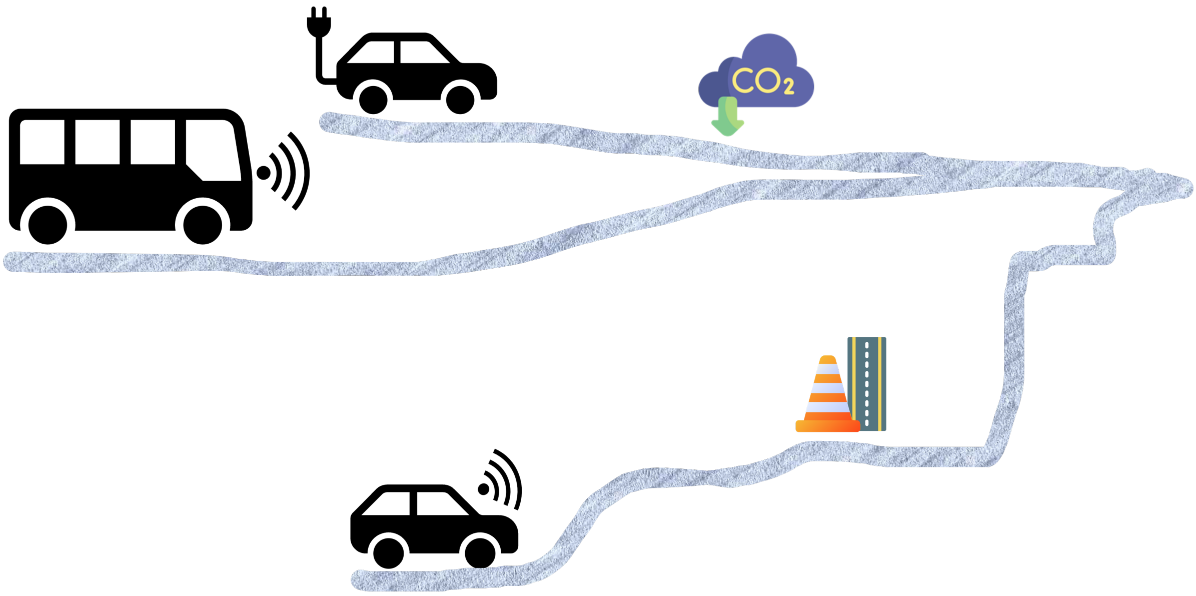

Public perception of the role of electric and automated vehicles in urban transport system transformation

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Abstract

Future urban transport mobility is likely to include more Electric Vehicles (EV) and Automated Vehicles (AV). In this study, we ask "How do citizens perceive that EV and AV would influence urban transport systems?" Our survey data (n = 1172) comprises full answers from citizens living in the five largest Swiss agglomerations and randomly assigned to control and experimental groups. We collected Likert scale assessments of positive or negative interactions between four objectives of urban transport systems (transport infrastructure, road safety, transport affordability, and climate-friendliness) from the perspective of different transport modes (bikes, cars, and public transport). The treatment groups were prompted to answer the questions imagining either living in a world where (1) all gasoline-powered vehicles would have been replaced by EV, or where (2) all vehicles would have become self-driving vehicles (full driving automation). We statistically test for differences between assessments from the control and specific treatment groups in terms of aggregate perceived effects on climate-friendliness and safety objectives. We find that for effects on climate friendliness, citizens perceive i) a high potential for electrification of cars but (ii) do not see much potential improvement in the automation of public transport. In terms of safety effects of automation of car driving, citizens are uncertain.

Keywords

Urban transport; Technology; Electrification; Automation; Survey

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1 Introduction

Cities are adopting technological innovations as potential solutions to improve urban transport efficiency and implement sustainable futures, such as reduced CO_2 emissions and improved accessibility, affordability and safety for all transport system participants. A systematic literature review and scenario analysis by Miskolczi *et al.* (2021) suggested a foreseeable slow shift in development toward self-driving, electric and shared mobility until the 2030s. Hence, future urban mobility is likely to include more electric and self-driving vehicles, which some have argued would have potential benefits for road safety (Shiao, 2023, pp. 39-42) and climate change mitigation (Alarfaj *et al.*, 2020; Obaid *et al.*, 2023).

