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The role of automobility engagement for car use and car use reduction intentions in Germany

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ABSTRACT

Currently, the car holds the position as the primary mode of transportation in Germany and many other countries, serving diverse purposes. This widespread reliance has resulted in negative impacts on individuals, societies, as well as the environment and the climate. Reducing car use would therefore come with considerable benefits. While the role of many socio-economic, structural and psychological factors in car use reduction is well established, the socio-cultural context of automobility is not well conceptualised and integrated into quantitative studies. The goal of this paper was to explore the role of the socio-cultural context of automobility, differentiating between past and future car use. To this end, we applied Automobility Engagement (AE) as a concept operationalising consumer interactions with cars within the automobility system. In regression models predicting past car use (i.e., one week of actual travel behaviour) and the intention to reduce car use in the future, we tested the explanatory power of AE's seven facets in addition to selected socio-economic, structural and psychological factors. We recruited a sample of more than 2,000 participants in the German federal states of Baden-Württemberg and Mecklenburg-Western Pomerania in the summer of 2023. Results showed that the AE facets perceived car dependence, concern about the negative environmental effects of car use, house ownership preferences and car identity made small but significant contributions to our models whilst the three remaining AE facets did not. We found stronger associations with several socio-economic, structural and psychological variables such as owning a car, degree of urbanisation and transportation habits. We discuss the relevance of AE as an operationalisation of the socio-cultural context of automobility, its relatedness to other psychological factors and derive implications for policy design.

1. Introduction

Today, the car is the number one means of transport in Germany for many different purposes (infas et al., 2018). Motorised individual transport (including cars and motorcycles) accounted for 79.7 percent of all person-kilometres travelled in 2023 (Federal Environment Agency, 2023). In addition, the car density has been steadily increasing to 585 cars per 1,000 inhabitants in 2023, which amounts to 77 percent of German households owning at least one car (Destatis, 2023; Federal Environment Agency, 2024b). On the one hand, car use provides certain benefits to today's societies. For example, it can facilitate suburbanisation and longer commuting

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distances (Sovacool & Axsen, 2018) and thereby provide access to more affordable or spacious housing or prevent the need to move house in case of changing workplace. It can be a source of independence, save time, and increase flexibility and autonomy for many people, particularly in rural areas (Hagman, 2003; Hiscock et al., 2002; Simons et al., 2013). It can serve as a fortress or cocoon (Gatersleben et al., 2013; Gross, 2023) and thereby provide benefits in terms of (perceived) safety and personal space (Carse et al., 2013). Lastly, car use may also serve symbolic purposes such as signalling social status or gender norms (Hiscock et al., 2002; Steg, 2005). On the other hand, car use leads to adverse effects on individuals' health (Cai et al., 2021; Chen & Hoek, 2020), as well as the environment and the climate (Miner et al., 2024). Individual mobility and, thus, driving a car, is one of the causes of the climate crisis (Ivanova et al., 2020; Ivanova et al., 2016). In Germany, the transport sector was responsible for 22 percent of all greenhouse gas (GHG) emissions in 2023, the second-biggest share alongside the industry sector and surpassed only by the energy sector (Federal Environment Agency, 2024a). In extension, car use is associated with negative external effects that may disproportionally affect vulnerable societal groups. Thus, it may also lead to intra- and intergenerational equity problems (Gössling et al., 2022; Mattioli, 2013; Miner et al., 2024). Reducing car use would therefore have considerable benefits for both individuals and societies (e.g., Schuster et al., 2023). Correspondingly, it could even be costly for a society not to capitalise on the health benefits of active travel (van den Bijgaart et al., 2024). Paradoxically, while there is quite some knowledge about the adverse effects of automobility and factors that could reduce it, even motorists who are particularly sensitive to the negative externalities caused by their car use prefer private vehicles over public or active transportation (Silvestri et al., 2022). This points to factors that reinforce automobility.

A plethora of social scientific research has shown that structural, socio-economic and psychological factors are important for reinforcing or reducing car use. Javaid and colleagues (2020) argued that structural factors such as population density, walkability of a neighbourhood or the availability of cycling or public transport infrastructure may influence car use even before personal and social factors come into play. When it comes to socio-economic factors, meta-analytic evidence showed that younger age was associated with more sustainable mobility behaviour (Javaid et al., 2020). With regard to gender, women tended to engage more in sustainable mobility behaviours, but the evidence is mixed (Javaid et al., 2020; Miralles-Guasch et al., 2016). Further, car use tended to be associated with access to a car, employment, and higher income (Smart & Klein, 2020), but these relationships may be more complex for younger adults (Kuhnimhof et al., 2012). With regard to psychological factors, different authors have put forward behavioural theories, particularly from psychology. Among these are Ajzen (1991) with his Theory of Planned Behaviour (TPB), Schwartz's (1977) Norm Activation Model (NAM) or Stern and colleagues' Value-Belief-Norm Model (VBN, Stern et al., 1999). Lanzini and Khan (2017) synthesised these theories in a meta-analysis and found that habits seemed to be the most important personal factor influencing car use alongside (different kinds of) intentions, followed by attitudes, perceived behavioural control, personal moral norms, environmental concern and additional factors (see also Gardner & Abraham, 2008; Hoffmann et al., 2017). Furthermore, perceived social norms (i.e., descriptive and injunctive) supported (non–)car use (Gardner & Abraham, 2008; Helferich et al., 2023; Hoffmann et al., 2017). Beyond these popular theories, there was some evidence that personal satisfaction with a certain transportation mode increased its usage (Bláfoss Ingvardson et al., 2020) and that the presence of children was associated with increased car use for a variety of reasons (McCarthy et al., 2017).

Many of these approaches neglect the socio-cultural context in which mobility behaviour is embedded. In Germany in particular, regional and national identities have formed around the car and car manufacturing, to the extent that Germany is widely known as a car nation (Kallenbach, 2020; Mögele & Rau, 2020). Consequently, individual behaviour, the infrastructure that is provided and much of urban planning is directed towards the car. This one-sided view on mobility as a way to satisfy individual mobility needs prevents more holistic views on mobility and shows why it is important to consider the socio-cultural context of automobility.

Sovacool (2017) developed a framework that captures the socio-cultural context of mobility integrating theories from psychology, mobility research, science and technology studies and behavioural science more generally. While this framework originally focused on the transition to electric vehicles, it is here applied to car use in general. Particularly, the framework refers to the socio-cultural context of mobility in the two facets "motile pleasure" and "sociality". While the former refers to "the joy of driving rooted in utilitarian calculations" (p. 84), the latter encompasses judgements from peers and a vehicle's ability to enhance a driver's sense of identity or freedom. These dimensions are extended with factors such as habits, social influences or economic considerations to counter common criticisms against Automobility Theory. This theory views cars as part of a complex cultural and social interplay between hardware and infrastructure, including identity patterns and attitudes about driving pleasure. However, it is criticised for neglecting the influences of performance, ease of use, and the lack of agency when it comes to mobility choices (Sovacool, 2017).

This framework, however, remains conceptual. Other authors have tried to operationalise some of the theory's dimensions, such as Gauer and colleagues (2022; 2023). They introduced Automobility Engagement (AE) as a concept to explore "consumer perceptions of and engagement with car ownership and use as components of the automobility system" (Gauer et al., 2022, p. 2). AE comprises seven facets that relate to the automobility system as part of the socio-cultural context in which mobility behaviour is embedded. These facets were identified by means of an extensive literature review on research into the individual-level perspective of the automobility system as well as of car ownership and use (Gauer et al., 2022). Among these facets, perceived car dependence, car identity, driving aversion (negative) and non-car travel norms (negative) were shown to be associated with car ownership importance. In addition, societal concern for car use, non-car travel norms and perceived car dependence predicted interest in mobility innovations such as shared, automated and electric vehicles, while other factors showed more specific associations. For example, driving aversion and car identity were associated with interest in automated vehicles (Gauer et al., 2022). Many of these patterns were confirmed in a German and a Canadian sample, with some factors like societal concern showing country-specific associations with interest in car sharing, for example (Gauer et al., 2023). The exact composition of these seven facets in terms of measurement varied in the two studies (Gauer et al., 2022; Gauer et al., 2023), but was always based on the same number of items and item content. In this paper, we use the version that was specifically designed for application within the German context (Kelber, 2021). In this version, the seven facets of AE include

