You Cooperate, I Reciprocate: Well-Being and Trust in Automated Vehicles

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***Abstract*— Cooperative automated vehicles (AVs) bring the potential for better safety, efficiency, and energy-savings on the individual and system level. Yet, these benefits can only be achieved if people cooperate. In this study, we explored the effects of cooperative and reciprocal AVs on people's well-being, trust, and cooperation. We conducted a mixed-design study ($n = 304$), where participants experienced four types of social interactions as between-subject conditions: 1) all altruistic interaction; 2) all selfish interaction; 3) altruistic other vehicle, selfish ego AV; 4) selfish other vehicle, altruistic ego AV. We found people's well-being was highest when other vehicle is selfish and ego AV is altruistic; whereas people's trust was the highest when people experienced all altruistic interactions. Results suggested a design balance when evaluating people's attitudes towards AVs: altruistic AVs can promote people's trust, whereas when evaluating people's well-being, the presence of selfish AVs may be beneficial. Future studies could model the balance between the user optimal and system optimal control policies.**

I. Introduction

Connected Autonomous Vehicles (CAVs) present a significant advancement in the realm of highly automated vehicles (AVs) by enabling seamless communication with other vehicles (V2V) and infrastructure (V2I), thereby harnessing the collective capabilities of AVs and their surroundings [1]. The potential benefits of CAVs are substantial, promising improved safety, energy efficiency, and driving comfort [2]. However, a pertinent challenge arises due to the presence of diverse AV companies, each employing distinct algorithms with varying principles and values. This can lead to a classical social dilemma known as the "tragedy of the commons," wherein individually rational behaviors of AVs may lead to collectively irrational outcomes, such as increased congestion, accidents, and energy consumption [3], [4]. To mitigate these challenges requires effective cooperation between humans and AVs for cooperation at a societal level [3]. The core idea is to facilitate better cooperative behavior between humans and AVs to achieve positive system-level outcomes.

The study makes two contributions. First, different from the prior studies in driver-vehicle cooperation directed toward the interaction between the driver and vehicle, we focus on the perspective of designing cooperative AVs as social actors on the public road [5]. Specifically, we investigated the interplay between the inter- and intra-vehicle social interactions by focusing on the cooperation between ego AV and other vehicles. Second, to capture the social interaction effects on user attitudes, we used *trust* to capture the interrelationship of the users with their own AVs, and adapted *well-being* and *cooperation* to the context of mobility to capture the intra-relationships between drivers. Our results provided insights for harmonizing human-AV interactions and guiding AV algorithms policy.

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II. Background

A. Driver-Vehicle Cooperation

Cooperative and connected intelligent transport system is an active area of research, where AVs can be connected to conduct cooperative decision-making to enhance traffic safety (e.g., avoid collision avoidance), efficiency (e.g., improve traffic flow), and reduce energy consumption (e.g. fuel and CO_2 reduction). These benefits can only be achieved if the tension between *user optimal* and *system optimal* can be resolved. Balancing individual goals with shared goals has been identified as a core issue for future transportation. One way to resolve this dilemma is driver-vehicle cooperation. Cooperation is defined as reconciling myriad competing goals between individual and collective benefits in a joint task to achieve collective system optimal over long-run [4], [6]. In most cooperative situations, some individuals may be worse off in the short term. However, in successful cooperation, the system joint payoffs should leave people collectively better-off than the individual optimal policy.

Cooperation is a multi-layer construct that involves both inter- and intra-driver-vehicle cooperation. Inter-driver-vehicle cooperation focuses on task allocation and shared control between drivers and their AV [7]. Intra-driver-vehicle cooperation focuses on road traffic conflict and interaction between multiple on-road users. Interactions and coordination between humans and other on-road users (e.g., AVs, manually-driven cars, pedestrians, and other service bots) form a hybrid society, with many opportunities for cooperation [8]. Cooperative behaviors occur at multiple levels from a cognitive perspective, including strategic level (e.g., route and mode choices), tactical level (e.g., open gaps for lane-changing vehicles), and operational level (e.g., motion control and trajectory planning) [9]. Prior research has shown on the strategic level when providing information about the aims of traffic management in combination with recommendations, people shifted their route choices for the common good [10]. On the tactical level, Zimmermann and colleagues found that when viewing lane change as a cooperative social dilemma, gamification of social status can motivate cooperation [11]. For the operational level, motion planning and trajectory control are often conducted to execute the maneuver generated from the tactical level [9].

