling approaches can combine AVs' capacity for long- and short-term planning to induce and control a variety of situations dynamically [FBS+19], which may not match how people typically drive. Participants were assigned to the same condition for the follow-up vignette as for the primary vignette.

3.4 Procedure and Measures

Participants were asked about public acceptance of the autonomous vehicles depicted in the vignette after the primary vignette and responsibility attribution in an accident after the secondary vignette.

Public acceptance was measured with a 6-item scale, consisting of 1 item about general impression ("What is your immediate feeling toward the AV(s) pictured in this survey?" 1 = "very negative," 6 = "neutral," 11 = "very positive"); modified from [CGGM15, SS14]), 1 on benefit to self ("How beneficial do you believe the specific AV(s) pictured in this survey could be to you?" 1 = "no benefit to you at all," 6 = "moderate benefit to you," 11 = "large and direct benefit to you"; modified from [CGGM15]), 1 on benefit to society ("How beneficial do you believe the specific AV(s) pictured in this survey could be to society?" 1 = "no benefit to you at all," 6 = "moderate benefit to you," 11 = "large and direct benefit to you"; modified from [CGGM15]), 2 on perceived safety and risk ("How strongly do you agree that the autonomous vehicle(s) pictured in this survey is safe?" 1 = "strongly disagree," 6 = "neutral," 11 = "strongly agree"; "How strongly do you agree that the AV(s) pictured in this survey is risky?", reverse-coded; modified from [CGGM15, SS14, KNJ19]), and 1 on risk acceptability ("To what extent

[3] The omission of a specific road type is in line with past vignettes that used a "main road" [BSR16] or "road" [LZC+16], although we note that some work has used specific road type (e.g., "two-way mountainside road" [ALKW+20] or "city street" [LZC+16]). .

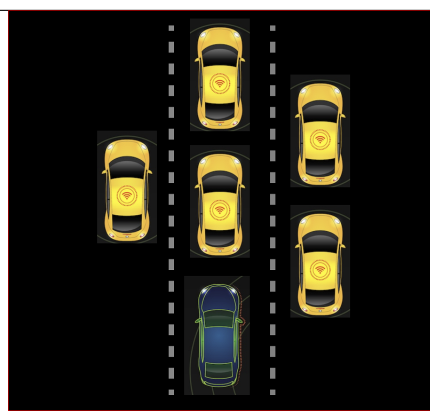
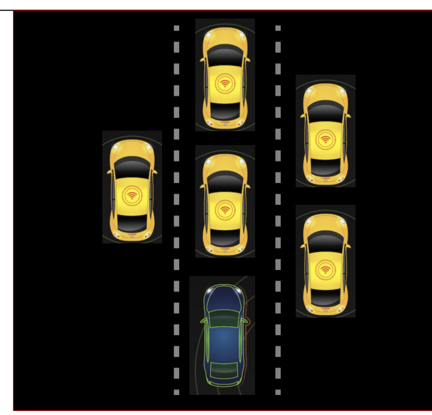
	Traffic regulation	*Destination transport*
Single vehicle:		
		
Public affiliation	A public transit agency's autonomous vehicle is driving in front of other vehicles and adjusts its speed to *regulate traffic*. The public transit agency's autonomous vehicle modifies its speed to *control the speed of the vehicles behind it.*	A public transit agency's autonomous vehicle is driving in front of other vehicles and adjusts its speed to *reach its destination*. The public transit agency's autonomous vehicle modifies its speed to *navigate through the vehicles in front of it.*
Private affiliation	A private commercial company's autonomous vehicle is driving in front of other vehicles and adjusts its speed to *regulate traffic*. The private commercial company's autonomous vehicle modifies its speed to *control the speed of the vehicles behind it.*	A private commercial company's autonomous vehicle is driving in front of other vehicles and adjusts its speed to *reach its destination*. The private commercial company's autonomous vehicle modifies its speed to *navigate through the vehicles in front of it.*
Group of vehicles:		
		
