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Asking the Wizard-of-Oz: How experiencing autonomous buses affects preferences towards their use for feeder trips in public transport

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ABSTRACT
Autonomous vehicles are expected to have a significant impact on the overall transport sector. Regarding public transport, autonomous buses may bring the opportunity to give more and better access to people by introducing small, flexible on-demand services, that can operate at lower costs due to the absence of a driver. As those autonomous on-demand buses are not available yet, the acceptance of riders and the potential for the public transport is very unknow so far. To shed light on these issues we combined a two-stage SP-experiment with a Wizard-of-Oz-experiment to analyze peoples mode choice behavior on autonomous buses as a feeder mode. Participants of the study had the opportunity to experience an ostensibly autonomous driven bus in a so-called Wizard-of-Oz-experiment over a period of two to four weeks and were confronted with a mode choice SP-experiment before and afterwards. By estimating a mixed logit model on the answers of both experiments, we were able to show, that there was a significant increase in favor of the autonomous bus as chosen mode for a feeder trip. Furthermore, the results indicate, that the participants preferred to order the vehicle right at the start of their trip instead of making a reservation before. Also, they prefer to be alone in the vehicle, rather than to share it with other passengers.

Keywords: autonomous vehicles, on-demand transport, stated preference, wizard-of-oz, public transport, SP-experiment

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1. INTRODUCTION

The introduction of autonomous vehicles (AVs) is expected to have a disruptive impact on the transportation systems (see e.g. Fagnant and Kockelmann, 2015; Milakis et al., 2018; Fraedrich et al., 2019). One of the most significant changes that AVs are likely to induce is enabling/facilitating the provision of highly flexible on-demand services, as the absence of a driver will result in a substantial reduction of the operational costs, and subsequently increasing the attractiveness of such services (Correia and v. Arem, 2016; Bösch et al., 2018; Bahamonde-Birke et al., 2018). The advance of on-demand services, in turn, is expected to affect the way mobility requirements are perceived by the end-users and has the potential to revolutionize transport and urban systems (Fagnant and Kockelmann, 2015; Bahamonde-Birke et al., 2018, etc.).

However, most of the aforementioned gains refer to a given point of time, when the integration of AVs and the development of on-demand services will have achieved a stationary status. The extensive adoption of both AVs and on-demand transportation is likely to take a long time. It is precisely this timeframe, when transportation and city planners will have the best chance to shape the transportation systems of the future and introduce regulation in order to steer transportation systems towards sustainability and social welfare optima (Smith, 2012; Bahamonde Birke et al., 2018).

One of the most widely discussed issues regarding on-demand services and AVs concerns their integration into the public transportation system (Davidson and Spinuola, 2015; Yap et al., 2016; Kolarova et al., 2019). This would ease the implementation of regulation, while, at the same time, avoiding that on-demand services cannibalize mass-transportation modes (which are the most efficient modes in terms of social costs) leading to the well-known Vicious Circle of the Decline in Public Transportation and Increased Urban Congestion (Ortúzar and Willumsen, 2011).

This study aims at evaluating the potential of AVs and on-demand services to improve the provision of public transportation services. To this aim, we analyze the preferences of individuals towards both autonomous buses and on-demand services in the context of modal choices. We follow an innovative research approach, which links stated-preferences (SP) experiments with the use of an AV in a "real context".

For this purpose, a three-stage experiment was conceived. First, an SP-experiment was developed and conducted, in which respondents were asked to state which transportation mode they would prefer to carry out a recent trip. The choice-set included potential on-demand autonomous bus services. On a second stage, the participants in the study had the opportunity to use an autonomous bus regularly over a period of two to four weeks. As the current use of autonomously driving buses only partially reflects future application scenarios (currently only very low speeds are permissible and the presence of a safety steward is required; furthermore, the operation is only rarely allowed in public road space), a so-called Wizard-of-Oz experiment (Kelley, 1984) was adopted for the test operation. Hereby, a conventional vehicle was modified in such a way that the driver is not visible, neither from the inside nor from the outside of the bus, leaving the passengers with the impression that they are traveling on an autonomous bus. After the completion of the Wizard-of-Oz experiment, the participants were asked to answer again the same SP-experiment they answered in the first stage in order to consider how experiencing autonomous bus services have affected their preferences towards them.