Given the complex multi-layer and multi-level construct of cooperation, we know little about the interplay between inter- and intra-driver-vehicle cooperation. The cooperative interactions depend on various on-road agents to coordinate their actions. Prior studies have shown that compared to using hard policies (e.g., infrastructure, costs, and rationing) to promote cooperation, soft policies that rely on information, feedback, social pressure, and persuasion can be more effective in inducing pro-social choices [4], [11], [12]. This suggests that social interactions, defined as a dynamic sequence of interdependent actions and reactions between two or more agents should be considered [13]. In the present study, we investigated the effect of other drivers' cooperative strategies on people's experiences and attitudes.

B. Reciprocity

Previous literature has shown that *reciprocity* is an important determinant of successful cooperation [14], [15]. Compared to direct reciprocity ("I help you and you help me") which requires two agents to interact, indirect reciprocity does not require the two same agents to encounter again, and is based a shared moral system and individual reputation [12]. It assumes that community members routinely observe and assess each other and that they use this information to decide who is good or bad, and who deserves cooperation [16]. There are types of indirect reciprocity: downstream reciprocity and upstream reciprocity [17]. Downstream reciprocity builds on reputation. For example, if individual A has helped B and therefore A has a good reputation and is more likely to receive help from another individual C. Upstream reciprocity builds on recent positive experiences. For example, individual B, who has just received help from A, goes on to help C. Social status information using downstream reciprocity can motivate cooperation [11]. However, how upstream reciprocity affects people's experiences and cooperation is not explored sufficiently in transportation. In this study, we investigated the relationships between upstream reciprocity and its effect on people's experience and cooperation. Specifically, we designed people's automated vehicles' reciprocal behaviors based on the behaviors they received from other on-road users.

C. Trust, Well-being, and Cooperation

In the present study, we used *trust* to capture the inter-relationship with their own AVs, and adapted *well-being* and *cooperation* to capture the intra-relationship with other vehicles. Trust is defined as "the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability" [18] and has been identified as a critical factor facilitating cooperation with other [6]. The present study measures drivers' perception of cooperation to determine the influences of social interactions and people's willingness to cooperate and use the system. The theory of interdependence proposed by Woide and colleagues linked driver-vehicle cooperation through five dimensions: conflict, power, mutual dependence, information certainty, and future interdependence [19]. Another construct explored in this study is how being socially engaged and cooperating can influence the sense of being connected and well-being [20]. Well-being is an individually judged, yet socially experienced state of happiness, freedom, safety, and capacity shaped by social and cultural interactions [21]. There are two frameworks for capturing well-being: (1) subjective well-being (SWB) and (2) psychological well-being (PWB) [22]. The SWB describes the happiness, levels of life satisfaction, and affect [23]. PWB focuses on the importance of life purpose and personal growth, which encompasses six distinct dimensions: autonomy, environmental mastery, personal growth, positive relations with others, purpose in life, and self-acceptance [24]. Since social interactions and cooperation mainly concern the relationships with others and cooperative efforts are the strongest correlates of well-being [25], [26], we evaluated one sub-dimension of PWB, *positive relations with others*. The *positive relations with others* dimension focuses on people's experience of affectionate, trusting, empathetic relationships and an understanding of reciprocity, which has been shown as a significant mediator of mobility [26].

Our research question for the present study is to understand how social interaction, including others' cooperative behaviors and individual responding reciprocity, influence people's trust, well-being, and cooperation in mobility.

III. Method

A. Participants

A total of 304 participants from 20 to 72 years old (M=40.5, SD=11.2) (145 males, 158 females, 1 preferred not to answer) were recruited via Amazon Mechanical Turk. All participants were screened for the following criteria: they must live in the United States (to ensure similar traffic rules) with a valid driver's license, have completed more than 1000 tasks with at least a 98% approval rate on Amazon Mechanical Turk, and have completed all the study tasks. To further validate our data quality, we excluded data from seven non-attentive participants whose item responses are always the same (e.g. choose 1 for all responses). All participants received $2.5 monetary compensation for 30-minutes of participation.