Recent policy recommendations by some experts concerning battery electric vehicles (EV) and automated vehicles (AV) include providing incentives for individuals and companies to encourage EV and promoting AV for shared mobility and public transport modes, to foster a modal shift away from private car use (Butler *et al.*, 2020). On the other hand, concerns have been raised regarding unintended effects of EV and AV technology for urban sustainability transformations, such as induced travel demands and increased urban land use for transport (Milakis *et al.*, 2017). Specifically regarding automated driving technology, further concerns have been raised regarding the dangers of an overly technology-centred societal view of future urban transport systems (Stilgoe and Mladenović, 2022) and an overly simplistic sustainability assessment of its outcomes (Schippl, 2024).

Whatever the eventual desirability of introducing AV and EV elements in the urban transport system, public policy-making or business-level decision-making is only one side of the coin in determining how AV and EV technology will be adopted. Uptake of EV and AV also depends on a societal shift towards public acceptance of these technologies. Public preferences are closely linked to individual worldviews and perceptions. Some studies stress the role of public perceptions and attitudes towards EV as a major factor concerning its adoption (Pani *et al.*, 2023). Further, perceptions of key aspects of urban mobility vary with different socio-demographic profiles (Burghard and Dütschke, 2019; Akgün-Tanbay *et al.*, 2022). Yet, there is limited research investigating public perceptions of EV and AV about their potential in initiating the transformation of urban transport systems.

We investigate the perceived systemic effects of EV and AV on the urban transport system as potential ways to reduce CO_2 emissions, enhance road safety, and increase financial and physical accessibility of transport using a survey-based experiment. We ask the following research question: "How do citizens perceive that EV and AV would influence urban transport systems?". Specifically, our study investigates perceptions of three main systemic effects:

- The perceived effects of EV on emissions from car use (1)
- The perceived effects of AV on emissions from public transport (2)
- The perceived effects of AV on road safety of car drivers (3)

2 Materials and methods

2.1 Study system

Our data was part of the results from a cross-sectional survey administered in late Summer 2024 to survey panel participants living in Swiss municipalities within the largest agglomerations in the country (i.e., Zurich, Geneva, Basel, Lausanne, and Bern). The boundaries of these agglomerations are from the official statistics in 2022 and include not only the five city centres, but also Swiss municipalities in the principal and secondary cores, as well as in the urban ring of the agglomerations. In total, the surveyed urban and peri-urban population revolves around the largest Swiss city centres and represents almost 40% of the population of Switzerland, with a balanced representation of gender and age (18-79 years old).

2.2 Data

We used an experimental survey design to test the perceived role of EV and AV in instigating change within the system. Specifically, the panel participants answering the survey were randomly assigned to control and experimental groups. We prompted the test groups' respondents to imagine living in a world where (1) all gasoline-powered vehicles would have been replaced by electric vehicles, or where (2) all vehicles would have become self-driving vehicles. This feature was implemented in our survey for a specific group of questions asking the respondents how four key objectives within the urban transport system (road safety, reduced CO_2 emissions, and physical and financial accessibility) impact one another positively or negatively at different transport mode levels (bikes, cars, public transport). Thus, our data (n = 1172) consists of a control group (n = 823) and two experimental test groups on the perceived role of EV and AV (n = 165 and n = 184, respectively).

2.3 Measurements

In total, the survey participants had to provide 36 answers on systemic interactions (3 transport modes $\times$ 4 impacting objectives $\times$ 3 impacted objectives). We provide in the Annex A.1 an excerpt of these array-type questions.