perceived car dependence, car identity, alternative travel norms, house ownership preferences, environmental concern, empowerment, and driving aversion. Some facets overlap with other concepts that have been linked to car use in previous research (e.g., perceived car dependence and alternative travel norms), while other facets add new angles to existing research (e.g., car identity and environmental concern) or have not been linked to car use in this way (e.g., house ownership preferences, empowerment, driving aversion). Each facet will now be explained in detail and linked to previous research. First, *perceived car dependence* refers to the extent to which people feel a need to use a car to fulfil their daily obligations – a phenomenon that is controversially discussed in the literature, particularly with regard to whether this dependence is objective or rather subjective (Lucas & Jones, 2009; van Eenoo et al., 2022). Second, *car identity* measures the extent to which people identify with their cars and want them to represent their personalities. Pro- and anti-car identities have been shown to reinforce or reduce car use, albeit with small effects (Hoffmann et al., 2017). Third, *alternative travel norms* combine descriptive social norms regarding travel mode choice and preferences for residential location. Items in this construct measure the extent to which people perceive their peers to use alternatives to the private car and to which they live in a neighbourhood where they do not need a car. The evidence regarding the role of descriptive norms for car use is mixed (Hoffmann et al., 2017; Semenescu et al., 2020), but residential location seemed to serve as an important factor for (non–) car use (Semenescu et al., 2020). Fourth, *house ownership preferences* refer to people's preferences to live in detached houses away from city centres, i.e., in suburban or rural areas. The degree of urbanisation has been found to act as a moderator of several different cognitive mechanisms for car use, such as attitudes and intentions (Hoffmann et al., 2017). Thus, it is assumed that these preferences are intertwined with preferences for mobility. Fifth, *environmental concern* measures the degree to which people are aware of the negative environmental effects of their car use. Problem awareness and general environmental concern predicted reduced car use (Gardner & Abraham, 2008), but this effect may be mediated by perceptions and feelings towards car use or the use of public transport (Bouscasse et al., 2018). The sixth factor, *empowerment*, measures the extent to which people associate positive feelings with car use, such as the feeling of control, of freedom or safety. Domarchi and colleagues (2008) found that car use habits are reinforced by associated positive emotions. Other researchers found that car use generally evokes more positive emotions than using public transport, although it is also associated with higher levels of stress and frustration (Le & Carrel, 2021). The level of stress and frustration is what the seventh facet of AE, *driving aversion*, aims to capture.

By applying AE with its seven facets, we seek to integrate the socio-cultural context of automobility into statistical models predicting car use. In particular, the main research question of this paper is:

> RQ1: In how far are the seven facets of AE (i.e., car dependence, car identity, alternative travel norms, environmental concern, driving aversion, empowerment, and house ownership preferences) related to car use?

Many of the theoretical approaches summarised above postulate that their respective independent variables influence behavioural intentions which then translate into actual behaviour. Since actual behaviour can be difficult to measure (Koller et al., 2023), many studies investigate intentions and extrapolate the findings to actual behaviour. Research on the intention-behaviour gap, however, argued that the intention-behaviour relation remained complex and that the assumption of intentions translating into behaviour may only hold true half of the time (Sheeran & Webb, 2016; Webb & Sheeran, 2006). In addition, previous research has shown that different sets of variables successfully predict past and future intended behaviour (Dütschke et al., 2022). Therefore, we investigate the effects of

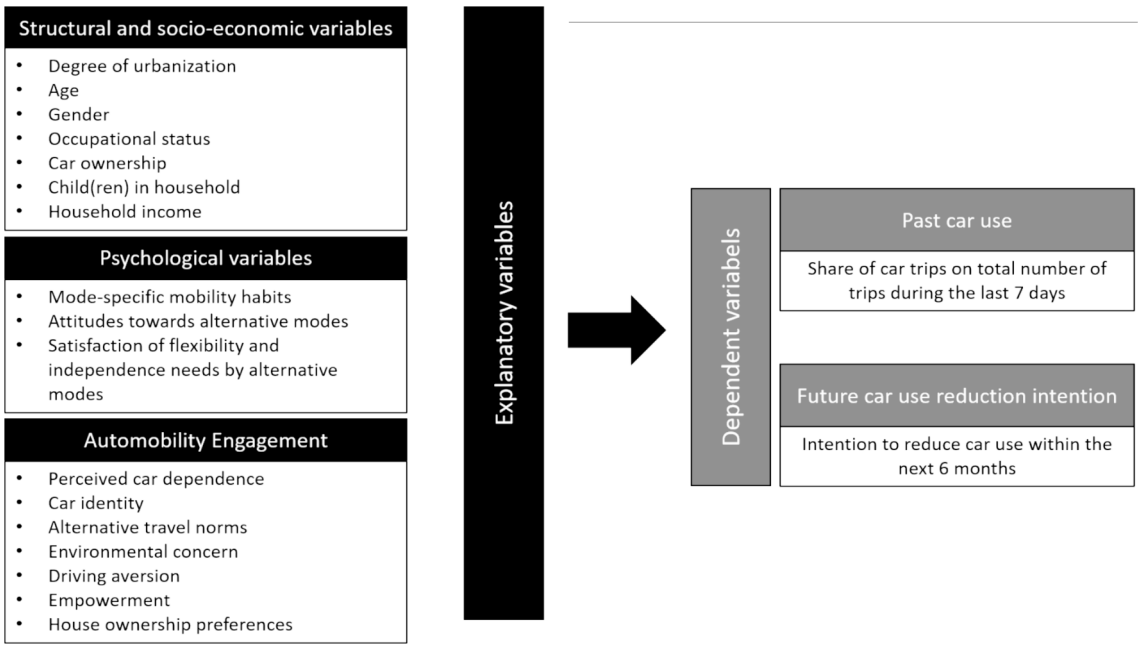

Fig. 1. Research framework.

our independent variables on intended (future) and actual (past) behaviour separately and additionally ask:

RQ2: How do the effects of the seven AE facets differ between intended (future) and actual (past) car use?

By applying this differentiation, we are able to contribute to the understanding of factors influencing both actual (past) car use and intended (future) car use reduction.

Building on previous research, we explore the effects of the seven AE facets after controlling for structural (i.e., degree of urbanisation), socio-economic (i.e., age, gender, occupational status, car ownership, presence of a child within the household, household income), and psychological (i.e., habits, attitudes, satisfaction of flexibility and independence needs) factors.

Fig. 1 illustrates the underlying research framework.

2. Method

Between June and August of 2023, we conducted an online survey with five main parts. First, the participants answered questions on their socio-economic characteristics. These were followed by questions about their mobility habits, their mobility behaviour during the previous week and their intentions to change their mobility behaviour in the future. Subsequently, the participants answered questions about their attitudes towards alternative modes of transport (i.e., public transport, walking, cycling). This was followed by the AE items. Lastly, participants answered questions on the extent to which alternative transport modes would satisfy different flexibility and independence needs. Further questions on the political context and electric mobility were included in the survey but exceed the scope of this paper. The questionnaire took approximately 15 min (median) to complete and the participants were financially remunerated by the market research company that had recruited them.

2.1. Participants

A total of 2,532 participants from the German states of Baden-Württemberg and Mecklenburg-Western Pomerania completed the questionnaire. We chose these two German states as our primary recruiting sites because they differ largely in important structural and mobility-related aspects (Baden-Württemberg State Ministry, 2022), which can consequently help to identify important correlates of people's mobility patterns. We included two attention check questions and excluded participants who answered both of them incorrectly (N=6). Due to their small number, we excluded people who identified as non-binary in terms of gender from the total sample (N=4), as well as participants with missing values on any of the variables included in the main analyses (N=131). For the analysis on past car use, this resulted in a final sample of N_{beh}=2,391. For the analysis regarding the intention to reduce car use, we further excluded participants who indicated they did not have access to a car[1] (N=275) for a final sample of N_{int}=2,116. Participants

Table 1
Sample characteristics.

	Sample for the behavioural analysis (N_{beh}=2,391)	Sample for the intentional analysis (N_{int}=2,116)
State		
Baden-Württemberg	68.5 % (N=1,637)	69.0 % (N=1,459)
Mecklenburg-Western Pomerania	31.5 % (N=754)	31.0 % (N=657)
Gender		
Male	47.8 % (N=1,143)	48.2 % (N=1,019)
Female	52.2 % (N=1,248)	51.8 % (N=1,097)
Age	M=48.3 (SD=16.6)	M=48.1 (SD=16.5)
Monthly net household income		
<1,300 €	13.9 % (N=333)	10.7 % (N=227)
1,300 € – 2,600 €	30.0 % (N=718)	29.3 % (N=620)
2,600 € – 3,600 €	24.5 % (N=585)	25.7 % (N=543)
3,600 € – 5,000 €	20.3 % (N=486)	22.3 % (N=471)
> 5,000 €	11.3 % (N=269)	12.1 % (N=255)
Car ownership	84.9 % (N=2,030) own a car	93.3 % (N=1,975) own a car
Child(ren) in household	27.0 % (N=645) with child(ren)	28.9 % (N=611) with child(ren)
Occupational status	61.6 % (N=1,473) work	64.3 % (N=1,361) work
Degree of urbanisation		
Urban	34.3 % (N=819)	31.0 % (N=657)
Semi-urban	40.9 % (N=976)	42.3 % (N=895)
Rural	24.9 % (N=596)	26.7 % (N=564)

[1] Not having access to a car was an answer option when we measured the intention to change current car use patterns. This facilitated interpretation of answers since people without access to a car would not have been able to meaningfully indicate whether they planned to increase, decrease or keep their car use at the current level. However, people indicated their past car use on a scale from 0 % to 100 %. People without access to a car thus predominantly indicated 0 %, which is a meaningful answer on this scale. Therefore, these participants were not excluded from the behavioural analysis.

were recruited in a way that ensured representativeness for the respective federal state in terms of gender, age and household income. Due to the exclusions outlined above, both samples N_{beh} and N_{int} included a slightly higher share of women and were slightly younger than would be representative for the populations of Baden-Württemberg and Mecklenburg-Western Pomerania, and the sample income was on average slightly higher than would be representative for Mecklenburg-Western Pomerania and slightly lower than representative for Baden-Württemberg. Table 1 gives an overview of the sample characteristics.