B. Cooperative Events

In this study, we defined *cooperative events* as: two road users who need to coordinate their behaviors interdependently to solve a space-sharing conflict. The space-sharing conflict is defined as "an observable situation from which it can be reasonably inferred that two or more road users are intending to occupy the same region of space at the same time in the near future." [27]. For example, lane change is a frequent cooperative event between multiple road users. We identified two roles in cooperative events: *contributor (C)* and *receiver (R)*. Contributors are usually the agent with more power to determine the situation and payoffs by responding to the requests by the receiver. Receivers, those

TABLE I
DETAILS FOR 6 COOPERATIVE EVENTS WITH 2 LEVELS OF COOPERATIVE BEHAVIORS FOR BOTH CONTRIBUTOR AND RECEIVER.

	Events	Cooperation Level	Contributor (C)	Receiver (R)
1	Straight (C) & oncoming left turn (R) with traffic at stop	Altruistic	Wait and allow R to make the left turn.	Turn left before C going straight.
	sign at almost the same time	Selfish	Stop briefly and directly go.	Turn left after C with increased traffic
2	Straight (C) with heavy traffic	Altruistic	Wait and let R turn left first.	Turn left before R going straight.
	& turn left (R) at yield sign	Selfish	Directly go straight without yielding.	Turn left after C with increased traffic.
3	Right (C) and left turn (R)	Altruistic	Wait until the R finish the turn	R makes right turn first
	conflict with traffic	Selfish	Directly make the turn	C makes left turn first
4	Turn left (C) and go straight	Altruistic	Wait until R go straight.	R goes after C.
	(R) in the roundabout	Selfish	Directly makes left turn.	R goes straight before C.
5	Go straight (C) and lane change (R) with traffic due to	Altruistic	Brake and open gaps for R lane change.	Successfully change lane.
	construction	Selfish	Directly go.	Stop and wait for next gap.
6	Go straight (C) and parked car	Altruistic	Wait for parked car to pull out.	R pulls out successfully.
	pulling out (R)	Selfish	Directly go.	Wait for next open gaps.

*Note only contributor would perform altruistic or selfish behaviors.

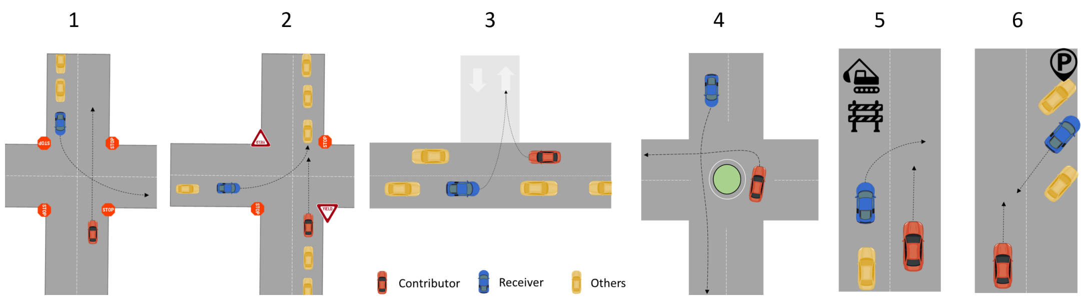

Fig. 1. Six cooperative events with the red car being the contributor, the blue car being the receiver, and the yellow car being other traffic. For details, see Table I. Note that both the ego AV and the other vehicle can be either the contributor or receiver in each of the scenarios.

TABLE II
A 2 (COOPERATION) × 2 (RECIPROCITY) × 4 (RECEIVER EXPOSURE/ROLE ORDERING) MIXED-DESIGN STUDY.

Within-subject variable	Between-subject variable			Interaction Effect
Receiver exposure	Role ordering	Other's Cooperation	Ego Reciprocity	Social Interaction
3 receivers (RRR)	Initial receiver exposure $(3_R2_R1_R0_R)$	Altruistic	Reciprocal	All altruistic interaction
2 receivers, 1 contributor (RRC)	Receiver-contributor $(2_R0_R3_R1_R)$		Non-reciprocal	Altruistic other vehicle, selfish ego AV
1 receiver, 2 contributors (RCC)	Contributor-receiver $(1_R3_R0_R2_R)$	Selfish	Reciprocal	All selfish interaction
3 contributors (CCC)	Initial contributor exposure$(0_R1_R2_R3_R)$		Non-reciprocal	Selfish other vehicle, altruistic ego AV

*Note interaction effect is included for the explicit group labelling.

with less power, depend on the contributor's responses to their requests. For example, in a lane-change scenario, the mainline driver, who can choose to "give way" or "do not give way" is the contributor in the cooperative event, whereas the on-ramp driver is the receiver, who can either "merge" or "do not merge".