Public affiliation	A public transit agency's **convoy of five** autonomous vehicles is driving in front of other vehicles and adjusts its speed to *regulate traffic*. The public transit agency's autonomous vehicles modify their speed to *control the speed of the vehicles behind them.*	A public transit agency's **convoy of five** autonomous vehicles is driving in front of other vehicles and adjusts its speed to *reach its destination*. The public transit agency's autonomous vehicles modify their speed to *navigate through the vehicles in front of them.*
Private affiliation	A private commercial company's **convoy of five** autonomous vehicles is driving in front of other vehicles and adjusts its speed to *regulate traffic*. The private commercial company's autonomous vehicles modify their speed to *control the speed of the vehicles behind them.*	A private commercial company's **convoy of five** autonomous vehicles is driving in front of other vehicles and adjusts its speed to *reach its destination*. The private commercial company's autonomous vehicles modify their speed to *navigate through the vehicles in front of them.*

Table 1: Vignette text and image based on vehicle purpose (column header), number of vehicles (row grouping) and vehicle affiliation (row header) of yellow fully-autonomous vehicle(s) in a one- or three-lane road section.

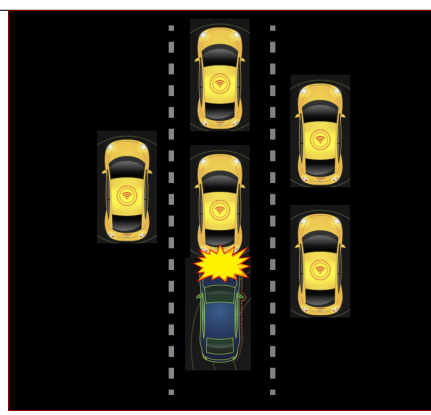
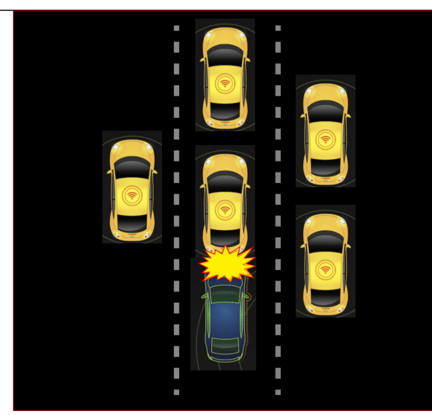
	Traffic regulation	*Destination transport*
Single vehicle:		
		
Public affiliation	While the public transit agency's autonomous vehicle modifies its speed to *regulate traffic,* the car behind the autonomous vehicle has difficulty anticipating the behavior of the autonomous vehicle in front and as a result, collides with it.	While the public transit agency's autonomous vehicle modifies its speed to *reach its destination,* the car behind the autonomous vehicle has difficulty anticipating the behavior of the autonomous vehicle in front and as a result, collides with it.
Private affiliation	While the private commercial company's autonomous vehicle modifies its speed to *regulate traffic,* the car behind the autonomous vehicle has difficulty anticipating the behavior of the autonomous vehicle in front and as a result, collides with it.	While the private commercial company's autonomous vehicle modifies its speed to *reach its destination,* the car behind the autonomous vehicle has difficulty anticipating the behavior of the autonomous vehicle in front and as a result, collides with it.
Group of vehicles:		
		
Public affiliation	While the public transit agency's **convoy of five** autonomous vehicles modifies its speed to *regulate traffic*, the car behind the autonomous vehicles has difficulty anticipating the behavior of the autonomous vehicles in front and as a result, collides with **one of them**.	While the public transit agency's **convoy of five** autonomous vehicles adjusts its speed to *reach its destination*, the car behind the autonomous vehicles has difficulty anticipating the behavior of the autonomous vehicles in front and as a result, collides with **one of them**.
Private affiliation	While the private commercial company's **convoy of five** autonomous vehicles modifies its speed to *regulate traffic*, the car behind the autonomous vehicles has difficulty anticipating the behavior of the autonomous vehicles in front and as a result, collides with **one of them**.	While the private commercial company's **convoy of five** autonomous vehicles modifies its speed to *reach its destination*, the car behind the autonomous vehicles has difficulty anticipating the behavior of the autonomous vehicles in front and as a result, collides with **one of them**.