2.2. Measures

2.2.1. Dependent variables

2.2.1.1. Car use. Participants were asked to indicate the percentage of trips they made by car[2] during the week preceding their participation in the survey. This percentage could range between 0 % and 100 %. Participants made an average of M=51.0 % (SD=39.9 %) of their trips by car during the previous week.

2.2.1.2. Intention to reduce car use. Participants were asked whether they intended to reduce or increase their car use during the following six months. They could also indicate that they would keep their car use at the same level or that they did not have access to a car. The latter participants were excluded from the intentional analysis in this paper. We dichotomized the intention variable in a way that participants who intended to increase their car use or keep it at the same level were coded as having no intention to reduce their car use (0). This applied to 80.7 % of the sample (N=1,707). The remaining participants (19.3 %, N=409) were coded as having an intention to reduce their car use (1).

2.2.2. Independent variables

2.2.2.1. Structural and socio-economic variables. Participants indicated their postcodes during the survey, which were subsequently matched with urbanisation data from Eurostat (2023) to derive the degree of urbanisation as a structural variable. Areas with more than 1,500 inhabitants per km^2 were coded as urban areas, those with 300 to 1,500 inhabitants per km^2 were coded as semi-urban areas and those with less than 300 inhabitants per km^2 were coded as rural areas. Furthermore, we included people's age (continuous variable), their gender, occupational status, car ownership and the presence of children in the household (dummy variables), and the monthly net household income (categorical variable) as socio-economic variables. Descriptive statistics for these variables are shown in Table 1.

2.2.2.2. Psychological variables. We included mobility habits, attitudes towards alternative modes of transport (i.e., public transport, walking, cycling) and the degree to which participants' flexibility and independence needs were satisfied by the alternative transport modes as psychological variables. Mobility habits were measured by presenting eleven situations (e.g., buying groceries for daily use, see Appendix A for full item list) and asking participants to indicate their usual transportation mode in each situation. The list comprised the following options to select from: going on foot, by bicycle, taking regional or long-distance public transport, taking a car with an internal combustion engine, an electric car, car sharing or indicate that a specific situation did not exist for them. We then built one composite variable each for the habits of taking the car, public transport, walking or cycling by summing up the situations in which each of these transportation modes were chosen. Higher numbers indicated stronger habits of taking them (Klosterkamp et al., 2022).

Following Ajzen (2006), people indicated on four semantic differentials (i.e., good-bad, pleasant-unpleasant, enjoyable-unenjoyable, and useful-useless) how they evaluated using public transport or the bicycle for the majority of their daily trips. For

Table 2
Descriptive statistics of psychological variables.

Variable (range)	M_{beh} (SD_{beh})	M_{int} (SD_{int})	# of items	Cronbach's α_{beh}	Cronbach's α_{int}
Habit of taking the car (0–11)	4.76 (3.44)	5.34 (3.20)	11	n/a	n/a
Habit of walking (0–11)	1.41 (1.73)	1.29 (1.61)	11	n/a	n/a
Habit of taking the bicycle (0–11)	1.10 (1.77)	1.08 (1.74)	11	n/a	n/a
Habit of taking public transport (0–11)	1.19 (1.84)	0.98 (1.61)	11	n/a	n/a
Attitudes towards public transport (1–5)	2.97 (1.33)	2.86 (1.31)	4	.94	.94
Attitudes towards cycling or walking (1–5)	3.23 (1.40)	3.21 (1.40)	4	.96	.96
Flexibility and independence needs met by public transport (1–5)	2.67 (1.03)	2.56 (0.99)	5	.89	.88
Flexibility and independence needs met by walking or biking (1–5)	3.29 (0.88)	3.25 (0.88)	5	.80	.80

Note. beh = statistics from the dataset for the behavioural analysis.
int = statistics the dataset for the intentional analysis.
n/a = No Cronbach's α available because the composites were built by summing up dichotomous variables.

[2] Both in the behavioural and the intentional measure, we did not differentiate between car trips as a driver or as a passenger.

Table 3
Descriptive statistics of AE variables.

Variable (range)	M_{beh} (SD_{beh})	M_{int} (SD_{int})	# of items	Cronbach's α_{beh}	Cronbach's α_{int}
Car dependence (1–5)	3.27 (1.00)	3.42 (0.89)	7	.84	.80
Car identity (1–5)	2.36 (0.88)	2.40 (0.87)	6	.83	.83
Alternative travel norms (1–5)	3.10 (0.87)	3.02 (0.85)	5	.81	.81
Environmental concern (1–5)	3.12 (0.98)	3.07 (0.97)	3	.84	.83
Driving aversion (1–5)	2.46 (1.04)	2.34 (0.96)	3	.80	.77
Empowerment (1–5)	3.36 (0.88)	3.45 (0.83)	4	.81	.79
House ownership preferences (1–5)	3.47 (1.01)	3.55 (0.98)	3	.67	.65

Note. beh = statistics from the dataset for the behavioural analysis.
int = statistics the dataset for the intentional analysis.

both transport modes, these four items were averaged per participant to build two composite variables with excellent internal consistency (Cronbach's $\alpha > .90$).

We used five items to measure the degree to which public and active transportation satisfied participants' flexibility and independence needs (Dütschke et al., 2015; e.g., "Public transport takes me anywhere I want", see Appendix A for complete item list). All items were measured on five-point Likert-type scales ranging from 1 (completely disagree) to 5 (completely agree), with an additional option of indicating that they could not judge a particular item. Items were averaged per means of transport and per participant to build two composite variables with good internal consistency (Cronbach's $\alpha \geq .80$). See Table 2 for descriptive statistics of the included psychological variables.

2.2.2.3. Automobility Engagement (AE). AE was measured with 31 items comprising seven facets (Kelber, 2021). All items were measured on five-point Likert-type scales ranging from 1 (completely disagree) to 5 (completely agree). Perceived car dependence was measured with seven items, e.g., "I need a car to fulfil my everyday obligations". Car identity was measured with six items, e.g., "I want my car to represent my personality". Alternative travel norms were measured with five items, e.g., "I know a lot of people who use public transit (bus, subway, etc.)". Environmental concern was measured with three items, e.g., "Air pollution from cars is a serious problem". Driving aversion was also measured with three items, e.g., "The idea of driving makes me tired". Empowerment was measured with four items, e.g., "Driving makes me feel free". House ownership preferences were measured with three items, e.g., "I prefer to live away from urban centres". See Appendix A for the complete item list. Internal consistency was good for most composite variables, with Cronbach's α values ranging around .80. House ownership preferences was the exception with Cronbach's α around .65. Since this value was still satisfactory, we proceeded with all items included in order to replicate the original scale. Table 3 shows the descriptive statistics of the seven facets of AE.

2.3. Preparatory analysis

We performed a confirmatory factor analysis (CFA) to test the seven-factor structure of AE. This was done because the factor structure of AE varied in different studies as outlined above. Using CFA, we ensured that the proposed factor structure (i.e., Kelber, 2021) fitted the collected data. We considered the χ^2 statistic, the Comparative Fit Index (CFI), the Root Mean Square Error of Approximation (RMSEA) and its corresponding confidence interval as well as the Standardised Root Mean Square Residual (SRMR) along with common cut-off values according to Hu and Bentler (1999) to evaluate model fit. We defined the measurement model in a way that ensured all items belonging to a single factor loaded on that factor alone. We chose the variance standardisation method for identifying the model, i.e., all observed variable loadings were free to vary. Only one observed variable showed a standardised factor loading of below .40, namely one of the car dependence latent factor. For the sake of replicating the original scale, we decided to keep this variable in the model and tolerated a slightly worse model fit. The model fit was still satisfactory, with $\chi^2(413) = 5202.7$, $p < .001$; CFI = .858; RMSEA[90% CI] = .07[.068, .071], and SRMR = .071. These values were close to the recommended cut-off values (Hu & Bentler, 1999).[3] These results allowed us to use composite variables for each latent factor in the main analyses.

2.4. Main analyses

First, we performed a correlation analysis to explore the general structure of the data. Second, we conducted a binary logistic regression with car use reduction intention as the dependent variable and a linear regression with past car use as the dependent variable. The independent variables were the same for both analyses (see Fig. 1). Both regressions were performed hierarchically. That is, we first put the socio-economic and psychological variables into the model (step 1) and then added the AE variables (step 2). All analyses were performed using R version 4.3.1 (R Core Team, 2023).

[3] They recommend RMSEA < .05, SRMR < .06 and CFI > .95 (Hu & Bentler, 1999, p. 24, 26).