The present paper reports the findings of the aforementioned study. Section 2 presents a brief review of the relevant literature dealing with mode-choice behavior of autonomous buses. Section 3 presents the details of the experimental setting, including both the SP-experiment as well as the Wizard-of-Oz experiment. Section 4 presents the methodological framework used to evaluate the results, while section 5 presents the results of the models and discusses the main findings of the study. Finally, section 6 summarizes the conclusions of the study.

2. LITERATURE REVIEW

User preferences and behavior play a relevant role regarding the adoption of autonomous vehicles in public transportation. As the technology does not exist so far, except for some slow autonomous minibusses which are often escorted by a steward, stated preference surveys are widely used to analyze future preferences in this regard. Recent studies on this topic have been conducted by Winter et al. (2019; the Netherlands and Germany), Smith et al. (2019; Australia), and Wicki et al. (2019; Switzerland)

The experiments by Winter et al. (2019) and by Wicki et al. (2019) were conducted in the context of the introduction of an experimental autonomous minibus (operating at low speed) in the region. Winter et al. (2019) conducted an SP-experiment on mode choices considering conventional and autonomous buses as well as a no-choice option. As variables, they included travel time, waiting time, and cost as well as surveillance, information, and type of service (scheduled vs. on-demand). Their results, based on a mixed logit model, indicate that preferences between vary depending on travel time so that on longer routes the standard bus is more likely to be chosen. The value of travel time when using autonomous buses is higher than for the standard bus, which means that the travel time is perceived worse than on conventional buses. Another finding by Winter et al. (2019) is that scheduled services would be valued higher than a flexible on-demand system.

Wicki et al. (2019) addressed mode choices among autonomous buses, walking, and rental bike and travel time, waiting time, costs, load factor (number of people in the bus), and weather as explanatory variables. They estimated a hybrid mixed logit model considering latent variables and panel effects. The results show that attitudinal traits have a significant impact on preferences. The attitude towards the technology does not correlate with time or cost, which harm the likelihood of choosing the alternative. Furthermore, bad weather increases the likelihood of opting for autonomous buses. However, the authors found that the willingness-to-pay for autonomous buses is rather low compared to other public transport modes.

Smith et al. (2019) collected their data by asking actual users of an autonomous shuttle bus that was used in the context of a pilot study on the campus of the University of Western Australia. The bus shuttle was allowed to drive at a low speed of 5 km per hour and was used on two fixed routes. They conducted SP-experiments, before using the bus on-board to capture eventual differences in preferences caused by experiencing the bus. The choice task considered the options autonomous bus and walking while distance, costs, travel (walking) time, waiting time, and weather conditions were considered as explanatory variables. The results suggest that the willingness-to-pay for the ride decreases after experiencing the bus, which may be due to the low operational speed (Smith et al., 2019). Furthermore, it is revealed that the weather and cost are key drivers for choosing the autonomous bus. Finally, Smith et al. (2019) raise the question of whether the parameters derived from experiments in pilot studies reveal the proper indicators for future use of AV and whether these parameters are biased by self-selection.

Besides studies focused on autonomous buses/minibusses, several studies have aimed at offering a broader perspective on the user's behavior and usage of autonomous vehicles (Fagnant and Kockelman, 2015; Thomopoulos and Givoni, 2015; Milakis et al., 2018; Bahamonde-Birke et al., 2018; Gkartzonikas and Gkritza,2019). There seems to exist a wide consensus regarding the barriers to adoption of AVs, such as cybersecurity or privacy concerns, but the same cannot be said regarding the evolution of the demand for mobility services and the broader impacts of this development (Gkartzonikas and Gkritza, 2019).