We identified three criteria for designing and identifying the cooperative events: (1) at least two road users are interacting, (2) same type of interacting agents but with different roles, and (3) ambiguous space-sharing conflict with respect to correct behavior. The cooperative events should be situated in an ambiguous environment where traffic rules do not clearly solve the conflict, however, either cooperative or competitive behaviors may lead to suitable outcomes. For example, compared to a signalized intersection, an unprotected stop-sign intersection can incur more cooperative events. We control the arriving time and traffic to manipulate the cooperation levels.

Based on the three criteria described above, we designed six events in urban settings (see Figure 1 and Table I). Each cooperative event consists of one contributor (red car) and one receiver (blue car). Contributor would behave either altruistically or competitively. Following the best practices of the attention and manipulation check [28], pilot testing ($n = 4$) with post-study interviews helped validate the study design. For the events 1, 2, 3 and 4 (see Figure 1), both agents arrive at the intersection at roughly the same time to ensure ambiguity in next decision. For selfish behaviors, more traffic following the receiver was designed to create an imbalanced situation. With the similar arrival time and more traffic, if the contributor waited for longer time, it would be characterized as altruistic behavior, otherwise it would be perceived as competitive behaviors.

C. Experimental Design

A $2(OtherCooperation) \times 2(EgoReciprocity) \times 4(ReceiverExposure)$ mixed-design study was used to analyze the effects of various social interactions on people's cooperation, trust, and well-being using online surveys (see Table II). For between-subject variables, we designed two levels of other driver's cooperative strategies (i.e., altruistic and competitive) and two levels of ego reciprocity (i.e., reciprocal and non-reciprocal). For within-subject variable, four levels of receiver exposure consisted of three drives (i.e., initial receiver exposure, initial contributor exposure, receiver-contributor, contributor-receiver). Participants were randomly assigned to one of the four social interaction conditions (i.e., all altruistic interaction; altruistic other vehicle, selfish ego AV; all selfish interaction, selfish other vehicle, altruistic ego AV). In total, each participant completed 12 cooperative events. The order of within-subject variable and cooperative events was counter-balanced with a balanced Latin-Square design.

D. Independent Variables

1) Other Cooperation: We defined two levels of cooperative strategies of automated vehicles (i.e., altruistic and selfish) adopting the social value orientation (SVO) theory [29], [30]. which indicates a person's preference of how to allocate rewards between themselves and another person. Note that these strategies only apply to the contributor in the cooperative events because receivers are usually passive and dependent on the contributor's behavioral outcomes during the interaction. As receivers, participants receive contributors' altruistic or competitive behaviors. For details, see in Table I.

2) Ego Reciprocity: We defined two levels of reciprocity (i.e. reciprocal and non-reciprocal). Reciprocity is operationalized by the mutual actions by both contributor and receiver. To simulate indirect upstream reciprocity, participants would always be receiver, followed by contributor to directly compare behavioral response when given the option while receiving/exhibiting altruistic or competitive behaviors.

3) Receiver exposure and role ordering: We defined *receiver exposure* as how many times that driver interacts with other on-road users as a receiver for each three drives. Each condition has three drives in total. For four levels of exposure, it describes: (1) RRR, being a receiver for three times; (2) RRC, two times receiver and one time contributor; (3) RCC, one time receiver and two time contributor; (4) CCC, being a contributor three times. The order is always receiver followed by contributor to measure cooperative behaviors influenced by indirect reciprocity.

The counterbalanced design of the within-subject variable, *receiver exposure*, generated four levels of *role ordering* as a between-subject variable, where people experience different initial roles throughout 12 drives. For easy annotation, we summarize the number of times participants experienced receiver (as the subscript) and noted as: (1) *initial receiver exposure* for being receivers three times for the initial exposure following the order of RRR, RCC, RCC, CCC, i.e., $3_R 2_R 1_R 0_R$ (2) *receiver-contributor* for being receivers then contributor: $2_R 0_R 3_R 1_R$, which is RRC, CCC, RRR, RCC; (3) *contributor-receiver* for being contributor then receiver: $0_R 1_R 2_R 3_R$, which is CCC, RCC, RRC, RRR; (4) *initial contributor exposure* for being contributor 3 times for the initial exposure :$0_R 1_R 2_R 3_R$, which is CCC, RCC, RRC, RRR.