Table 2: Follow-up vignette text for rear shunt (crash) scenario and image based on vehicle purpose (column header), number of vehicles (row grouping) and vehicle affiliation (row header) of yellow, fully-autonomous vehicle(s) in a one- or three-lane road section.

do you think the risks associated with the use of the AV(s) pictured in this survey are acceptable?" 1 = "not acceptable at all," 6 = "neither acceptable nor unacceptable," 11 = "definitely acceptable"; modified from [CGGM15]). We harmonized the questions (e.g., changing "Describe your immediate feeling" to "What is your immediate feeling") for consistency with the other questions, and using 11-point Likert scales for all items, regardless of the original scale. Questionnaire items about enjoyment, ease of use and interest/willingness to buy (used in [SS14, KHdW15, KNJ19]) were excluded as the current study specified organization (rather than individual) ownership of the autonomous vehicles; similarly, trust in safety items [KNJ19] were addressed by the safety item, while items about specific concerns (e.g., hacking, privacy, level of automation) [KHdW15, SS14, KNJ19] were too narrow for the current study. Scale internal consistency was Cronbach's $\alpha = 0.922$ (6 items, 1175 samples).

Participants were asked to assign relative responsibility to the AV(s)' owner and the normal car's driver after reading the follow-up vignette in Table 2 ("How much are each of the following parties to blame for the traffic accident?"; 11-point Likert scale, 1 = "no blame at all", 6 = "moderate blame", 11 = "Full Blame", followed by the two parties; "How much are each of the following parties at fault for the traffic accident?", followed by the two parties; modified from [PRL+20, LZC+16] to an 11-point Likert scale and two parties[4] for simplicity). Scale internal consistency with driver fault/blame items reverse-coded[5] was Cronbach's $\alpha = 0.889$ (4 items, 1175 samples).

All procedures were approved by the research ethics board at Anon. University and preregistered on osf.io (link for peer review).

3.5 Analysis

We used a 2 x 2 x 2 Analysis of Variance (ANOVA) with three between-participant factors (number of, purpose of and affiliation of vehicle(s)) to analyze our results. One ANOVA was done for the measure of public acceptance and one ANOVA was done per judgment target for responsibility attribution. We used linear regression models as post-hoc tests to compare specific cells in our study design with other specific cells, to do follow-up comparisons for any aggregate ANOVA effects we find. We performed case-wise exclusion for missing data. All statistical analyses were done in R version 4.0.5 and RStudio version 1.4.1106.

4 Results

4.1 Effect of Convoys

Research Question 1 asked whether people rate the presence of vehicle convoys as more or less acceptable than lone autonomous vehicles. In support of an affirmative answer to this question, an ANOVA on acceptance with vehicle number, affiliation and purpose as between-participant variables found a significant effect of vehicle number (Table 3, first row). Participants rated a convoy of five autonomous vehicles as less acceptable than a lone autonomous vehicle (Figure 1). No interaction effects were found, all ps > 0.39. Autonomous vehicle convoys were therefore rated as less acceptable than lone autonomous vehicles.

Research Question 2 asked whether people assign responsibility differently for accidents involving autonomous vehicle convoys compared to a lone autonomous vehicle. In support of an affirmative answer to this question, an ANOVA on blame with vehicle number, affiliation and purpose as between-participant variables found a significant effect of vehicle number (Table 3, second row). Participants assigned greater blame to autonomous vehicle convoys than to lone autonomous vehicles (Figure 2). No interaction effects were found, all ps > 0.73, except the interaction between vehicle number and affiliation, which had $p = 0.09$. Greater blame was assigned to the owner of convoys of autonomous vehicles than the owner of a lone autonomous vehicle for an accident in which a normal vehicle driver rear shunted an autonomous vehicle, accounting for the affiliation of the autonomous vehicle(s).