We collected Likert scale assessments of positive or negative interactions between the four objectives of urban transport systems from the perspective of the different transport modes. Figure 1 show how we then transformed the answer options into numerical values ranging from -2 to +2, dismissing the unclear assessments (i.e., "It doesn't make sense" and "I don't know"). After aggregating the numerical values by mean, we compared them in the control and test groups of interest. Therefore, the perceived impact of an objective A on an objective B is defined as an edge that is directed from A to B, with a signed and weighted value equalling the average perception within the control or the test group, and has a potential value ranging from -2 to +2.

This enables us to translate the survey answers into perceived urban (sustainable development) transport systems with objectives as system components influencing one another to different degrees. In the following, we present small networks of four nodes representing the four objectives, which are interconnected through directed, signed, and weighted edges. The size of the nodes is a factor of the weighted indegree of the four system components (i.e., the sum of the total impact incoming a specific outcome objective).

Table 1: Answer options to qualify the different statements on the effects among the objectives, and their transformation as numerical values.

Survey answer	Edge's weight
"Very negative"	-2
"Negative"	-1
"No impact"	0
"Positive"	1
"Very positive"	2
"It doesn't make sense"	NA
"I don't know"	NA

We investigate our three main perceived systemic effects of interest one by one by (a) displaying the perceived interactions between objectives in the urban transport system at car level or public transport level, and (b) testing the variation in the control and test group (EV or AV) for the specific outcome objective we are interested in, that is, reduced CO_2 emissions or road safety.

2.4 Statistical test

To statistically investigate our three main perceived systemic effects of interest, for every survey respondent i, we regressed treatment group status $x_{\mathrm{treatment\_group_i}}$ (thus whether the respondent was assigned to the control, EV or AV test groups) on $y_{\mathrm{outcome\_objective_i}}$, the weighted indegree of the outcome objective of interest for the specific respondent's perception of interactions between objectives within the transport system (i.e., the combined impacts on "reduced emissions" (*clim*) or "road safety" (*saf*)). Specifically, we define simple Bayesian regression model, of the form 1:

$$\begin{aligned} y_{\mathrm{outcome\_objective_i}} &\sim \mathrm{Normal}(\mu_i, \sigma) \\ \mu_i &= \alpha + \beta x_{\mathrm{treatment\_group}_i} \end{aligned} \tag{1}$$

where model parameter α indicates the model intercept, β the coefficient for the effect of the assigned treatment group and σ the standard deviation of the normal (Gaussian) distribution.

We estimated the models in R using the `brms` package (Bürkner, 2017). We used uninformative `brms` default priors for α, β and σ.

3 Preliminary results

3.1 Overview of results

As synthesized in Table 2, we did find a positive association of EV to perceived reduced emissions, and AV to perceived increased road safety. We found a negative association of AV to perceived reduced emissions at the public transport level. In each statistical tests, the test groups had greater variance in respondents' answers, compared to the control group.