E. Dependent Variables

We measured cooperation, trust, and well-being using the full survey after each receiver exposure condition (i.e. after three drives). Details see Table III.

1) Well-being: Well-being was measured by a modified version of psychological well-being [32]. We focused on "positive relations with others" in mobility and included statements relevant to this dimension. The statements of the survey were modified to fit the context of transportation and mobility domains.

2) Trust: Trust was measured by subjective self-report surveys . Participants completed the 12-item 7-point Likert scale survey by Jian et al. [31]. Participants were asked to rate their trust in their AV: "Based on most recent situation that your automated vehicle interacting with other on road users, how would you rate your trust in your automated vehicle?".

3) Cooperation: The Human-Machine-Interaction Interdependence Questionnaire (HMII) [19] was adapted, which contains seven dimensions (e.g., conflict, future interdependence system to human, etc.). Since the original scale captures the inter-human-driver cooperation, we selected and adapted three sub-dimensions (i.e. conflict, mutual dependence, and power) that are relevant to the intra-driver-human cooperation.

To assess individual differences in cooperation and prosocial behaviors, we used the Honesty-Humility dimension as proposed in the HEXACO model of personality on a 7-point Likert scale [33] (60-item version). Honesty-Humility represents the "tendency to cooperate with others even when one might exploit them without suffering retaliation"' [34].

TABLE III
DEPENDENT VARIABLES AND SURVEY ITEMS ADOPTED.

Construct	#	Dimension	Measure
Well-being	Q1	General	Maintaining cooperation with other drivers has been difficult and frustrating for me.
	Q2	Contributor	Other drivers would describe me as a giving and altruistic person, willing to yield, share space, and ensure everyone around me feels safe.
	Q3	Receiver	I have not experienced a lot of cooperative behaviors from other drivers, while driving.
Cooperation	Q1	Conflict	Our preferred outcomes in this situation are in conflict.
	Q2	Mutual dependence	We need each other to achieve our best outcome in this situation.
	Q3	Power	Who felt they had the most influence on what happened in the past situations?
Trust			12-item survey by Jian, Bisantz, and Drury [31].

Prior studies have shown that the Honesty-Humility trait can predict prosocial behaviors in similar settings [16].

Fig. 2. Web-based driving environment.

F. Stimuli

The study was conducted online using video recordings of a medium-fidelity driving simulator rendered using Unreal Engine 4.24 [35] with AirSim [36]. The videos were recorded using two cameras: one front-facing camera with rear and left mirrors and one third-person camera to show the vehicle's surrounding situation. The vehicle's speed and navigation information, and third-person view were overlaid at the bottom of the screen (see Figure 2).

G. Procedure

Upon finishing the consent form, pre-experiment survey, and initial trust, participants completed a five-minute training including speed, navigation, interactive vehicle and intent to accelerate and decelerate. A post-survey was shown. Participants were informed of their automated vehicle (AV) would interact with other vehicles. They were instructed to pay attention to the interactions and then complete the surveys. After each of three cooperative events, they would answer surveys on well-being, trust, and cooperation. In total, they would complete surveys for each dependent variable for four times. Once they completed the experiment, participants provided their demographic information and were compensated. The study took approximately 30 minutes.

IV. RESULTS

We conducted linear mixed models (LMMs) using R software (version 4.2.1) and *lme4* to analyze the relationship between the independent variables (other cooperation, ego reciprocity, receiver exposure) and dependent variable $y \in \{\text{well-being}, \text{trust}, \text{cooperation}\}$ [37], [38]. The sample size is balanced across four between-subject variables. Visual inspection of residual plots did not reveal any obvious deviations from homoscedasticity or normality. No extreme outliers were detected. The linear mixed-effect model allows both fixed and random effects, which are particularly useful when data is non-independent. Subjects and role ordering were treated as random effects. Prosocial propensity was included as moderator. For all dependent variables, multi-item surveys after each exposure condition were considered. The best fit model using the backward elimination procedure with the likelihood ratio test at $\alpha = 0.05$ with the smallest Akaike's Information Criteria (AIC) scores is:

$$\begin{aligned} y \sim\ & OtherCooperation * EgoReciprocity \\ & + ReceiverExposure \\ & + OtherCooperation * ProsocialPropensity \\ & + EgoReciprocity * ProsocialPropensity \\ & + (1|Subject) + (1|RoleOrdering) + \epsilon \end{aligned} \tag{1}$$