3. Results

3.1. Bivariate results

Table 4 displays the bivariate correlations between all independent and dependent variables used in the main analyses alongside information regarding statistical significance. The results showed that past car use was highly[4] and significantly correlated with perceived car dependence and car habits. Furthermore, past car use showed moderate significant correlations with driving aversion, alternative travel norms, empowerment, car ownership, walking habits, cycling habits, public transport habits, the satisfaction of flexibility and independence needs, attitudes towards public transport, and attitudes towards cycling. Lastly, past car use showed small significant correlations with environmental concern, house ownership preferences, car identity, employment status, and age.

The intention to reduce car use showed small significant correlations with environmental concern, driving aversion, alternative travel norms, the presence of children in the household, car habits, cycling habits, public transport habits, the satisfaction of flexibility and independence needs, attitudes, as well as age. Taken together, the correlations with car use reduction intention were overall much smaller than the correlations with past car use.

3.2. Regression results

Table 5 shows the results from both regression analyses. Table 6 shows a summary of these results, listing factors with significant associations in one or both steps of the respective hierarchical regressions. The behavioural model could explain 62.4 % of variance in the dependent variable in step 1, which increased to 64.2 % when AE variables were added.[5] This was a significant increase in

Table 4
Pearson correlation coefficients between all variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
2	.64		−.24	.31	−.30	−.43	.37	.25	.22	.02†	.36	.11	.62	−.24	−.32	−.36	−.29	−.40	−.33	−.23	−.01†	−.02†
3	−.28	−.26		.00†	.48	.47	−.22	−.07	.00†	.05	−.07	.02†	−.26	.08	.17	.19	.32	.38	.34	.28	−.11	.18
4	.24	.37	−.03†		−.09	−.17	.23	.10	.07	−.01†	.16	.12	.27	−.23	−.08	−.09	−.04†	−.14	−.13	.02†	−.04†	.01†
5	−.38	−.39	.48	−.14		.38	−.40	−.10	−.01†	.04†	−.17	.05	−.30	.11	.17	.25	.28	.40	.37	.22	−.15	.14
6	−.46	−.46	.47	−.21	.43		−.13	.03†	−.03†	.02†	−.13	.02†	−.43	.22	.25	.35	.44	.59	.54	.35	−.12	.16
7	.31	.45	−.23	.29	−.45	−.18		.45	.11	.01†	.17	.07	.28	−.09	−.14	−.17	−.09	−.18	−.22	−.09	−.08	−.02†
8	.12	.33	−.09	.15	−.15	−.02†	.47		.16	−.06	.07	.13	.13	−.01†	−.04†	−.04	−.01†	.08	−.04	−.02†	−.20	.02†
9	.11	.24	−.01†	.09	−.03†	−.05	.13	.16		.00†	.12	.22	.16	.03†	.07	−.01†	.02†	−.03†	.01†	.10	−.31	.03†
10	−.04†	.01†	.04†	−.01†	.04	.03†	.00†	−.06	.00†		.00†	.06	.00†	.02†	.00†	.01†	−.02†	−.05	−.03	.02	−.18	.01†
11	.47	.54	−.13	.28	−.31	−.26	.32	.17	.19	−.01†		.05	.37	−.18	−.08	−.26	−.08	−.19	−.12	−.03†	.09	.02†
12	.01†	.15	.00†	.13	.00†	−.01†	.09	.13	.21	.06	.11		.09	.04†	.07	.00†	.02†	.06	.07	.14	−.35	.07
13	.76	.67	−.28	.32	−.37	−.47	.35	.18	.20	−.01†	.53	.13		−.38	−.40	−.46	−.29	−.39	−.38	−.27	.04†	−.09
14	−.31	−.27	.08	−.24	.15	.23	−.13	−.02†	−.01†	.02†	−.25	.02†	−.38		−.10	.01†	.16	.16	.17	.08	−.10	.03†
15	−.33	−.26	.16	−.06	.15	.21	−.12	−.03†	.07	.00†	−.06	.06	−.34	−.12		−.03†	.33	.18	.17	.49	−.12	.12
16	−.44	−.43	.21	−.16	.32	.39	−.24	−.10	−.04†	.00†	−.38	−.04†	−.49	.02†	−.07		.08	.38	.42	.07	−.20	.10
17	−.36	−.31	.33	−.07	.30	.43	−.12	−.04	.01†	−.02†	−.15	.00†	−.30	.17	.32	.10		.45	.31	.49	−.08	.14
18	−.46	−.47	.38	−.21	.45	.61	−.25	.01†	−.07	−.04	−.34	.02†	−.45	.19	.15	.42	.46		.58	.26	−.13	.13
19	−.42	−.37	.34	−.18	.39	.54	−.25	−.08	−.02†	−.02†	−.24	.04	−.41	.18	.15	.44	.31	.60		.38	−.13	.15
20	−.30	−.19	.27	.03†	.18	.31	−.07	.00†	.11	.01†	−.03†	.13	−.23	.07	.49	.04†	.47	.23	.35		−.18	.22
21	.13	−.04†	−.08	−.06	−.12	−.08	−.10	−.21	−.31	−.16	.01†	−.34	.01†	−.11	−.14	−.14	−.07	−.09	−.09	−.19		−.12

† Correlation is not significant, $p > .05$.
Note. Correlations below the diagonal are from the dataset for the behavioural analysis, correlations above the diagonal are from the dataset for the intentional analysis.
1 = car use (1) vs. no car use (0); 2 = car dependence, 3 = environmental concern, 4 = house ownership preferences, 5 = driving aversion, 6 = alternative travel norms,
7 = empowerment, 8 = car identity, 9 = working (1) vs. not working (0), 10 = female (1) vs. male (0), 11 = car (1) vs. no car (0) in household, 12 = child (1) vs. no child (0) in household, 13 = car habits, 14 = walking habits, 15 = cycling habits, 16 = public transport habits, 17 = flexibility and independence needs met by active travel, 18 = flexibility and independence needs met by public transport, 19 = attitudes towards public transport, 20 = attitudes towards cycling, 21 = age, 22 = intention (1) vs. no intention (0) to reduce car use.

[4] According to Cohen (1992), correlations are large if $r \geq .50$, medium if $.30 \leq r < .50$, and small if $.10 \leq r < .30$.

[5] With AE variables only, the behavioural model explained 45.3 % of the variance. With structural and socio-economic variables only, the model explained 27.2 % of the variance. With psychological variables only, the model explained 61.2 % of the variance. This indicates that some of the psychological variables were suppressing effects of some structural, socio-economic and AE variables in the full model.

Table 5
Results from both regression analyses.