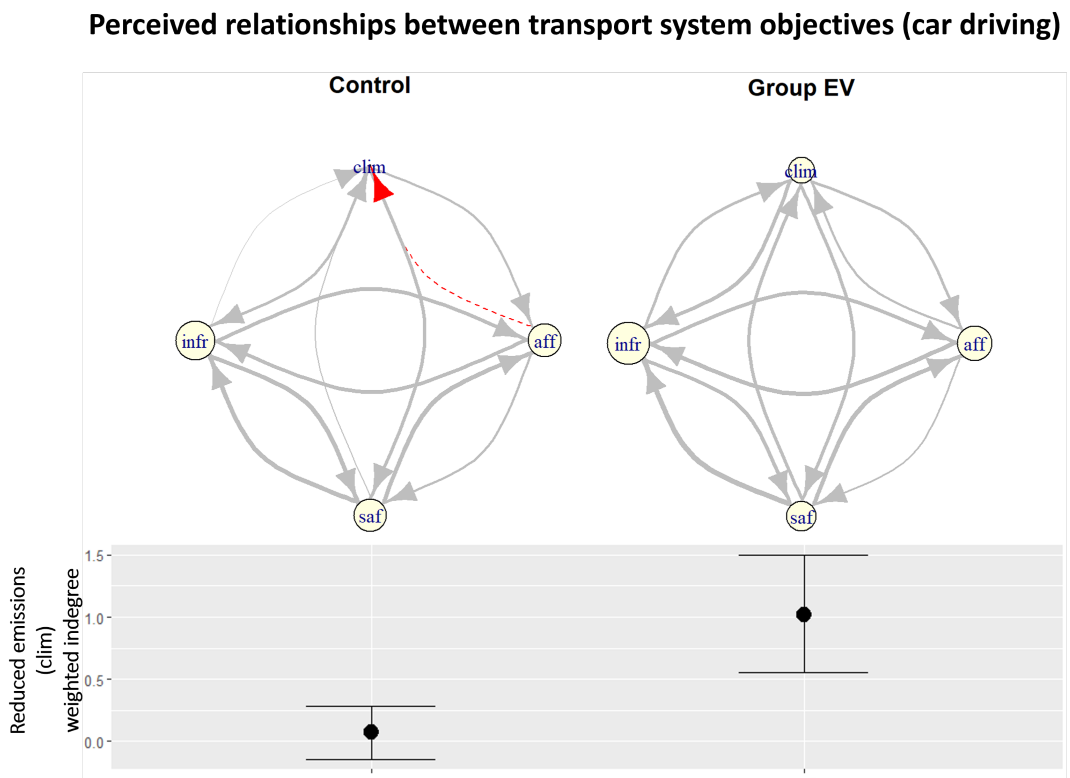
Table 2: Overview of tested differences between control and treatment groups for perceived systemic effects of AV and EV

Tested effect	Perceived role of technology	Transport mode level	Result
(1)	EV $\rightarrow$ reduced emissions (*clim*)	car-driving	Yes
(2)	AV $\rightarrow$ reduced emissions (*clim*)	public transport	No
(3)	AV $\rightarrow$ road safety (*saf*)	car-driving	Yes

3.2 EV for climate change mitigation

Figure 1 shows that the average perception of car-related transport systems varies significantly between the control and test groups. We observe in particular an increased size of the node representing the objective of reduced CO_2 emissions (*clim*), as well as a clear mitigation of the negative influence (dashed lines in red) of affordable (*aff*) car driving on emissions, as well as also a more positive effect (thicker lines) of transport infrastructure (*infr*) and road safety (*saf*) on the climate outcome. The statistical test shows further that the perceived systemic outcome for climate change mitigation (i.e., the sum of the averaged effects of transport infrastructure, road safety and transport affordability on the objective of reduced CO_2 emissions) improved significantly in the EV test group. The average assessments regarding this systemic outcome vary markedly (+0.96) between the control and test groups (see in Annex A.2). Therefore, the test for difference is conclusive of a public perception of the role of EV in altering the urban transport system toward reduced CO_2 emissions.