The Likelihood ratio tests rejected the null model for all three dependent variables: well-being ($\chi^2(1)$ = 3.94, p = 0.04), trust ($\chi^2(1)$ = 3.93, p = 0.04), and cooperation ($\chi^2(1)$ = 6.21, p = 0.04). Results for the LMMs are reported as significant for $\alpha < 0.05$ in the Table IV.

A. Well-being

As shown in Table IV, the main effect of *Other Cooperate* was significant (F(1,295) = 6.19, p = 0.01). We found that when people interact with other selfish drivers, their well-being actually increased by around 1.17 ± 0.41 points on a 7-point Likert scale. Tukey's HSD tests suggests that difference of well-being was significantly different between selfish other vehicle (M = 4.35) and altruistic other vehicle (M = 4.22) with negative small effect (difference = -0.13, 95% CI [-0.24, -0.02], p = 0.017).

Interaction effect between other's cooperation and ego's reciprocity was significant (F(1, 295) = 3.91, p = 0.04). Post-hoc Tukey test showed that well-being in *selfish other vehicle, altruistic ego AV* (M = 4.47) social interaction was significantly higher than *altruistic other vehicle, selfish ego AV* condition (M = 4.16) (difference = 0.31, 95% CI [0.11, 0.50], $p < 0.001$), *all selfish interactions* condition (M = 4.21) (difference = 0.26, 95% CI [0.06, 0.46], p = 0.01), *all altruistic interactions* (M = 4.27) (difference = 0.20, 95% CI [0.01, 0.40], p = 0.04). Other comparisons were non-significant. Prosocial propensity as a moderator was found to be significant (F(1, 295) = 106.8, t = 0.01). More

TABLE IV

Linear mixed model outputs on well-being, trust, and cooperation.

Fixed Effects	Well-being				Trust				Cooperation			
	Est.	*SE*	*t*	*p*	Est.	*SE*	*t*	*p*	Est.	*SE*	*t*	*p*
(Intercept)	1.52	0.37	4.06	**0.01**	2.80	0.41	6.80	**0.01**	3.94	0.30	13.02	**0.01**
Other Cooperate (Selfish)	1.17	0.41	2.82	**0.01**	0.95	0.46	2.07	**0.04**	0.71	0.34	2.09	**0.04**
Ego Reciprocate (Reciprocate)	0.48	0.41	1.19	0.24	0.78	0.45	1.74	0.08	0.20	0.33	0.59	0.55
Receiver Exposure	0.04	0.05	0.86	0.39	0.13	0.04	3.38	**0.01**	0.01	0.01	0.42	0.67
Prosocial Propensity	0.67	0.09	7.31	**0.01**	0.41	0.10	4.06	**0.01**	0.17	0.07	2.34	**0.02**
Other (Selfish) × Ego (Reciprocate)	-0.32	0.16	-1.98	**0.04**	-0.35	0.18	-1.99	**0.04**	0.06	0.13	0.50	0.06
Other (Selfish) × Prosocial	-0.24	0.10	-2.40	**0.02**	-0.21	0.11	-1.90	0.06	-0.18	0.08	-2.27	**0.02**
Ego (Reciprocate) × Prosocial	-0.10	0.10	-0.98	0.33	-0.14	0.11	-1.25	0.21	-0.07	0.08	-0.90	0.37