	Past Behaviour			Intentions		
Independent variables	*B* (95 % CI)	β	*p*	*B*	OR (95 % CI)	*p*
Step 1						
Intercept	34.90 (26.87, 42.93)		<.001	−3.89***	0.02 (0.01, 0.06)	<.001
Structural and socio-economic variables						
Semi-urban vs. urban	0.71 (−1.66, 3.09)	.01	.557	0.50***	1.64 (1.24, 2.17)	.001
Rural vs. urban	1.52 (−1.27, 4.30)	.02	.286	0.46**	1.59 (1.15, 2.19)	.005
Working vs. not working	1.34 (0.98, 3.65)	.02	.256	0.04	1.05 (0.80, 1.37)	.745
Female vs. male	−2.35** (−4.37, −0.34)	−.03	.022	−0.05	0.95 (0.75, 1.20)	.672
1300 € − 2600 € vs. < 1300 €	0.16 (−3.19, 3.50)	.00	.926	−0.21	0.81 (0.54, 1.23)	.321
2600 € − 3600 € vs. < 1300 €	−1.41 (−5.02, 2.20)	−.02	.443	−0.17	0.84 (0.55, 1.30)	.433
3600 € − 5000 € vs. < 1300 €	−2.43 (−6.28, 1.41)	−.02	.214	−0.49*	0.61 (0.39, 0.96)	.032
> 5000 € vs. < 1300 €	−2.20 (−6.55, 2.16)	−.02	.323	−0.59*	0.55 (0.33, 0.92)	.024
Car vs. no car in household	11.02*** (7.53, 14.51)	.10	<.001	0.68**	1.97 (1.19, 3.36)	.010
Child vs no child in household	−3.06** (−5.50, −0.61)	−.03	.014	0.07	1.07 (0.83, 1.39)	.590
Age	0.14*** (0.07, 0.21)	.06	<.001	−0.01**	0.99 (0.98, 0.99)	.001
Psychological variables						
Car habits	6.39*** (5.89, 6.88)	.55	<.001	0.01	1.01 (0.95, 1.07)	.865
Walking habits	−1.09*** (−1.81, −0.36)	−.05	.003	0.01	1.01 (0.93, 1.11)	.757
Cycling habits	−1.81*** (−2.59, −1.02)	−.08	<.001	0.02	1.02 (0.94, 1.11)	.607
PT habits	−1.84*** (−2.60, −1.07)	−.08	<.001	0.11*	1.12 (1.02, 1.23)	.019
Need satisfaction active travel	−3.09*** (−4.50, −1.68)	−.07	<.001	0.13	1.13 (0.96, 1.35)	.150
Need satisfaction PT	−2.02*** (−3.39, −0.65)	−.05	.004	0.11	1.11 (0.95, 1.30)	.176
PT attitudes	−0.79 (−1.81, 0.24)	−.03	.132	0.06	1.06 (0.95, 1.19)	.310
Cycling attitudes	−1.56*** (−2.49, −0.63)	−.05	.001	0.37***	1.44 (1.29, 1.62)	<.001
F(19,2371)	209.34***			Model χ^2	1905.1*** ($df = 1096$)	
Adjusted R^2	.624			Nagelkerke R^2	.125	
Step 2						
Intercept	18.04*** (7.43, 28.64)		<.001	−5.82***	0.00 (0.00, 0.01)	<.001
Structural and socio-economic variables						
Semi-urban vs. urban	−1.42 (−3.80, 0.96)	−.02	.243	0.46**	1.58 (1.18, 2.11)	.002
Rural vs. urban	−1.42 (−4.30, 1.46))	−.02	.335	0.46**	1.58 (1.12, 2.23)	.010
Working vs. not working	−0.89 (−3.18, 1.41)	−.01	.448	−0.00	1.00 (0.76, 1.32)	.987
Female vs. male	−2.40* (−4.39, −0.42)	−.03	.018	−0.09	0.91 (0.72, 1.15)	.436
1300 € − 2600 € vs. < 1300 €	0.40 (−2.87, 3.67)	.00	.809	−0.22	0.80 (0.53, 1.23)	.305
2600 € − 3600 € vs. < 1300 €	−0.06 (−3.59, 3.47)	−.00	.974	−0.21	0.81 (0.53, 1.26)	.350
3600 € − 5000 € vs. < 1300 €	−1.19 (−4.96, 2.58)	−.01	.537	−0.50*	0.61 (0.38, 0.97)	.034
> 5000 € vs. < 1300 €	−0.33 (−4.62, 3.95)	−.00	.878	−0.62*	0.54 (0.31, 0.91)	.021
Car vs. no car in household	6.10*** (2.53, 9.66)	.05	<.001	0.54*	1.72 (1.03, 2.97)	.044
Child vs no child in household	−3.87** (−6.26, −1.47)	−.04	.002	0.04	1.04 (0.80, 1.36)	.752
Age	0.15*** (0.08, 0.22)	.06	<.001	−0.01**	0.99 (0.98, 1.00)	.008
Psychological variables						
Car habits	5.80*** (5.30, 6.29)	.50	<.001	−0.00	1.00 (0.94, 1.07)	.987
Walking habits	−0.71 (−1.43, 0.01)	−.03	.053	0.03	1.03 (0.94, 1.13)	.519
Cycling habits	−1.14** (−1.92, −0.37)	−.05	.004	0.05	1.05 (0.96, 1.15)	.292
PT habits	−1.15** (−1.91, −0.39)	−.05	.003	0.13**	1.14 (1.03, 1.25)	.009
Need satisfaction active travel	−2.60*** (−4.00, −1.19)	−.06	<.001	0.06	1.07 (0.89, 1.27)	.471
Need satisfaction PT	−0.37 (−1.80, 1.06)	−.01	.613	0.03	1.03 (0.87, 1.22)	.742
PT attitudes	−0.78 (−1.80, 0.25)	−.03	.137	0.00	1.00 (0.89, 1.13)	.951
Cycling attitudes	−1.40** (−2.32, −0.48)	−.05	.003	0.35***	1.42 (1.26, 1.60)	<.001
Automobility engagement						
Car dependence	8.52*** (6.95, 10.10)	.21	<.001	0.30**	1.35 (1.12, 1.62)	.002
Environmental concern	0.80 (−0.42, 2.02)	.02	.197	0.26***	1.30 (1.12, 1.52)	.001
House ownership preferences	−1.54** (−2.63, −0.44)	−.04	.006	−0.02	0.98 (0.86, 1.12)	.787
Driving aversion	−0.59 (−1.83, 0.65)	−.02	.350	0.10	1.10 (0.95, 1.28)	.196
Alternative travel norms	−1.35 (−3.00, 0.30)	−.03	.109	0.197	1.22 (0.99, 1.49)	.058
Empowerment	0.84 (−0.61, 2.29)	.02	.258	0.01	1.01 (0.84, 1.21)	.911
Car identity	−2.15** (−3.47, −0.83)	−.05	.001	−0.01	0.99 (0.84, 1.16)	.919
F(26,2364)	165.93***			Model χ^2	1868.3*** ($df = 2089$)	
Adjusted R^2	.642			Nagelkerke R^2	.151	
N	2391			*N*	2116	

*$p < .05$, **$p < .01$, ***$p < .001$, *B*=regression coefficient, β=standardized regression coefficient, OR=Odds Ratio, CI=Confidence Interval, PT=public transport.

Table 6
Summary of regression results.

	Past car use[a]	Car use reduction intention[b]
Structural and socio-economic variables		(+) Semi-urban vs. urban areas[1,2]
		(+) Rural vs. urban areas[1,2]
		(−) Monthly net household income: 3,600 € − 5,000 € vs. < 1,300 € [1,2]
		(−) Monthly net household income: >5,000 € vs. < 1,300 € [1,2]
	(−) Female[1,2]	
	(+) Owning a car [1,2]	(+) Owning a car [1,2]
	(−) Child in household [1,2]	
	(+) Age [1,2]	(−) Age [1,2]
Psychological variables	(+) Car habits [1,2]	
	(−) Walking habits [1]	
	(−) Cycling habits [1,2]	
	(−) Public transport habits [1,2]	(+) Public transport habits [1,2]
	(−) Need satisfaction active travel [1,2]	
	(−) Need satisfaction public transport [1]	
	(−) Cycling attitudes[1,2]	(+) Cycling attitudes [1,2]
AE facets*	(+) Car dependence	(+) Car dependence
		(+) Environmental concern
	(−) House ownership preferences	
	(−) Car identity	

Notes. [1] significant in the first step only.
[1,2] significant in both steps of the hierarchical regressions.
* AE only included in the second step.
(−) Factor is negatively associated with the dependent variable.
(+) Factor is positively associated with the dependent variable.
[a] Linear regression: higher values represent higher past car use.
[b] Logistic regression: 0 = no intention to reduce car use, 1 = intention to reduce car use.

explained variance, albeit a very small one. The intentional model explained 12.5 % of the variance in step 1, which increased to 15.1 % in step 2.[6] This increase was higher than in the behavioural model, albeit on a very low level compared to the behavioural model.

4. Discussion

The goal of this paper was to explore the role of the socio-cultural context of automobility for car use (RQ1), differentiating between actual (past) and intended (future) car use to account for possible intention-behaviour gaps (RQ2). To this end, we applied the recently introduced concept of AE and investigated its role in explaining past car use and respective future reduction intentions in addition to socio-economic and psychological variables of interest.

4.1. Automobility Engagement: Car dependence and environmental concern are important

Regarding the role of the seven AE facets for car use, we found that perceived car dependence was a significant positive predictor of both past car use and car use reduction intentions. Environmental concern was a positive predictor of car use reduction intentions only, and house ownership preferences as well as car identity were additional negative predictors of past car use only. However, while these effects were significant in a statistical sense, they added only small amounts of explained variance in both past car use and car use reduction intentions. This indicates that while the AE facets have some relevance for both outcomes, other factors such as habits or car ownership are more important and possibly reduce or suppress the effects of the AE facets as shown by analyses where only AE variables were added (see footnotes 5 and 6). This finding is in line with our understanding of AE as a concept which operationalizes the wider socio-cultural context of automobility. Thus, while the role of AE is to capture this wider context, structural, socio-economic and psychological variables also emerge in this context and have a larger, more direct influence. Regarding the socio-economic and structural variables in the car use reduction intention model, car ownership, income and urbanization showed stronger significant associations with car use reduction intentions than the significant AE facets. As for the psychological variables, cycling attitudes showed stronger significant associations with car use reduction intentions than the significant AE facets. Considering the past car use model, socio-economic and structural variables showing stronger significant associations with past car use than some or all significant AE facets were age and car ownership. As for the psychological variables, car habits, need satisfaction by active travel, car ownership, cycling habits, public transport habits and cycling attitudes showed stronger significant associations with past car use than some or all significant AE facets. Nevertheless, AE adds to the amount of variance explained.

[6] With AE variables only, the intentional model explained 7.5 % of the variance. With structural and socio-economic variables only, the model explained 3.6 % of the variance. With psychological variables only, the model explained 9.7 % of the variance. Suppression effects were thus not as pronounced as in the behavioural model.

Out of the seven AE facets, car dependence was the most relevant and a positive predictor of both past car use and the intention to reduce car use in the future. This raises the question of whether people are actually dependent on the car in the sense that other modes of transport are not available to them (e.g., due to a lack of options or physical impairments), or to what extent car dependence is a subjective perception, in the sense that people may not be aware of alternatives or may not make the effort to change their mobility behaviour. In the second case, mechanisms to reduce cognitive dissonance could be at work. Here, dissonance could arise because car use reduction intentions are not followed by corresponding behaviour, which could consequently be alleviated by car dependence as a consonant cognition (e.g., McGrath, 2017). This connects with research by Anable (2005) identifying malcontented motorists who seek to justify the discrepancy between their goal to reduce car use and their actual car use. In addition, car dependence may also arise from the socio-cultural context and existing mobility norms, where driving is considered the common way of being mobile despite existing alternatives, particularly in Germany (Kallenbach, 2020; Mögele & Rau, 2020). This could be caused by a different cognitive mechanism, maybe one that is guided by the car-centred norm (both individual and collective) of mobility in which other modes of transportation do not immediately come to mind or are implicitly evaluated more negatively (see also the discussion around script-based mobility, e.g., Klöckner & Matthies, 2012).