[4]Five parties (the driver/user/owner, vehicle, other road users, manufacturer, and government) were used in past work that involved accidents between an AV and road users such as pedestrians [PRL+20, LZC+16]; we reduced it to two parties since some work suggests that human drivers and companies are the primary parties found at fault (e.g., [LZC+16, CCK21]) and the accidents in our vignettes were between two vehicles

[5]This study was designed assuming fault was zero-sum across the two parties, so we used reverse coding to obtain a single measure of blame; however, we performed separate analyses for each party as exploratory tests to check this assumption (and because past work looking at five or more parties analyzed each party separately; e.g., [LZC+16])

Dependent measure		Five		One		ANOVA: main effect of number			
		n	M (SD)	n	M (SD)	df	F *value*	p *value*	η_p^2
Acceptance		586	4.3 (2.4)	589	4.7 (2.4)	1, 1167	6.8	.009	.006
Blame	Composite score	586	5.8 (2.8)	589	5.2 (2.8)	1, 1167	11.5	<.001	.010
	Toward AV affil.	586	6.4 (3.3)	589	5.8 (3.4)	1, 1167	11.9	<.001	.010
	Toward NV driver	586	6.9 (2.9)	589	7.3 (2.9)	1, 1167	6.9	.009	.006

Table 3: Descriptive statistics for each dependent measure in each "vehicle number" group and ANOVA results for the main effect of vehicle convoys

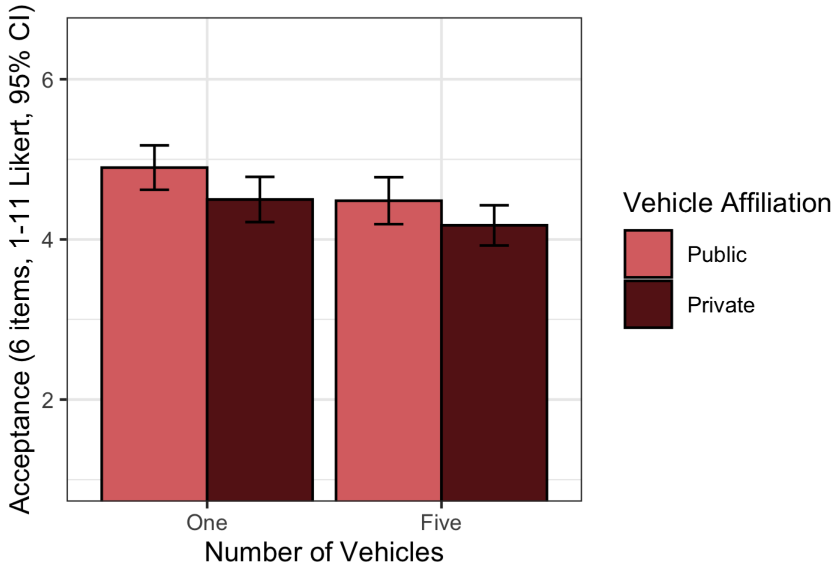


Figure 1: Bar plot of public acceptance of autonomous vehicles versus number of vehicles, grouped by vehicle affiliation.

An exploratory test for Research Question 2 was performed to separately look at blame attribution to the autonomous vehicle affiliation versus to the driver of the normal vehicle. An ANOVA on blame toward AV affiliation with vehicle number, affiliation and purpose as between-participant variables found a significant effect of vehicle number (Table 3, third row). Participants assigned greater blame to organizations affiliated with autonomous vehicle convoys than to those affiliated with lone autonomous vehicles. The interaction between vehicle number and affiliation was not significant, $p = 0.056$; however, based on the p-value, a post-hoc Tukey's HSD test found significantly greater AV affiliation blame toward a convoy versus lone vehicle when the vehicles were from a private company, $p < 0.001$, $0.3 < \mu_{five} - \mu_{one} < 1.7$, but not when they were from a public agency, $p = 0.71$, $-0.4 < \mu_{five} - \mu_{one} < 1.0$ (Figure 3, left). A separate ANOVA on blame toward the normal vehicle's driver with vehicle number, affiliation and purpose as between-participant variables found a significant effect of vehicle number (Table 3, bottom row). Participants assigned less blame to drivers who hit autonomous vehicle convoys than to those who hit lone autonomous vehicles. The interaction between vehicle number and purpose was not significant, $p = 0.09$; however, based on the p-value, a post-hoc Tukey's HSD test found significantly lower blame of a normal vehicle driver who rear shunted a convoy versus a lone vehicle used for traffic regulation, $p = 0.01$, $-1.3 < \mu_{five} - \mu_{one} < -0.1$, but not when used for destination transport, $p = 0.91$, $-0.8 < \mu_{five} - \mu_{one} < 0.5$ (Figure 3, right). Thus, the exploratory test showed that autonomous vehicle number affected both blame attribution to the autonomous vehicles and to the normal vehicle driver.