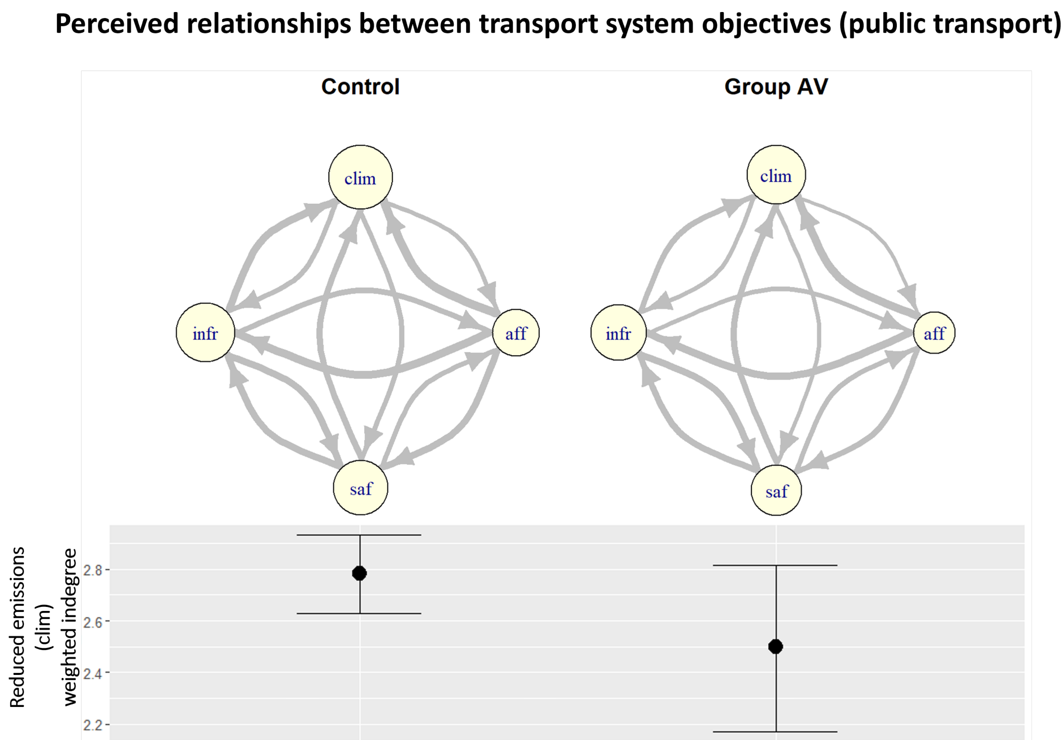
Figure 1: Top panel: Perceived relationships between transport objectives in urban transport system for car mode in control and EV treatment group (group considering full electrification of transport system). Node sizes are weighted indegree and the edge color indicates whenever an average perception is negative (red, dashed line). The thickness of the lines indicates the degree of influence. Bottom panel: Effect of treatment group on perceived climate change outcome for car mode, based on statistical model (posterior predictions). Bars indicate the 95% credible interval.



3.3 Shared use of AV for climate

Figure 2 illustrates, first and foremost, that the average perceived systemic effects of public transport are typically much more positive compared to the effects of cars displayed earlier – especially in terms of impact on climate. When prompted to assess the effect of assessing the impact of AV on climate effects of public transport, we do however not observe a positively perceived influence of AV on the climate outcome, nor on other objectives. On the contrary, the statistical test shows a negative sign, with a parameter value of -0.28, for the effect capturing the difference between the control and AV test group for the value of the climate outcome (see model summary in the Annex A.2). The test for difference therefore is not conclusive. Further, the 95% credible interval reveals a lot of variance in the respondents' answers.