Alternatively, reported car dependence may be due to no, few or incompatible alternatives, at least in people's current living situation. In line with this, our results showed that people stating the intention to reduce car use as well as reporting higher perceived car dependence were more likely to live in rural rather than urban areas. This implies that (some) people in rural areas wish to reduce their car use but are less able to do so, probably because there are fewer alternatives to the car available than in cities. This indicates that there are both perceived and more objective parts that contribute to car dependence which are not easy to disentangle because they influence each other and constitute a part of the socio-cultural (mobility) system people are embedded in (Mattioli et al., 2020; Sierra Muñoz et al., 2024).

Concern about the negative environmental consequences of car use was positively associated with the intention to reduce car use, but not with past car use. This is in line with other studies showing that environmental identity was related to pro-environmental intentions, but not or even negatively related to impactful pro-environmental behaviour such as reduced car driving (Culiberg et al., 2023; Moser & Kleinhückelkotten, 2018). This finding also relates back to research on the intention-behaviour gap indicating that intentions do not always translate into behaviour (Sheeran & Webb, 2016; Webb & Sheeran, 2006) and underlines the necessity to differentiate between intended and actual behaviour as we did in this study.

Car identity was a negative predictor of past car use. Thus, individuals claiming to identify more with their car reported lower levels of car use. In contrast, previous work by Gauer and colleagues (2022; 2023) found car identity to be positively related to interest in several mobility innovations such as electric and autonomous vehicles. Similarly, a study by Hoffmann and colleagues (2017) showed that pro-car identity was positively related to car use (but they used a different measure of car identity than we did). Our finding indicates that there might be a difference between the significance of owning a car and the frequency of using it. Some people seem to rather want to own a car to signal social status and prestige than to drive frequently. This underlines the cultural importance of owning a car as an important milestone in life (Biehl, 2021; Sachs, 1992). However, the interpretation of this finding is not straightforward since we also found car ownership to be positively associated with car use, which we discuss below.

Furthermore, we found house ownership preferences to negatively predict past car use, i.e., people who preferred living in detached houses outside city centres were also more likely to report lower levels of car use, a finding that was unexpected with regard to previous studies. Gauer and colleagues (2022) reported positive associations of this factor with interest in private forms of mobility (e.g., electric vehicles), and negative associations with collective forms of mobility (e.g., car sharing). Interestingly, house ownership preferences seem to be a facet of AE that does not emerge in all cultural contexts and sometimes overlaps with other factors like car dependence (e.g., in Canada, Gauer et al., 2023). Our finding could be interpreted as an indication that (some) people preferring to live in the countryside are willing to make efforts to reduce their car use although there might only be few alternatives at their disposal. This indication is supported by the finding that living outside urban areas was associated with the intention to reduce car use, which we discuss below.

Finally, for three facets of AE, namely driving aversion, alternative travel norms, and empowerment we did not find significant relationships with the dependent variables under investigation. Previous studies (Gauer et al., 2022; Gauer et al., 2023) were able to link not identical, but similarly constructed factors with interest in shared, automated and electric vehicles. This points out that the facets of AE vary in relevance depending on the target behaviour of study.

Coming to conclusions with regard to AE, we find that including the concept into car-centred mobility studies adds value. However, based on our findings, we also conclude that more methodological work is needed to further validate the effects of the seven AE facets. This includes possibly reconsidering the measurement of some of the AE facets. This is underscored by the result that the CFA fit indices for AE were not ideal and that the factor structure that we employed slightly varies from the one identified by Gauer and colleagues (2022; 2023) in previous studies. Nevertheless, using AE as an operationalisation of the socio-cultural context of automobility has had some added value for explaining past car use and car use reduction intentions in our study.

4.2. Control variables: Important role of gender, car ownership and habits

Among the included structural and socio-economic variables, owning a car and the respondents' age were positively associated with past car use and positively (car ownership) and negatively (age) associated with the intention to reduce car use. Gender and the presence of a child in the household were negatively associated with past car use (i.e., women and people with children used cars less), while the degree of urbanisation (positive) and household income (negative) were associated with car use reduction intentions (i.e., people in less urbanised areas and with lower income were more likely to state car use reduction intentions). Regarding the

psychological variables, transportation mode habits (positive for car habits, negative for alternative transportation habits) and the degree to which individual flexibility and independence needs are perceived to be met by alternative transport modes (negative) were associated with past car use. Furthermore, public transport habits and cycling attitudes were negatively associated with past car use and positively associated with car use reduction intentions.

With regard to gender, we found that identifying as female was associated with lower past car use. This is in line with previous studies showing that women are more inclined to travel sustainably than men and that men use cars more often (Polk, 2003, 2004). This finding may be linked to gendered roles in society, i.e., that women do care work more frequently than men, which has been shown to be associated with more diverse travel patterns (Craig & van Tienoven, 2019; Miralles-Guasch et al., 2016). Apart from this, gender had no effect on the intention to reduce car use, thus, men and women seemed to be equally compelled to reduce their car use, while previous research showed that women are more willing to reduce their car use (Polk, 2003). Our results underline the necessity of gender-responsive transport policies and transport planning to accommodate the different needs and preferences of diverse genders in the transport system (Brooks et al., 2023; Kronsell et al., 2023; Kronsell et al., 2020; United Nations Economic Commission for Europe [UNECE], 2024).

Previous research has shown that the presence of a car in the household was related to more care use and intentions to use a car (e.g., Dütschke et al., 2022; Mattioli et al., 2020). Contrarily, we found that car ownership was in fact positively related to both past car use and the intention to reduce car use during the next six months. This could indicate that some people may reluctantly own and use a car – an observation that links back to Anable's (2005) malcontented motorists referred to above. Especially for these people, it is relevant to reduce both perceived and real barriers to car use reduction. Examples on how this could be achieved will be outlined below.

Mobility behaviour has been shown to be linked to strong habits, which can make it difficult to change behaviour (Dütschke et al., 2022; Lanzini & Khan, 2017; Rejeb et al., 2023). We replicated these findings by showing that car habits are the strongest predictor of past car use and habits of using alternative modes of transportation are negatively associated with past car use. Furthermore, habitually using public transport was associated with a higher probability of intending to reduce car use in our study. In line with previous research, this indicates again that establishing new habits is crucial when it comes to sustainable mobility behaviour (Gärling & Axhausen, 2003; Garvill et al., 2003).

4.3. Limitations and future research

Comparing past behaviour and future intentions is a strength of our study, since similar studies often focus on either one of them. Nevertheless, one can ask about the validity of survey methods for mobility data. Although our data relied on self-reports, we are confident in their accuracy because we specifically restricted the report period to the week preceding survey participation to facilitate memory. However, since data collection stretched over a few weeks, not all participants reported on their mobility behaviour during the same week, which could be a source of bias in our data (e.g., differences in mobility behaviour could in part be due to changing weather conditions rather than the factors measured in this study). We therefore suggest that future research use more objective methods for collecting behavioural data (e.g., through mobility diaries or tracking applications).

We recruited participants in a way that ensured a representative sample of the populations of Baden-Württemberg and Mecklenburg-Western Pomerania, to be able to better account for differences between different degrees of urbanisation. Due to different exclusion criteria outlined above, the sample was slightly younger and included more men than the population of these two states, and the income distributions were slightly skewed, too. This means that generalisability is limited to the two German states with these caveats in mind. The results might not generalise to the whole German population (which our study was not designed to deliver), so one next step should be a nationally representative survey trying to replicate the results of the present study.

The focus of this study was on the relevance of AE for past car use and car use reduction intentions. Therefore, our models needed to be parsimonious and lack a few "classic" variables that are theorized to predict intentions, such as perceived behavioural control (Ajzen, 1991), personal norms (Schwartz, 1977) or different kinds of value orientations (Stern et al., 1999). This might be a reason for why the amount of explained variance was smaller in the intentional model compared to the behavioural model. Since we focussed on the role of AE rather than maximising the amount of explained variance in the models, we believe that our approach served the purpose of this study well while keeping the length of the questionnaire manageable.

As indicated above, not all of our findings on AE are fully in line with previous research and the AE studies so far that employ the current conceptualisation have pointed to some variation in the factor structure of the concept. Future research would be helpful to broaden the view on more dimensions of the measurement which are not yet well assessed. This research could then be a basis for the extension of AE as an effective quantitative measurement of the socio-cultural context.