4.2 Effect of Affiliations

Research Question 3 asked whether people rate autonomous vehicles affiliated with a public transit agency as more or less acceptable than those affiliated with a private commercial company. In support

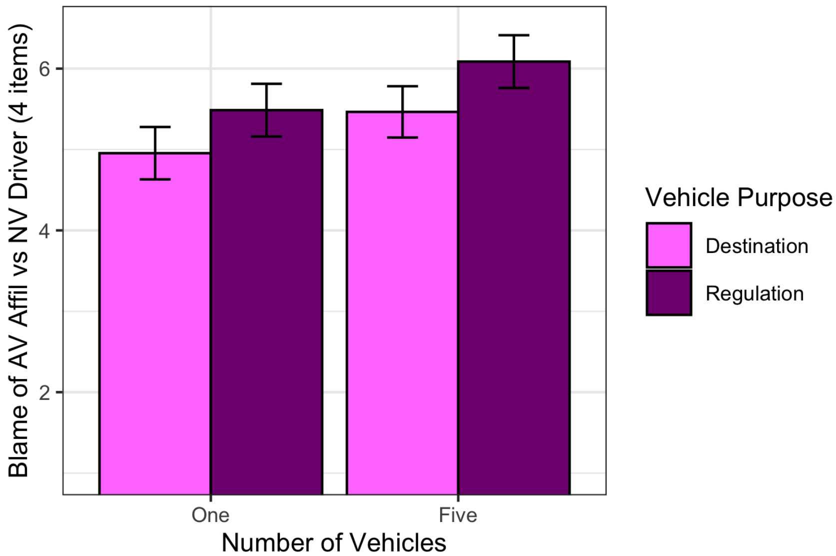


Figure 2: Bar plot of blame toward autonomous vehicle affiliation (rather than normal vehicle driver) versus number of vehicles, grouped by vehicle purpose.

of an affirmative answer to this question, an ANOVA on acceptance with vehicle number, affiliation and purpose as between-participant variables found a significant effect of vehicle affiliation (Table 4, first row). Participants rated autonomous vehicles affiliated with a private commercial company as less acceptable than those affiliated with a public transit agency (Figure 1). Private commercial autonomous vehicles were therefore rated as less acceptable than public transit autonomous vehicles.

Research Question 4 asked whether people assign responsibility differently for accidents involving autonomous vehicle(s) affiliated with a public transit agency versus a private commercial company. An ANOVA on blame with vehicle number, affiliation and purpose as between-participant variables did not find a significant effect of vehicle affiliation (Table 4, second row). No support was found for assigning blame differently between autonomous vehicle(s) affiliated with a public transit agency versus a private commercial company.

An exploratory test for Research Question 4 was performed to separately look at blame attribution to the autonomous vehicle affiliation versus to the driver of the normal vehicle. An ANOVA on blame toward AV affiliation with vehicle number, affiliation and purpose as between-participant variables did not find a significant effect of vehicle affiliation (Table 4, third row). However, a post-hoc Tukey's HSD test suggested that the influence of number on AV affiliation blame may have been stronger for private companies than for public agencies (as presented in Section 4.1 and Figure 3, left). A separate ANOVA on blame toward the normal vehicle's driver with vehicle number, affiliation and purpose as between-participant variables did not find a significant effect of vehicle affiliation (Table 4, bottom row). No interactions involving vehicle affiliation were found, all $ps > 0.26$. Thus, the exploratory test did not find consistent evidence of AV affiliation affecting blame assignment toward the affiliation and toward a normal vehicle driver.