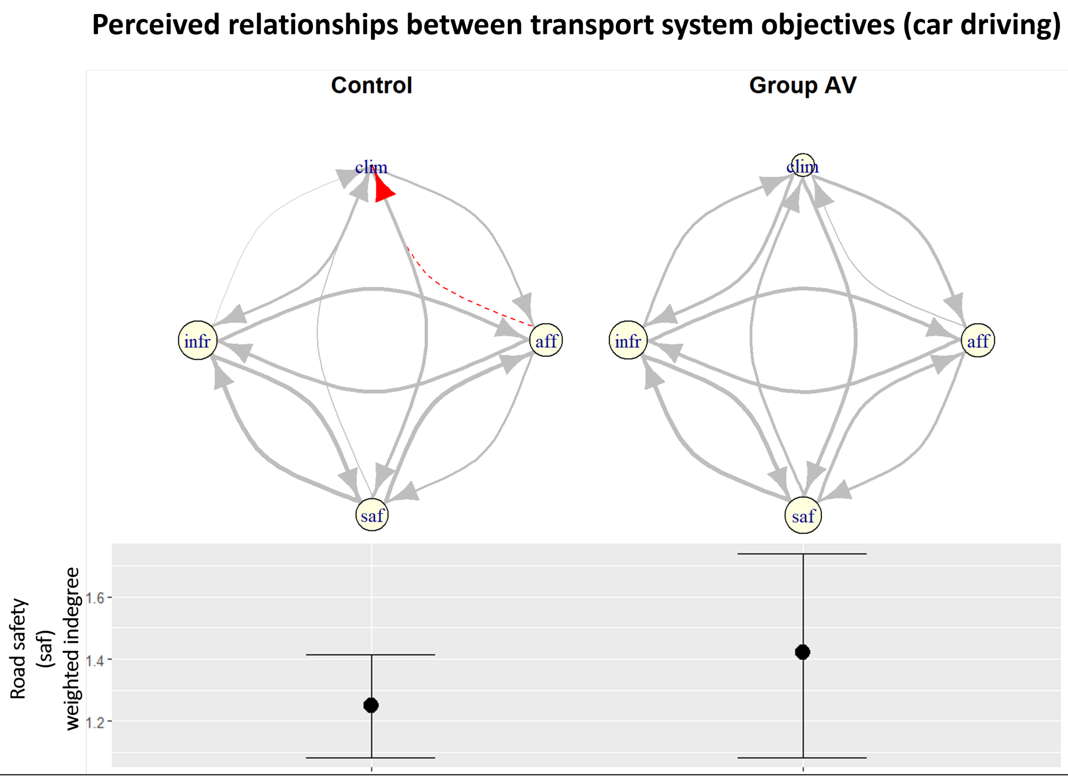
Figure 2: Top panel: Perceived relationships between transport objectives in urban transport system for public transport mode in control and EV treatment group (group considering full electrification of transport system). Node sizes are weighted indegree. The thickness of the lines indicates the degree of influence. Bottom panel: Effect of treatment group on perceived climate change outcome for public transport, based on statistical model (posterior predictions). Bars indicate the 95% credible interval.



3.4 AV for car users' safety

Figure 3 shows a comparable difference in the car-related transport system when comparing the control group with the EV test group (as in Figure 1) or with the AV group. In light of the small networks as well as in the statistical test, we observe a slight positive association (+0.17) of AV to be perceived positively for safer car traffic, although the uncertainty involved in predictions is too high to make a definitive statement in this regard.

Figure 3: Top panel: Perceived relationships between transport objectives in urban transport system for car mode in control and AV treatment group (group considering full automation of transport system). Node sizes are weighted indegree and the edge color indicates whenever an average perception is negative (red, dashed line). The thickness of the lines indicates the degree of influence. Bottom panel: Effect of treatment group on perceived safety outcome for cars, based on statistical model (posterior predictions). Bars indicate the 95% credible interval.



4 Discussion and conclusion

In addition to sufficiency storylines such as avoiding unnecessary travel and shifting travel modes (Arnz and Krumm, 2023), technological solutions to urban transport system transformations are investigated. This paper investigated the public perception of urban transport systems with and without drastic uptake of two key technological innovations, electrification and automation of vehicles.

Provided that the source of electricity is clean, EV are – despite the externalities related to their batteries, manufacturing, and the necessary infrastructure – a concrete solution to effectively reduce CO_2 emissions from the transport sector (Woody *et al.*, 2022; Hoekstra, 2019). While comparing the perceived systemic outcomes for reduced CO_2 emissions makes clear that there is a shared understanding that the system would emit less if cars were all electrified, we observed mostly a lot of disagreement as to the potential benefits of AV.

With the increasing prevalence of information and communication technologies (ICT) in our societies and urban development trends moving toward smart cities, a techno-optimist opportunity to increase shared, as opposed to private, mobility lies in the increasingly high levels of vehicle automation. Yet, such benefits are not perceived as straightforward, as our results show. AV, also typically referred to as connected and automated vehicles, display features such as advanced driver-assistance systems through sensing and control systems (e.g., providing traffic-related information, backing tired or distracted drivers, etc) (Shiao, 2023). As such, their deployment in cars is indeed expected by some to reduce road accidents and traffic congestion (Obaid *et al.*, 2023). On the other hand, an increasing adoption of AV, especially to support car-dependent individualized mobility, has been critically examined by some for its potential to lock urban transport systems into continuing dependence on multi-dimensionally harmful car use (Miner *et al.*, 2024). Our results confirm that public perception is similarly split in this regard and that there my be important differences between some expert estimations on AV and subjective perceptions among citizens (Maczionsek *et al.*, 2023; Pot *et al.*, 2021; Boffi *et al.*, 2022)