3. EXPERIMENTAL SETTING

The experimental setting of the study consists of three-steps. First, an SP-experiment was developed and conducted in order to capture mode choice preferences ex-ante. In a second step, a Wizard-of-Oz experiment was developed and conducted. Finally, the SP-experiment was repeated to capture preferences ex-post.

The Wizard-of-Oz experiment offered the participants the possibility of experiencing autonomous bus services during a certain period of time. They were told that the bus will drive autonomously while a safety engineer will observe the systems in the driver cabin and can be reached via intercom in urgent emergencies. The aim was to enable users to experience the use of autonomous buses, in particular the absence of a driver who, in addition to controlling the vehicle, is also responsible for providing information, selling tickets, assisting persons with reduced mobility, and ensuring safety in the vehicle. In order to make these changes perceptible, the aim was to operate the bus as realistically as possible. At present, however, the use of autonomous buses is only possible with a number of restrictions, such as very low speeds or the need for a safety driver on board. For this reason, a conventional, electrically driven, and manually controlled bus was modified for the experiment in such a way that the driver is not visible from the outside or inside and the vehicle appears to be an autonomously driving vehicle. That means the driver compartment was completely separated from the passengers as well as all windows of the driver cabin were darkened. This enabled the vehicle to be used under real conditions in public road space and in accordance with the existing speed limits. In addition, the drivers received special training to ensure that the vehicles are driven as expected by AVs. Furthermore, the users were informed in advance that an autonomously driving service would be offered, but only after the experiment was completed, they were informed about the actual setup. A picture of the outside and inside of the used vehicle is shown in figure 1.

Figure 1: Used vehicle from outside and inside; passenger compartment shown down right

The SP-experiments were carried out in two cities in Germany, namely Berlin (big-sized city; ca. 3.7 M inhabitants) and Braunschweig (medium-sized city; ca. 0.28 M inhabitants). In Braunschweig, the experiment was carried out in August 2019 for a total of two weeks and in Berlin, it was conducted in November 2019 for a total of four weeks. Bus services were provided on the so-called first/last mile as a connection from the origin or destination to the next mass transportation mode station, reflecting a favored field of application for autonomous buses in public transport. In Berlin, services were offered in a residential area connecting two subway stations with the surrounding campus of the Freie Universität Berlin. In Braunschweig, the services were offered connecting an industrial area near the airport with the central station.

The dataset received from the SP-experiment consists of 65 individuals, 14 from the city of Braunschweig while the others are from Berlin. All individuals answered the experiment ex-ante, while only 33 of them answered the experiment ex-post, from which twelve are from Braunschweig and 21 from Berlin. In each wave, each individual provided answers to twelve choice situations. In total, the experiment yielded 1 176 observations (780 ex-ante and 396 ex-post). Given the short duration of the experiment, it was considered that the outside conditions remained stable and no control group was considered. The key attributes in terms of the sociodemographic composition are shown in Table 1 disaggregated by city and time. The majority of participants of the study in Berlin are male, while in Braunschweig males represents 50% of the sample. The average (mean) age is about 30 years in Berlin and slightly under 30 in Braunschweig. Regarding education and income levels, in both cities most of the participants hold a university or college degree and have a relatively high income above 2 000 € per month; overall, the income of the participants in Braunschweig is slightly higher than in Berlin. In Braunschweig, over 90% of the sample has a driving license while only roughly 40% is in possession of a public transport season or monthly pass. In contrast, about two-thirds of the respondents in Berlin have a seasonal public transport ticket and only three-quarters are allowed to drive a car. The commuting time to the workplace is similar in both cities taking ca. thirty minutes one way.