Dependent measure		**Private**		**Public**		**ANOVA: main effect of affil.**			
		n	*M (SD)*	*n*	*M (SD)*	*df*	*F value*	*p value*	η_p^2
Acceptance		592	4.3 (2.3)	583	4.7 (2.5)	1, 1167	6.2	.013	.005
Blame	Composite score	592	5.4 (2.9)	583	5.6 (2.8)	1, 1167	.7	.390	-
	Toward AV affil.	592	6.2 (3.3)	583	6.0 (3.4)	1, 1167	1.0	.320	-
	Toward NV driver	592	7.1 (2.8)	583	7.2 (3.0)	1, 1167	.3	.600	-

Table 4: Descriptive statistics for each dependent measure in each "vehicle affiliation" group and ANOVA results for the main effect of vehicle affiliation

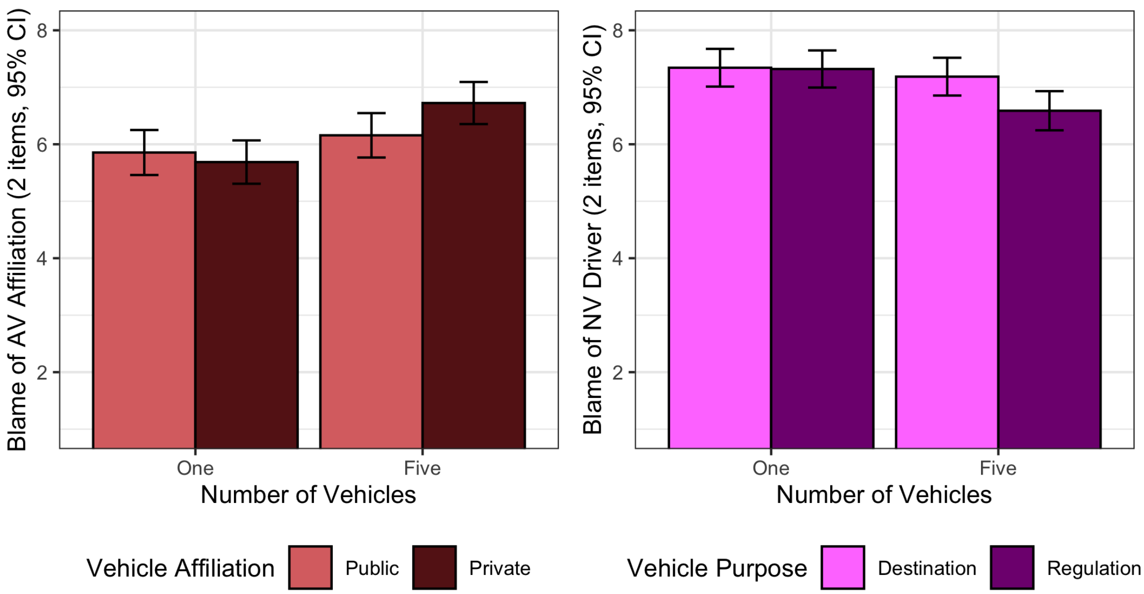


Figure 3: Left: Bar plot of blame toward autonomous vehicle (AV) affiliation versus number of vehicles, grouped by vehicle affiliation. Right: Bar plot of blame toward normal vehicle (NV) driver versus number of vehicles, grouped by vehicle purpose.

4.3 Effect of Vehicle Purpose

Research Question 5 asked whether people rate autonomous vehicles whose purpose is traffic regulation as more or less acceptable than those whose purpose is destination transport. An ANOVA on acceptance with vehicle number, affiliation and purpose as between-participant variables did not find a significant effect of vehicle purpose (Table 5, first row). No support was found for rating autonomous vehicles used for traffic regulation as more or less acceptable than those used for destination transport.

Research Question 6 asked whether people assign responsibility differently for accidents with autonomous vehicles for traffic regulation versus those for destination transport. In support of an affirmative answer to this question, an ANOVA on blame with vehicle number, affiliation and purpose as between-participant variables found a significant effect of vehicle purpose (Table 5, second row). Participants assigned greater blame to autonomous vehicles used for traffic regulation than to autonomous vehicles used for destination transport (Figure 2). Greater blame was assigned to the affiliated owner of an autonomous vehicle(s) versus the driver of a normal vehicle who rear shunted the autonomous vehicle when the autonomous vehicle(s) were regulating traffic than when they were driving to reach a destination.