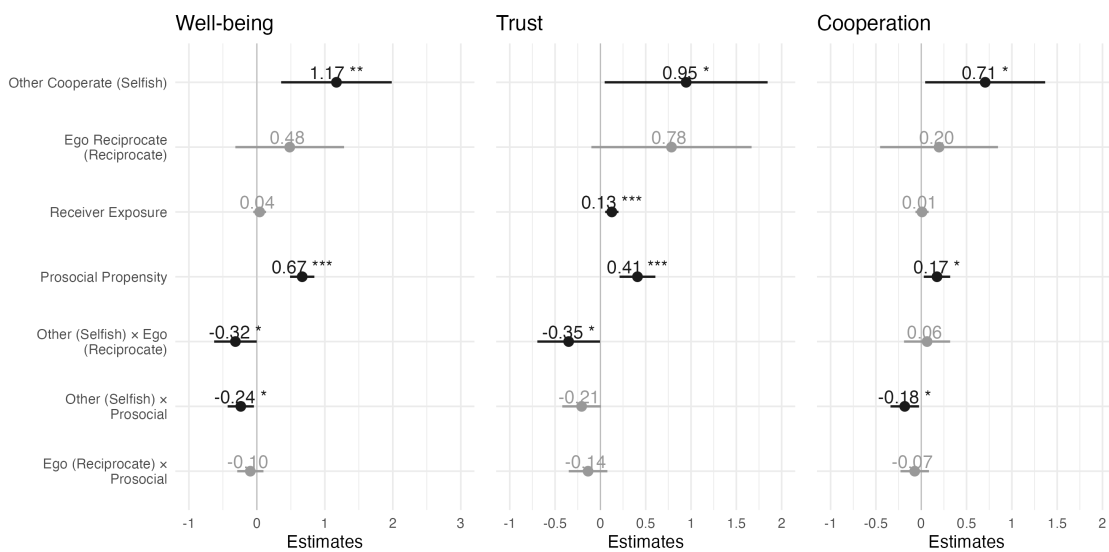

Fig. 3. Effects of cooperation, reciprocity, exposure, and prosocial propensity on well-being, trust, and cooperation.

prosocial individuals tend to show higher trust. The interaction between prosocial propensity and other's cooperative behavior was also significant (F(1, 295) = 5.75, t = 0.01). Results indicate that people's well-being is the highest in the *selfish other vehicle, altruistic ego AV* condition and people's prosocial propensity affects how people perceive others' behaviors.

B. Trust

The main effect of *Other Cooperate* was significant (F(1,295) = 2.94, t = 0.04). Similar to well-being, when people interacted with other selfish drivers, their trust increased by 0.95 $\pm$ 0.46 points out of a 7-point Likert scale. Receiver exposure also showed a significant effect (F(1,909) = 7.59, t = 0.01). With more receiver exposures, the more people gain trust in their AVs. The interaction effect between other's behaviors and ego's reciprocity was significant (F(1,295) = 3.95, t = 0.04). Post-hoc Tukey test showed that trust in *all altruistic interactions* (M = 4.68) was significantly higher than *altruistic other vehicle, selfish ego AV* condition (M = 4.44) (difference = 0.24, 95% CI [0.06, 0.43], $p < 0.001$) and *all selfish interactions* condition (M = 4.45) (difference = 0.23, 95% CI [0.04, 0.41], p = 0.01), while other comparisons were non-significant. Additionally, individual differences on prosocial propensity as a moderator was significant (F(1,295) = 19.77, t = 0.01). Different from well-being rating, where people's highest rating reflected in *selfish other vehicle, altruistic ego AV*, people's highest trust rating is experienced in the *all altruistic interactions* condition.

C. Cooperation

The main effect of *Other Cooperate* was significant (F(1, 295) = 4.96, t = 0.02). When people interact with other selfish drivers, their cooperation actually increased by 0.71 $\pm$ 0.34 points out of a 7-point Likert scale. Individual differences on prosocial propensity as a moderator was significant (F(1, 295) = 1.42, t = 0.02). The interaction between prosocial propensity and other behaviors was significant (F(1, 295) = 5.15, t = 0.02).

V. Discussion

Findings suggest that others' cooperative behaviors significantly affect people's well-being, trust, and cooperation. Although reciprocity was not significant, the interaction between ego car's reciprocity and others' behavior significantly influenced people's well-being and trust. These effects were moderated by prosocial propensity.

A. *Comparative Altruistic Behaviors Promote People's Well-being*

We found that when interacting with selfish drivers, people's well-being was higher. While this contradicts prevailing wisdom that people's well-being is higher when receiving altruistic behaviors, it suggests that well-being may be relative to the others' action in traffic. It means that contrast between ego-behavior compared to other agent, may promote greater well-being. Significant interaction between other's behaviors and ego's reciprocity also explain the result. We noted that *"selfish other vehicle, altruistic ego AV"*, was ranked as highest for well-being, which was even higher than *"all altruistic"* social interactions.