Table 1 – Key Characteristics of Participants

Attribute	***Level***	***Berlin***		***Braunschweig***	
		Pre	***Post***	***Pre***	***Post***
Gender	*Male*	*63%*	*76%*	*46%*	*55%*
Age	*Years*	*31*	*34*	*28*	*29*
Income per month	*0 € - <900 €*	*32%*	*29%*	*23%*	*27%*
	900 € - <2000 €	*14%*	*24%*	*0%*	*0%*
	2000 € - <2600 €	*29%*	*14%*	*54%*	*46%*
	2600 € - <3000 €	*20%*	*33%*	*23%*	*27%*
	>3000 €	*4%*	*0%*	*0%*	*0%*
Education	*University, College*	*75%*	*67%*	*92%*	*91%*
	Professional Training	*6%*	*5%*	*0%*	*0%*
	Other	*19%*	*28%*	*8%*	*9%*
Driving License	*Yes*	*75%*	*76%*	*92%*	*91%*
Public Transport Season Pass	*Yes*	*65%*	*67%*	*38%*	*45%*
Commuting Time	*Minutes*	*31*	*34*	*32*	*31*

The SP-experiment represents a modal choice situation. The setting of the modal choice is supposed to represent the last feeder trip from home to a mass transportation mode station. Feeder trips were selected as they most closely resemble the setting, in which the Wizard-of-Oz experiment with autonomous busses was conducted. For the purposes of the feeder trip, individuals were offered five transportation alternatives, namely:

a) Conventional public transport (bus), including the attributes walking time to the bus stop, waiting time at the bus stop, and travel time in the vehicle
b) Walking, including the attribute walking time to the mass transportation mode station
c) Biking, including the attribute travel time as well as walking time representing the additional walking time required to park/secure the bike at the mass transportation mode station
d) Autonomous on-demand bus, including the attributes walking time to the pick-up point (which may be zero if the person is picked-up at home), waiting time (either at home or at the pick-up point), travel time in vehicle, as well as information regarding whether further passengers were on-board or has to be picked up after and whether it was possible to reserve a given pick-up time in advance (in this case the users still faced a waiting time, which only applies if they do not reserve in advance)

Regarding the cost attribute, it was considered that the price of conventional public transport (CPT) was included in the price of mass transportation mode. Consequentially, neither conventional public transport, nor walking or biking resulted in an increase of the costs faced by the user. The autonomous on-demand bus, in turn, considered a premium to be paid on top of the price of the mass transportation mode ticket. It ranged between 0€ and 1€. Finally, every choice situation included five alternatives, as two alternatives offering autonomous on-demand bus services were included. The reason behind it is that autonomous on-demand bus services included more attributes than conventional services and, consequentially, more options were required to depict this higher degree of internal variability.

Table 2 – Attributes and Levels

Attribute	***Alternative***	***Levels***	
Premium Price	*AV1, AV2*	*0, 0.5, 1*	*Euro*
Walking Time	*Walking*	*20, 25, 30*	*Minutes*
	Bike	*2, 5*	*Minutes*
	CPT	*5, 10*	*Minutes*
	AV1. AV2	*2, 5, 10*	*Minutes*
Waiting Time	*CPT*	*5, 10*	*Minutes*
	AV1, AV2	*5, 10, 15, 20*	*Minutes*
Travel Time	*Bike*	*12,15, 20*	*Minutes*
	CPT	*7, 10, 15*	*Minutes*
	AV1, AV2	*7, 10, 12, 15*	*Minutes*
Further Passengers in Bus	*AV1, AV2*	*0, 1*	
Last Passenger to Board	*AV1, AV2*	*0, 1*	
Reservation Possible*	*AV1, AV2*	*0, 1*	
****if reservation is used, waiting time will reduce to 0***			

The attribute selection is based on qualitative analysis, which was specially conducted in the context of the experiments (Stark et al., 2019). An overview of the attributes and their levels is given in table 2 and a representation of a choice situation is shown in figure 3. The SP design was considered with help of personal interviews (which included the collection of choices to estimate prior-model) and the final design was defined by maximizing the D-efficiency relying on the aforementioned priors (Rose and Bliemer, 2009).