5. Policy implications

The results of the present study indicate that the socio-cultural context as operationalised by AE is important for car use. However, some structural, socio-economic and psychological factors have a larger immediate impact. These factors all contribute to the socio-cultural context people are embedded in and need to be addressed to accelerate mobility transitions, i.e., the question of how people will move collectively and individually in a post- or low-carbon future (Temenos et al., 2017). For an example of how such a transition to a low-carbon transport system could look like, we refer to Geels (2012). Since the transitions to more sustainable and just mobilities are considered inherently political (Nikolaeva et al., 2019), policies building on our results need to take into account the structural, socio-economic as well as psychological antecedents of car use. In summary, it is important to provide infrastructure for alternative

transportation modes, particularly active mobility (e.g., foot and bike paths) as well as public transport (e.g., on-demand PT services). In addition, leveraging psychological factors such as mobility-related norms, concern about the negative environmental consequences of car use or perceived car dependence can be a fruitful tool for policies geared towards lower-carbon mobility. Below we derive more detailed policy implications from our results.

It is important to address the more objective part of car dependence by creating or increasing the offer of alternative transport modes, particularly in rural areas. Our results showed that many people in rural areas want to reduce their car use but lack the alternatives. On-demand public transport services could prove useful particularly in rural areas to counter the critique that demand for alternative transport modes in those areas is too low to offer regular services (Hansen & Sener, 2023). Furthermore, simplifying tariff structures for alternative transport services and offering trial periods can help to gather first experiences with new transportation modes and start breaking existing driving habits (Münsch & Lell, 2024), another strong predictor of car use in our study. In urban areas, where public transport infrastructure is often better than in rural areas, it may help to improve the existing or create new infrastructure for walking and cycling to reduce car use. Our results further showed that the extent to which people perceive alternative transport modes to be able to fulfil their personal needs for flexibility and independence was associated with driving less. Creating or improving these alternatives and subsequently raising awareness about them could help to increase the extent to which people perceive a compatibility between their mobility needs and alternative transport modes and subsequently lead to increased usage. Previous research has shown that more experience with public transport may lead to more positive perceptions of public transport accessibility (Lukina et al., 2023).

Once new offers are in place, it is therefore important to address the perceived part of car dependence by raising awareness about the existence of alternatives and the negative environmental consequences of car use – a factor that was significantly related to car use reduction intentions in our study. In addition, further elements are important to communicate, such as the social costs of cars (Gössling et al., 2022) and the positive side-effects of more active travel modes (van den Bijgaart et al., 2024). In particular, letting people experience the positive side of switching to active travel mode can prove useful (Harris & Crone, 2021).

This knowledge and experience can be gained through personalised transport planning (PTP; Münsch & Lell, 2024). It includes individual consulting on routes, stops and transportation modes with regard to individual mobility needs and has been shown to be effective in different meta-analyses (Graham-Rowe et al., 2011; Kuss & Nicholas, 2022). Drivers with strong driving habits or a strong moral motivation to reduce car use can be a good first target group (Graham-Rowe et al., 2011).

In line with Sandberg (2021), interplay and collaboration between all societal actors is needed to advance transitions in the mobility system. And these actors, e.g., politicians, company leaders, heads of organizations and people in their different societal roles and positions (see Hampton & Whitmarsh, 2023 for a review of these roles) need to be aware of the barriers that prevent change and work together to address structural barriers by policies and a change of the environment (i.e., disruption; Kivimaa et al., 2021), which then guide people to successful changes. As a starting point, municipalities could offer PTP for citizens at low costs or even free of charge. Companies could then motivate their employees to participate in PTP by offering a lottery based on the resulting behaviour change on commuting trips.

The effectiveness of PTP is even higher when improvements around alternative transportation modes are stressed (Graham-Rowe et al., 2011), which highlights the need to really work on these improvements, particularly by municipalities, public transport operators, and different levels of government. Combining measures can be particularly fruitful as indicated by research on policy packaging (Thaller et al., 2021; Thaller et al., 2024). Constructing infrastructures that promote alternative transport modes and reduce the attractiveness of owning or using a car can contribute to reshaping the norm of mobility, away from the private car towards alternative modes (see Mulder et al., 2024). This, in turn, may gradually reduce people's perceived car dependence, even in rural areas. At the end of this journey, a new mobility "script" (Klöckner & Matthies, 2012) could emerge, one that centres alternative transportation rather than the privately owned car.

6. Conclusion

In this study, we applied AE to operationalise the socio-cultural context of automobility and conducted regression analyses to predict past car use and car use reduction intentions. We found that perceived car dependence and environmental concern are important AE facets. At the same time, factors like car ownership and transportation habits showed larger impacts, possibly suppressing AE effects. Well-designed policy measures to reduce car use should address car dependence, which is a question of (re) constructing infrastructures in favour of more active mobility and public transport and of strengthening environmental concern. Lastly, our findings also point out that mobility behaviour is intertwined with other fields of policy making such as housing. This is particularly apparent in the findings regarding perceived car dependence, degree of urbanisation and house ownership preferences. These results imply that (some) people living in rural areas wish to reduce their car use but are less able to do so, possibly because of fewer available alternatives. This might lead to higher perceived car dependence and makes the link between mobility and housing policies apparent, which should be elaborated on by future research.

CRediT authorship contribution statement

Marvin Helferich: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Josephine Tröger:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Elisabeth Dütschke:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data and analysis code used for this paper are available on OSF: https://osf.io/p6emd/?view_only=97afb5a9d61c40a6b2b1410eea043045.

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Appendix A. Item List

Construct	Items	Source
Perceived car dependence[1]	Owning a car is important to me. I need a car to fulfil my everyday obligations. It is easy to plan my day without a car. It is difficult for me to access my friends and family without a car. In my area, every household needs a car. I need a car for my job. Sometimes I feel too dependent on my car.	(Gauer et al., 2023; Kelber, 2021)
Car identity[1]	Owning a car shows that I am successful. I want my car to represent my personality. You can learn a lot about someone by looking at their car. Buying a car is an important milestone in life. A car is just a way to get around and nothing more. I often feel emotionally connected to cars.	
Alternative travel norms[1]	It is important that I live in a neighbourhood where I can walk to shops and other destinations. It is important for me to live in a place where I can easily access transit. I know a lot of people that use public transit (bus, subway, etc.). Many of my friends are trying to reduce their car use. Many of my friends commonly walk or cycle to get around.	
Environmental concern[1]	Air pollution from cars is a serious problem. Car use is causing climate change. Cars, streets and parking take away too much public space.	
Driving aversion[1]	If possible, I'd prefer not to own a car. Driving is stressful. The idea of driving makes me tired.	
Empowerment[1]	I feel in control when I am driving. Driving makes me feel free. Being inside a car feels like a safe, protected space. Widespread car use is needed to support jobs and the economy.	
House ownership preferences[1]	My ideal situation is to live in a private, detached home (not apartment or townhome). It is important for me to own my home. I prefer to live away from urban centres.	
Habits[2]	Which means of transportation are you most likely to use in each of the following situations? If you would use several means of transportation, please refer to the largest part of the route. You want to visit a friend in a nearby town (5–10 km). You want to go shopping in the city center. You want to go to a bar / to the cinema / to a theater in the evening. You want to do a daytrip to a destination that is 50–100 km away. You want to buy groceries for the day. You want to get to work. You want to go on a week's vacation in a faraway German city. You want to go to the gym / do sports. You want to bring your own or children in your family to school, to childcare or to close-by activities. You want to go on a business trip (approx. 250 km). You have an appointment with your family doctor.	(Klosterkamp et al., 2022)

(*continued on next page*)

(*continued*)

Construct	Items	Source
Attitudes towards public transport[3]	Using public transport for the majority of my trips is / would be … for me. If you do not use public transportation regularly, please imagine what it would be like for you to regularly travel by public transport. • good – bad • pleasant – unpleasant • enjoyable – unenjoyable • useful – useless	(Ajzen, 1991, 2006)
Attitudes towards taking the bicycle[3]	Using the bicycle for the majority of my trips is / would be … for me. If you do not use the bicycle regularly, please imagine what it would be like for you to regularly travel by bicycle. • good – bad • pleasant – unpleasant • enjoyable – unenjoyable • useful – useless	(Ajzen, 1991, 2006)
Flexibility and independence needs met by public transport[1]	Public transport takes me wherever I want to go. With public transport, I am not dependent on others. With public transport, I can determine my own route. Public transport is useful for special outings (e.g., weekend trips). With public transportation, I have sufficient transport capacity for me.	(Dütschke et al., 2015)
Flexibility and independence needs met by walking or biking[1]	I can get anywhere I want to go by bicycle or on foot. When I cycle or walk, I am not dependent on others. When I cycle or walk, I can determine my own route. Cycling or walking is useful for special outings (e.g., weekend trips). If I cycle or walk, I have sufficient transport capacity for me.	(Dütschke et al., 2015)

[1] Response scale: 1 = completely disagree, 2 = disagree, 3 = Partly disagree partly agree, 4 = agree, 5 = completely agree.

[2] Response options: On foot, Bicycle, Public transport (incl. regional trains), Long distance train / bus, Car with internal combustion engine, Battery-electric car (no hybrid), Carsharing, This situation is not relevant for me.

[3] Semantic differentials with five levels each.