One explanation is the concept of 'helper's high', where people show positive emotions and intrinsic satisfaction following selfless service to others. This phenomenon is often associated with hedonic motivations for engaging in donations and charitable activities. Another explanation of comparative well-being is via the rational utility-based model [39]. People can consider ego AVs providing altruistic behaviors as beneficial and receiving others' altruistic behaviors as costly [40]. Receiving social support in social relationships has also been shown to be linked to decreased positive mood, inferiority, relationship inequality, and feelings of dependence [41]. To optimize people's utilities, their AVs should be altruistic while interacting with other selfish on-road users. Future studies should further analyze optimal proportion of selfish on-road users that could ensure people's well-being while achieving system-optimal behavior.

B. *All Altruistic Interactions Promote People's Trust in AVs*

Trust influenced social interactions between ego's reciprocity and others' cooperation. Our results verified hypotheses in prior work that altruistic AVs can potentially earn people's trust due to a smaller driver-perceived safety clearance [42]. In contrast with well-being scores in *"altruistic other vehicle, selfish ego AV"* condition, people showed high trust in *"all altruistic interactions"*. This can be justified since trust is partially analytical based on an assessment of the perceived risk in the environment [18], and all altruistic interactions are operationalized as more waiting time and promote trust by perceived conservative approach. Additionally, trust also contains the analogical processes, which focus on the relationships with others and reputation systems in fostering cooperative behaviors [18]. Thus, the reciprocal altruistic relationship promoting trust supports the prior work on the analogical and analytical processes of trust.

C. *Prosocial Propensity Moderates Intra-driver-vehicle Cooperation and Well-being*

Individual differences in Honesty-Humility, measured by the HEXACO scale, defined as prosocial propensity, strongly moderates relationships between others' behaviors and perceived well-being and cooperation: people who are more honest and humble are more sensitive to the cooperation-related behavior of others. Results aligned with the prior study that prosocial propensity consistently predicted cooperation and showed positive relations with well-being [16], [43]. Additionally, it is notable that high well-being and trust are in conflict, where trust is higher in altruistic interactions and well-being is higher when the ego vehicle is altruistic and others are selfish. We speculate that Trust captured people's attitude toward their own car; well-being, measuring positive relations with others may capture inter-driver-vehicle relationship. Future studies could focus on modeling the driver responses to the proportion of between altruistic and selfish vehicles.

VI. Limitation and Future Work

We acknowledge three limitations. First, because our study is an online study with pre-recorded videos; people cannot control or takeover automated vehicles' behaviors. This can potentially lead to a lost sense of control in AVs, which are shown associated with well-being and trust [44], [45]. Further verification of this relationship requires in-person studies. Second, we only captured one dimension of well-being, positive relationships with others, out of six dimensions [24]. Future research should explore cooperative AVs' impact on other well-being dimensions for a comprehensive analysis. Third, the representation of altruistic and selfish AVs in our study may have been abstract for participants to comprehend. Open-ended survey response questions and transparency in scenarios could enhance comprehension.

VII. Conclusion

In this study, we examined the impact of other automated vehicles' cooperative strategies and ego vehicle's reciprocity on people's well-being, trust, and cooperation. Our findings showed that others AVs' cooperative behaviors strongly affected people's well-being, trust, and cooperation. Notably, people's well-being was highest when their AVs exhibited altruistic behaviors while observing others engaging in selfish behaviors, indicating the positive effect of comparative altruistic behaviors. Additionally, altruistic social interactions, where both ego and other vehicles displayed altruistic behaviors, significantly promoted people's trust in AVs. Furthermore, individual differences in prosocial propensity moderated people's perception of other vehicles' behaviors. These results offer implications for future AVs' algorithms and policy designs: when focusing on trust from an inter-driver-cooperation perspective (e.g., car manufacturer), designing altruistic algorithm can promote people's trust in their own AVs; when considering people's well-being from a societal level (e.g., policy maker), especially when focusing on the relations with other, some selfish AV algorithms presence can promote people's well-being.

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