	Bus	Walk	Bike	AV On-Demand Bus (1)	AV On-Demand Bus (2)
Premium Price				1 Euro [Premium price, additionally to the usual public transport ticket]	0 Euro [Premium price, additionally to the usual public transport ticket]
Walking Time	10 Min	30 Min	2 Min	2 Min	2 Min
Waiting Time	10 Min			0 Min (10 Min)*	0 Min (10 Min)*
Travel Time	10 Min		20 Min	7 Min [Travel time in vehicle, incl. detours to pick up other passengers]	12 Min [Travel time in vehicle, incl. detours to pick up other passengers]
Further Passengers				No, **I am the only passenger**	Yes, there are **further passengers**
Last Passenger					Yes, I am the last passenger to bord
Reservation				**Yes**	**Yes**
Your Choice	○	○	○	○	○
* If you make a reservation, **you do not need to wait.** If you **do not** make a reservation, you may have to wait. **The waiting time in this case is shown in the brackets**					

Figure 3: Representation of a Choice Task (Translated into English, Experiment was in German)

4. METHODOLOGICAL APPROACH

Under the assumption that individuals q are rational decision makers, it can be assumed that individuals facing a set of available alternatives A_q, will choose the alternative i that hat exhibits the highest utility U_{iq} among the set of utilities $U_{q.}$ (where $U_{q.}$ is a vector containing as many elements as available alternatives in A_q). In accordance with Random

Utility Theory (Thurstone, 1927; McFadden, 1974), it is possible to depict the utility of the different alternatives in the choice set (U_q) as the sum of a representative component (V_q) and an error term (ε_q), which, under the assumption of additive linearity, leads to the following expression (Train, 2009; Ortúzar and Willumsen, 2011):

$$U_q = X_q \cdot \beta + \varepsilon_q \qquad [4.1],$$

where X_q is a matrix standing for observed attributes of the alternatives and characteristics of the individuals and β a matrix of parameters to be estimated (whose rows are associated with the different elements of X_q, while the columns represent the different alternatives in the choice-set). If the elements of the vector of error terms ε_q are assumed to be independent EV1 distributed with same mean (for all alternatives) and diagonal homoscedastic covariance matrix (Σ_ε), the choice probabilities will be given by a Multinomial Logit model (MNL; Domencich and McFadden, 1975).

However, the assumption of independence does not hold, when multiple observations are collected from the same individual (pseudo-panel data) as they are likely to be correlated. Consequentially, it is not adequate to assume independent error terms across observations.

A possible way to overcome this problem is given by the Mixed Logit models (ML; Cardell and Dunbar, 1980; Ben-Akiva and Bolduc, 1996). Here, it is assumed that the stochastic component of the model would be given by the sum of the previously described independently identically EV1 distributed error terms ε_{qt} (that in this case are specific to each individual q and each choice-situation t) and other stochastic elements η_q and φ_q that can follow any desired distribution (or interact with measured variables X_q,). In this case, the utility function would take the following shape:

$$U_{qt} = X_{qt} \cdot (\beta + \varphi_q) + \eta_q + \varepsilon_{qt} \qquad [4.2]$$

Here, η_q and φ_q are vectors of error components following a given distribution and whose covariance matrices Σ_η and Σ_φ are not subject to homoscedasticity and no-autocorrelation restrictions (as long as the model is identified). This way, for instance, it can be accounted for correlation between individuals and alternatives. Under these assumptions, the likelihood function may be depicted as follows:

$$L = \int_\varphi \int_\eta \prod_q \prod_t P(y_{qt} \mid X_{qt}, \eta_q, \varphi_q; \beta, \Sigma_\varepsilon) \cdot f(\eta_q \mid \Sigma_\eta) \cdot f(\varphi_q \mid \Sigma_\varphi) \cdot d\eta \cdot d\varphi \qquad [4.3],$$

where the first component stands for the usual MNL probabilities (y is a matrix whose elements take a value of 1 if a given alternative is selected in a given choice situation and 0 otherwise), while the second and third terms represent the distribution of the error terms η_q and φ_q respectively. As normally this representation will not lead to closed-form expressions for the probabilities, the likelihood function must be integrated over the domain of the stochastic component η, making use of simulated likelihood techniques (McFadden, 1986).