An exploratory test for Research Question 6 was performed to separately look at blame attribution to the autonomous vehicle affiliation versus to the driver of the normal vehicle. An ANOVA on blame toward AV affiliation with vehicle number, affiliation and purpose as between-participant variables found a significant effect of vehicle purpose (Table 5, third row). Participants assigned greater blame to autonomous vehicles for traffic regulation than to autonomous vehicles for transport. No interactions

Dependent measure		**Regulation**		**Destination**		**ANOVA: main effect of purpose**			
		n	*M (SD)*	*n*	*M (SD)*	*df*	*F value*	*p value*	η_p^2
Acceptance		587	4.4 (2.5)	588	4.6 (2.3)	1, 1167	1.1	.290	-
Blame	Composite score	587	5.8 (2.9)	588	5.2 (2.8)	1, 1167	12.4	<.001	.010
	Toward AV affil.	587	6.5 (3.4)	588	5.7 (3.3)	1, 1167	19.0	<.001	.020
	Toward NV driver	587	7.0 (2.9)	588	7.3 (2.9)	1, 1167	3.4	.070	-

Table 5: Descriptive statistics for each dependent measure in each "vehicle purpose" group and ANOVA results for the main effect of vehicle purpose

involving vehicle purpose were found, all $ps > 0.3$. A separate ANOVA on blame toward the normal vehicle's driver with vehicle number, affiliation and purpose as between-participant variables did not find a significant effect of vehicle purpose (Table 5, bottom row). However, a post-hoc Tukey's HSD test suggested that participants may have assigned less blame to drivers who hit an autonomous vehicle convoy than those who hit a lone autonomous vehicle specifically for vehicles used for traffic regulation (as presented in Section 4.1 and Figure 3, right). Thus, the exploratory test showed that autonomous vehicle purpose primarily affected blame attribution to the owner affiliated with the autonomous vehicle rather than to the normal vehicle driver.

5 Discussion

5.1 Summary of Results

Autonomous vehicle convoys were perceived as less acceptable and led to greater blame of their owning organizations (and less blame to a normal vehicle driver) in the event of a rear shunt accident on a one- or three-lane road section than lone autonomous vehicles. Autonomous vehicles affiliated with a private commercial company were perceived as less acceptable than those affiliated with a public transit agency. In a rear shunt accident, the organization affiliated with autonomous vehicles that regulated traffic was blamed more than when the autonomous vehicles were used for transportation purposes.

5.2 Policy Implications

Simulated results already show that automated vehicle convoys will be able to control highway bottlenecks once they reach 10 percent of all vehicle traffic, acting as moving road obstacles that would restructure the behavior patterns of other road users [VKLF+18]. Moreover, in our study the number of collocated autonomous vehicles was the most important policy factor among the three investigated–influencing both participants' acceptance of autonomous vehicles and blame attribution toward the organizations affiliated with those vehicles. Together, these facts suggest the importance of maintaining numerical balance in mixed autonomy traffic, particularly in traffic situations where the experience of human road users is directly impacted.

In the event of an accident, autonomous vehicles whose purpose was to regulate traffic led to greater blame of their owners than did autonomous vehicles used for destination transportation. This may mean that organizations that wish to use autonomous vehicles to regulate traffic face harsher moral standards than those that aim to focus on transportation of persons or items. However, the purpose of autonomous vehicles did not influence participants' acceptance of the vehicles, suggesting that people evaluating the general concept of AVs in a poll (rather than actually driving behind autonomous vehicles) may not particularly care about why those autonomous vehicles are on the road. Meanwhile, existing surveys show very low consumer knowledge about the capabilities of fully-automated vehicles [BR+22], suggesting this variable may not yet enter the minds of survey respondents. To move beyond the limits of general concept polling (e.g. [ZSW+16]), future public surveys should address this discrepancy by distinguishing possible intended purposes of vehicle automation when asking participants to evaluate AVs.

Participants were influenced by the ownership of autonomous vehicles when determining acceptability of the vehicles. Autonomous vehicle affiliation may therefore influence public trust (as has been previously demonstrated for AI algorithms [ZD20])—with private corporations requiring greater public relations effort than public agencies. However, affiliation did not influence blame attribution for a rear shunt of an autonomous vehicle, perhaps because ownership is less important than facts relevant to an accident.

5.3 Implications for Theory

Convoys of autonomous vehicles led to lower acceptance and higher blame than lone autonomous vehicles. This demonstrates that "number of robots" effects previously observed in human-robot interaction apply to autonomous vehicles as well.