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A Annex

A.1 Wording used in the survey

- More affordable car driving would have an impact on ...
  - ... safer roads for car drivers
  - ... easier physical access for car drivers
  - ... a reduction in CO_2 emissions
- Safer roads for car drivers would have an impact on ...
  - ... more affordable car driving
  - ... easier physical access for car drivers
  - ... a reduction in CO_2 emissions
- Easier physical access for car drivers would have an impact on ...
  - ... more affordable car driving
  - ... safer roads for car drivers
  - ... a reduction in CO_2 emissions
- A reduction in CO_2 emissions would have an impact on ...
  - ... more affordable car driving
  - ... safer roads for car drivers
  - ... easier physical access for car drivers
- More affordable public transport would have an impact on ...
  - ... safer roads for public transport users
  - ... easier physical access for public transport users
  - ... a reduction in CO_2 emissions
- Safer roads for public transport users would have an impact on ...
  - ... more affordable public transport
  - ... easier physical access for public transport users
  - ... a reduction in CO_2 emissions
- Easier physical access for public transport users would have an impact on ...
  - ... more affordable public transport
  - ... safer roads for public transport users
  - ... a reduction in CO_2 emissions
- A reduction in CO_2 emissions would have an impact on ...
  - ... more affordable public transport
  - ... safer roads for public transport users

- ... easier physical access for public transport users

The table 3 below is the data summary after the transformation of the responses into numerical values.

Table 3: Data summary. The rows related to the bike-level assessments have been removed.

	Mean	SD
car: aff → saf	0.3	1.0
car: aff → infr	0.5	1.0
car: aff → clim	-0.0	1.2
car: saf → aff	0.5	0.9
car: saf → infr	0.6	0.9
car: saf → clim	0.2	1.1
car: infr → aff	0.5	0.9
car: infr → saf	0.5	0.9
car: infr → clim	0.2	1.1
car: clim → aff	0.3	0.9
car: clim → saf	0.4	0.9
car: clim → infr	0.4	0.9
PT: aff → saf	0.8	0.9 0
PT: aff → infr	1.0	0.9
PT: aff → clim	1.0	0.9
PT: saf → aff	0.7	0.9
PT: saf → infr	0.8	0.9
PT: saf → clim	0.8	0.9
PT: infr → aff	0.7	0.9
PT: infr → saf	0.8	0.8
PT: infr → clim	0.9	0.8
PT: clim → aff	0.6	0.9
PT: clim → saf	0.6	0.8
PT: clim → infr	0.6	0.8

A.2 Model summary

Table 4 presents the model summaries for each test. In model (1), the dependent variable is the perceived effects of EV on emissions from car use, in (2) the perceived effects of AV on emissions from public transport and in (3) the perceived effects of AV on road safety of car drivers.

Table 4: Model summary

	(1)	(2)	(3)
α	0.07 [−0.15, 0.28]	2.78 [2.63, 2.93]	1.25 [1.08, 1.41]
$\beta_{\text{treatment\_group}_{\text{EV}}}$	0.96 [0.45, 1.48]		
σ	3.04 [2.91, 3.19]	2.20 [2.11, 2.30]	2.32 [2.23, 2.43]
$\beta_{\text{treatment\_group}_{\text{AV}}}$		−0.28 [−0.65, 0.06]	0.17 [−0.20, 0.53]
Num.Obs.	981	999	1002
R2	0.014	0.003	0.001
R2 Adj.	0.011	0.000	−0.002
ELPD	−2484.5	−2207.3	−2268.8
ELPD s.e.	18.8	20.1	22.2
LOOIC	4969.0	4414.6	4537.5
LOOIC s.e.	37.6	40.1	44.4
WAIC	4969.0	4414.6	4537.5
RMSE	3.04	2.20	2.32