To deal with panel or pseudo-panel data, it can be assumed that the error components η_q and φ_q are common to all answers provided by the same individual, while the independent and identically distributed (i.i.d.) EV1 error term ε_{qt} is different in each choice-situation (Walker et al., 2007). Therefore, it will be possible to estimate the variability of these individual-specific perturbation relative to the variability of ε_{qt}. Obviously, in this case, the integration over the domain of η_q and φ_q must be conducted at individuals' level rather than choices.

5. RESULTS AND DISCUSSION

Table 1 reports the model estimates. The model was estimated in accordance with eq. [4.2] and the structure of all utility functions was assumed to be linearly additive. The error terms ε_{qt} were assumed to follow an i.i.d. EV1 distribution, while η_q and φ_q were assumed to be normally distributed with mean zero and standard deviation to be estimated. To compute the simulated likelihood, 2 000 MLHS draws were used.

The first column of Table 3 indicates the variable associated with the estimators (either variables presented in the SP-experiment or associated with the individual/wave or interactions), the second is indicative for the utility function affected by the variable, while the third, fourth and fifth stand for the expected value of the estimator, its standard deviation and the t-test against zero, respectively. The estimates for all parameters for which a random distribution across the population was estimated are presented in two rows: the first row considers the estimate of the mean, while the second, in parenthesis, presents the estimator for the standard deviations. The model reports all parameters to be found statistically significant at a significance level of 5%, but it also includes parameters found to be insignificant but that are deemed relevant for the analysis. Similarly, differences between parameters *ex-ante* and *ex-post* are only included when found to be statistically significantly different from zero, or when deemed relevant for the analysis. No further parameter was found to be statistically significantly different from zero. No alternative specific parameters were considered due to the size of the sample, which may have led to overfitting.

Table 3 - Model Estimates

Variable	*Equation*	*Model*		
ASC Bike BS	*Utility Alternative Bike*	**0**	*(fixed)*	*fixed*
		(3.27)	*(0.77)*	*4.25*
ASC Bike B	*Utility Alternative Bike*	**0**	*(fixed)*	*Fixed*
		(2.81)	*(0.574)*	*4.9*
ASC Conventional Public Transport (CPT) BS	*Utility Alternative CPT*	**-0.688**	*(0.966)*	*-0.712*
ASC Conventional Public Transport (CPT) B	*Utility Alternative CPT*	**0.551**	*(0.617)*	*0.894*
		(1.64)	*(0.493)*	*3.32*
ASC Walking BS	*Utility Alternative Walking*	**0.138**	*(1.31)*	*0.105*