People perceived organizations affiliated with AVs as more blameworthy in accidents involving an AV convoy versus a lone AV—even in a rear shunt accident where the AV gets shunted, which is usually considered the fault of the following rather than leading vehicle. This extends past work that finds autonomous vehicles lead people to assign greater responsibility to their owning organizations for accidents involving another party even when the other party is at fault (e.g., [LZC+16]). A possible explanation is that a greater number of autonomous vehicles increases system complexity, which increases the difficulty of determining legitimate targets of responsibility for accidents caused by autonomous systems [SdSM21]. People therefore increasingly use speculative moral judgment [Dan16], since traditional means of responsibility ascription are incompatible with complex autonomous systems [Mat04].

These results point to the significance of the fleet ownership model on opinions around AVs—whereas past work on individual AVs primarily considered consumer choices as the rationale for deploying AVs (e.g., whether purchasers would prefer sacrificial AVs [BSR16] or network-connected AVs [MJPC21]), AV fleets highlight deployment rationales beyond AV ownership to include AVs as 'material' objects that have spatial presence and behaviors to contend with on the road. AV convoys and their everyday driving behaviors affect public opinion, which extends existing work on how AVs may alter urban space use [Oke20, SFC21] and calls for framing AV survey research around scenarios which are the most salient to other road users and most likely to take place on public roads first—such as spatial conflicts between autonomous and non-autonomous vehicles—since negative sentiment towards fleet-owned AVs might change opinions people have towards driving in the presence of AVs.

5.4 Limitations and Future Work

This work relied on an online poll to assess acceptance and blame attribution in public use of autonomous vehicles. Some of the variables explored here may be more salient in a real world study. For example, past work on the influence of multiple versus single robots or agents has typically been done in person (although some work has used images or visuals). Similarly, autonomous vehicle purpose may have a greater effect on participants who experience driving behind such a vehicle, since they would be an active party in the traffic scenario rather than evaluating the scenario online and in the role of a neutral citizen.

This work looked at how AV policy factors influence the acceptance of AVs and the responsibility allocated to autonomous vehicles versus human drivers in rear shunt collisions. However, we did not explore potential reasons or models for why this may be the case. Research suggests that robot groups may influence the perception of threat or authoritativeness of the robots [FSS+17] and that authoritativeness may in turn influence people's acceptance of robots [LJN15]. Similarly, research in cognitive psychology suggests that judgments of robot responsibility may be influenced by the robot's perceived capacity for intentional actions [BWAG19]. In particular, studies have shown that humans make judgments about and assign responsibility for consequential decisions based on their perception of "agency" and "patiency" in moral dilemmas [GYW12]. This suggests that flipping a given vehicle's role from patient (e.g., transporting people/goods) to agent (e.g., regulating traffic) might alter how bystanders perceive and evaluate its agency, and in turn its role and responsibility in accident situations. Yet another influencing factor may be trust, since opinions about different affiliations may be related to user trust [ZD20]. However, the current survey did not consider any potentially mediating factors, such as perceived authority, agency or trust, which could help explain why policy factors in AV use on public roads affect public opinion. More advanced causal modeling is therefore left as future work.

6 Conclusion

Some of the first large-scale deployment of autonomous vehicles are likely to be of fleet-owned vehicles, which can be deployed in multiples and behave in a coordinated fashion. To anticipate practical issues of public opinion which are likely to occur in response to these autonomous vehicles, we have conducted a survey study examining the effects of convoys, government or corporate ownership, and vehicle purpose on the acceptance and responsibility attribution in a rear-shunt scenario. We found that people found autonomous vehicle convoys to be less acceptable than lone autonomous vehicles, and to have greater responsibility for accidents in which a normal vehicle driver rear-shunted an autonomous vehicle. Public transit AVs were rated to be more acceptable than private commercial AVs, and AVs performing traffic regulation were blamed more than AVs used for transportation purposes. This study indicates that the number, ownership and use scenario of autonomous vehicles are likely to have strong impact on public opinion during deployment, and suggests that further research looking at scenarios and use cases around fleet, convoy, and platoon scenarios for other road users will be important to predict and inform the public response to autonomy.

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