ASC Walking B	*Utility Alternative Walking*	**0.294**	*(0.791)*	*0.372*
ASC Autonomous Vehicle BS	*Utility Alternatives AV1, AV2*	**0.214**	*(0.897)*	*0.239*
ASC Autonomous Vehicle B	*Utility Alternatives AV1, AV2*	**2.18**	*(0.546)*	*3.98*
		(1.66)	*(0.28)*	*5.94*
Premium Price BS	*Utility Alternatives AV1, AV2*	**-2.18**	*(0.416)*	*-5.23*
Premium Price B	*Utility Alternatives AV1, AV2*	**-3.02**	*(0.434)*	*-6.95*
		(2.31)	*(0.373)*	*6.21*
Travel Time BS	*Utility Alternatives Bike, CPT, AV1, AV2*	**-0.297**	*(0.0514)*	*-5.78*
		(0.111)	*(0.0523)*	*2.12*
Travel Time B	*Utility Alternatives Bike, CPT, AV1, AV2*	**-0.252**	*(0.0248)*	*-10.2*
Walking Time BS	*Utility All Alternatives*	**-0.399**	*(0.0581)*	*-6.87*
Walking Time B	*Utility All Alternatives*	**-0.289**	*(0.0303)*	*-9.55*
Waiting Time BS	*Utility Alternatives CPT, AV1, AV2*	**-0.237**	*(0.0747)*	*-3.18*
Waiting Time B	*Utility Alternatives CPT, AV1, AV2*	**-0.235**	*(0.0523)*	*-4.49*
		(0.162)	*(0.0393)*	*4.12*
Waiting Time when reserved BS	*Utility Alternatives AV1, AV2*	**0.0105**	*(0.0338)*	*0.31*
Waiting Time when reserved B	*Utility Alternatives AV1, AV2*	**-0.0448**	*(0.0243)*	*-1.84*
		(0.0957)	*(0.0175)*	*5.48*
Change in ASC Autonomous Vehicle ex-post BS	*Utility Alternatives AV1, AV2*	**1.35**	*(0.86)*	*1.57*
Change in ASC Autonomous Vehicle ex-post B	*Utility Alternatives AV1, AV2*	**1.46**	*(0.746)*	*1.96*
		(1.86)	*(0.531)*	*3.5*
Change in Premium Price ex-post BS	*Utility Alternatives AV1, AV2*	**-0.881**	*(0.633)*	*-1.39*
Change in Premium Price ex-post B	*Utility Alternatives AV1, AV2*	**-1.12**	*(0.534)*	*-2.1*
Change in Reservation B	*Utility Alternatives AV1, AV2*	**-0.972**	*(0.397)*	*-2.45*
Change in Further Passengers ex-post BS	*Utility Alternatives AV1, AV2*	**-1.23**	*(0.705)*	*-1.74*
Change in Further Passengers ex-post B	*Utility Alternatives AV1, AV2*	**-0.792**	*(0.516)*	*-1.53*
Change in Last Passenger ex-post BS	*Utility Alternatives AV1, AV2*	**-1.08**	*(0.669)*	*-1.62*
Change in Last Passenger ex-post B	*Utility Alternatives AV1, AV2*	**-0.404**	*(0.468)*	*-0.865*
Log-likelihood			**-918.9488**	

The parameters associated with travel costs as well as with travel, waiting, and walking time exhibit the expected signs. Similarly, in line with the hypothesis, walking time is perceived more negatively than travel time in both cities. Also, in both cities, waiting time is perceived as less negative than travel time. While these results may seem surprising, it is important to consider that, in the context of the experiment, the waiting time for autonomous busses was assumed to be at home instead of at a station or bus stop.

The magnitude of both the cost and time parameters in Berlin is smaller than in Braunschweig. A comparison between the marginal utility of travel time and the marginal utility of price this yields a value of time of 8.17 €/hr in Braunschweig and 5.01 €/hr in Berlin. After exposure, we observe a significant change in the price attribute for Berlin, while in Braunschweig the change is not significant. Consequentially, the value of travel time decreased to 5.82 €/hr in Braunschweig and 3.57 €/hr in Berlin. As a possible explanation can be postulated that the willingness-to-pay to use a novelty decreases after experiencing it. The estimates for the value of travel time align with previous studies in Germany (Ehreke et al., 2015, Wardman et al., 2016; Steck et al., 2018).

When reserving a given pick-up time was possible, the waiting time was found to be not statistically significant in both cities. In this case, the waiting time reflects how long individuals would have to wait if they did not previously reserve a pick-up time; hence, the insignificance of the parameter means that the individuals were willing to reserve a vehicle and forgo the waiting time. The necessity of having to reserve a vehicle was also found to be statistically insignificant prior to the experiment. After exposure, no changes in the valuation of waiting time when reserving a given pick-up time were identified, but a significant disutility was identified in association with the necessity itself of reserving a vehicle (in order to avoid waiting times) in Berlin. It remained an insignificant factor in Braunschweig. The disutility of reservation amounts to 4.33 minutes of waiting time when reservation is not possible. That means that a person would prefer the need for a reservation upfront if the waiting time would be otherwise longer than 4.33 minutes.

Furthermore, before exposure it was found that being the last passenger boarding the vehicle or traveling with further passengers had no significant impact. However, in Berlin after exposure the disutility of traveling with other people was found statistically significant at a significance level of 5%; in Braunschweig, this disutility was found to be statistically significant at a 10% level (considering one-tailed tests in both cases, as the direction of the effect is known *a priori*). While the estimates associated with being the last passenger after exposure are still not statistically significant for both cities, a negative trend is observed in both cases (which may be associated with having troubles finding a desired place to sit, which may be accentuated due to the small size of the vehicles to which the individuals were exposed).

Finally, in Berlin, the ASC of the alternative AV was found to significantly increase after exposure. In Braunschweig, there is a clear indication of an increase as well, but the difference is not statistically significant (probable due to the small sample size). This means that the individuals were more likely to use the alternative AV, after having taking part in the experiment. Along these lines, it is important to note that the ASC of autonomous buses is higher than the ASC of conventional public transport.

The most important takeaway from the results is that experiencing autonomous busses results in a clear positive effect towards the acceptance of AV feeder trips. This finding differs from the results presented by Smith et al. (2019), who also considered changes after exposure. The reason behind these divergent results may be given by the characteristics of the vehicles considered in the experimental setting: while Smith et al. (2019) considered actual AVs offering a very low level of service (very low operational speed), in our experiment the level of service was much higher and close to the level of service expected from AVs once they are permitted to operate. Hence, we consider that these results offer clear insights on how preferences may be affected by experience, once fully capable AVs are available.

However, exposure to AVs does not only results in a higher valuation of the alternative in general, but also in stronger apprehension to travel with further passengers (most likely due to the small size of the vehicles compared with conventional busses) and being the last passenger (the last to be confirmed with a larger sample). Along these lines, exposure also increases the disutility associated with the premium paid to use the autonomous feeders. Consequentially, the impact of experiencing the actual services will also depend on their characteristics. Nonetheless, it must be pointed out that the general valuation of AVs is higher than the valuation of conventional public transport services, which offers a significant opportunity for public transport.

Finally, the results indicate that experiencing AVs results in increased awareness regarding the disutility of having to reserve pick-up times in advance when using on-demand services. This disutility amounts to a little bit less than 5 minutes, which indicates that an optimized on-demand service (from a user perspective) should either reduce waiting times to less than five minutes or otherwise allow reserving pick-up times.

6. CONCLUSIONS

The study reports the results regarding preferences towards the use of on-demand autonomous buses for the purposes of feeder trips in the cities of Braunschweig and Berlin. The results show that experiencing autonomous bus services positively impacts the propensity of using such services in the future. Furthermore, the results indicate that the experience increased the negative disutility associated with having to reserve a pick-up time a priori, which may have been neglected *ex-ante*, given the hypothetic nature of SP-experiments. Also traveling with further passengers becomes negatively significant in the propensity of using the new services in both cities. A similar tendency is observed for being the last passenger but without the certainty of statistical significance.

Regarding the typical attributes considered in mode choice models, we observe that the disutility of travel time as well as waiting and walking time remain constant after exposure. The disutility of paying a premium price to use autonomous feeders, however, increases after the experiment (although the effect is only significant in Berlin) and a slight decrease is observed in the value of travel time. This may be explained by novelty effects.

From a policy perspective, the most important finding of the study is that, in contrast to previous studies, experiencing autonomous buses increases the propensity of using such services. Similarly, AVs seem to be better perceived by the users than conventional bus services. This represents a significant opportunity for public transport; however, it is important to take into account that autonomous buses are likely to be introduced together with smaller vehicles meant for individual use (be they private or shared), which relativizes this advantage. Finally, it was estimated that the disutility of reserving a pick-up time in advance amounts to a little bit less than five minutes. It implies that, from a demand perspective, this possibility should be offered if waiting times are longer than this amount of time.

Notwithstanding, it is important to acknowledge that the results are neither representative for the German society nor for any of the two cities, as the sampling is affected by location and self-selection issues. Furthermore, the results are limited by the sample size. However, the main results of the study, such as the value of travel time are consistent with the average for the German population as reported by previous studies and the estimates align with the working hypothesis. Further research is necessary in order to confirm these results with a representative population.

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