References

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Ajzen, I. (2006). *Constructing a Theory of Planned Behavior Questionnaire*. http://people.umass.edu/~aizen/pdf/tpb.measurement.pdf.

Anable, J. (2005). 'Complacent Car Addicts' or 'Aspiring Environmentalists'? Identifying travel behaviour segments using attitude theory. *Transport Policy, 12*(1), 65–78. https://doi.org/10.1016/j.tranpol.2004.11.004

Baden-Württemberg State Ministry. (2022). *Baden-Württemberg und die anderen Länder*. https://www.baden-wuerttemberg.de/?id=2093&compare=MV&faktid=137.

Biehl, B. (2021). Luxury in Germany: Sick Cars and Healthy Bodies. *Society, 58*(5), 385–391. https://doi.org/10.1007/s12115-021-00610-x

Bláfoss Ingvardson, J., Kaplan, S., de Abreu e Silva, J., Di Ciommo, F., Shiftan, Y., & Nielsen, O. A. (2020). Existence, relatedness and growth needs as mediators between mode choice and travel satisfaction: Evidence from Denmark. *Transportation, 47*(1), 337–358. https://doi.org/10.1007/s11116-018-9886-3

Bouscasse, H., Joly, I., & Bonnel, P. (2018). How does environmental concern influence mode choice habits? A mediation analysis. *Transportation Research Part D: Transport and Environment, 59*, 205–222. https://doi.org/10.1016/j.trd.2018.01.007

Brooks, L., Godward, M., & Hoggard, M. (2023). Do transport professionals GET IT? The Gender Equality Toolkit in Transport. *Transportation Research Procedia, 72*, 2700–2707. https://doi.org/10.1016/j.trpro.2023.11.810

Cai, Y., Ramakrishnan, R., & Rahimi, K. (2021). Long-term exposure to traffic noise and mortality: A systematic review and meta-analysis of epidemiological evidence between 2000 and 2020. *Environmental Pollution (Barking, Essex : 1987)*, *269*, 116222. DOI: 10.1016/j.envpol.2020.116222.

Carse, A., Goodman, A., Mackett, R. L., Panter, J., & Ogilvie, D. (2013). The factors influencing car use in a cycle-friendly city: The case of Cambridge. *Journal of Transport Geography, 28*(100), 67–74. https://doi.org/10.1016/j.jtrangeo.2012.10.013

Chen, J., & Hoek, G. (2020). Long-term exposure to PM and all-cause and cause-specific mortality: A systematic review and meta-analysis. *Environment International, 143*, Article 105974. https://doi.org/10.1016/j.envint.2020.105974

Cohen, J. (1992). A Power Primer. *Psychological Bulletin, 112*(1), 155–159.

Craig, L., & van Tienoven, T. P. (2019). Gender, mobility and parental shares of daily travel with and for children: A cross-national time use comparison. *Journal of Transport Geography, 76*, 93–102. https://doi.org/10.1016/j.jtrangeo.2019.03.006

Culiberg, B., Cho, H., Kos Koklic, M., & Zabkar, B. (2023). From car use reduction to ride-sharing: The relevance of moral and environmental identity. *Journal of Consumer Behaviour, 22*, 396–407. https://doi.org/10.1002/cb.2080

Destatis (2023). *Straßenverkehr: Dominanz des Autos ungebrochen*. https://www.destatis.de/Europa/DE/Thema/Verkehr/Auto.html.

Domarchi, C., Tudela, A., & González, A. (2008). Effect of attitudes, habit and affective appraisal on mode choice: An application to university workers. *Transportation, 35*(5), 585–599. https://doi.org/10.1007/s11116-008-9168-6

Dütschke, E., Engel, L., Theis, A., & Hanss, D. (2022). Car driving, air travel or more sustainable transport? Socio-psychological factors in everyday mobility and long-distance leisure travel. *Travel Behaviour and Society, 28*, 115–127. https://doi.org/10.1016/j.tbs.2022.03.002

Dütschke, E., Wietschel, M., Globisch, J., Schneider, U., Schlosser, C., Sevin, D., & Wilhelm, T. (2015). *Elektromobilität in Haushalten und Flotten: Was beeinflusst die Kauf- und Nutzungsbereitschaft.*. https://doi.org/10.24406/publica-fhg-297552

Eurostat. (2023). *Degree of urbanisation*. https://ec.europa.eu/eurostat/web/degree-of-urbanisation/background.

Federal Environment Agency. (2023). *Fahrleistungen, Verkehrsleistungen und Modal Split in Deutschland*. https://www.umweltbundesamt.de/daten/verkehr/fahrleistungen-verkehrsaufwand-modal-split#fahrleistung-im-personen-und-guterverkehr.

Federal Environment Agency. (2024a). *Klimaschutz im Verkehr*. https://www.umweltbundesamt.de/themen/verkehr/klimaschutz-im-verkehr#rolle.

Federal Environment Agency. (2024b). *Mobilität privater Haushalte*. https://www.umweltbundesamt.de/daten/private-haushalte-konsum/mobilitaet-privater-haushalte#-hoher-motorisierungsgrad.

Gardner, B., & Abraham, C. (2008). Psychological correlates of car use: A meta-analysis. *Transportation Research Part F: Traffic Psychology and Behaviour, 11*(4), 300–311. https://doi.org/10.1016/j.trf.2008.01.004

Gärling, T., & Axhausen, K. W. (2003). Introduction: Habitual travel choice. *Transportation, 30*(1), 1–11.
Garvill, J., Marell, A., & Nordlund, A. (2003). Effects of increased awareness on choice of travel mode. *Transportation, 30*(1), 63–79.
Gatersleben, B., Murtagh, N., & White, E. (2013). Hoody, goody or buddy? How travel mode affects social perceptions in urban neighbourhoods. *Transportation Research Part F: Traffic Psychology and Behaviour, 21*, 219–230. https://doi.org/10.1016/j.trf.2013.09.005
Gauer, V. H., Axsen, J., Dütschke, E., & Long, Z. (2022). Exploring "automobility engagement": A predictor of shared, automated, and electric mobility interest? *Transportation Research Part D: Transport and Environment, 109*, 1–17. https://doi.org/10.1016/j.trd.2022.103353
Gauer, V. H., Axsen, J., Dütschke, E., Long, Z., & Kelber, A. (2023). Who is more attached to their car? Comparing automobility engagement and response to shared, automated and electric mobility in Canada and Germany. *Energy Research & Social Science, 99*, Article 103048. https://doi.org/10.1016/j.erss.2023.103048
Geels, F. W. (2012). A socio-technical analysis of low-carbon transitions: Introducing the multi-level perspective into transport studies. *Journal of Transport Geography, 24*, 471–482. https://doi.org/10.1016/j.jtrangeo.2012.01.021
Gössling, S., Kees, J., & Litman, T. (2022). The lifetime cost of driving a car. *Ecological Economics, 194*, Article 107335. https://doi.org/10.1016/j.ecolecon.2021.107335
Graham-Rowe, E., Skippon, S., Gardner, B., & Abraham, C. (2011). Can we reduce car use and if so, how? A review of available evidence. *Transportation Research Part a: Policy and Practice, 45*, 401–418. https://doi.org/10.1016/j.tra.2011.02.001
Gross, M. (2023). Car driving as inverted quarantine and the sensory response to collective threats: Challenges for public transport. *The Senses and Society, 18*(3), 241–253. https://doi.org/10.1080/17458927.2023.2197684
Hagman, O. (2003). Mobilizing meanings of mobility: Car users' constructions of the goods and bads of car use. *Transportation Research Part D: Transport and Environment, 8*, 1–9.
Hampton, S., & Whitmarsh, L. (2023). Choices for climate action: A review of the multiple roles individuals play. *One Earth, 6*(9), 1157–1172. https://doi.org/10.1016/j.oneear.2023.08.006
Hansen, T., & Sener, I. N. (2023). Strangers On This Road We Are On: A Literature Review of Pooling in On-Demand Mobility Services. *Transportation Research Record: Journal of the Transportation Research Board, 2677*(3), 1368–1381. https://doi.org/10.1177/03611981221123801
Harris, M. A., & Crone, D. (2021). Using gamification to encourage active travel. *Journal of Transport & Health, 23*, Article 101275. https://doi.org/10.1016/j.jth.2021.101275
Helferich, M., Thøgersen, J., & Bergquist, M. (2023). Direct and mediated impacts of social norms on pro-environmental behavior. *Global Environmental Change, 80*, Article 102680. https://doi.org/10.1016/j.gloenvcha.2023.102680
Hiscock, R., Macintyre, S., Kearns, A., & Ellaway, A. (2002). Means of transport and ontological security: Do cars provide psycho-social benefits to their users? *Transportation Research Part D: Transport and Environment, 7*, 119–135.
Hoffmann, C., Abraham, C., White, M. P., Ball, S., & Skippon, S. (2017). What cognitive mechanisms predict travel mode choice? A systematic review with meta-analysis. *Transport Reviews, 37*(5), 631–652.
Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1–55. https://doi.org/10.1080/10705519909540118
infas, DLR, IVT, & infas 360. (2018). *Mobility in Germany (on behalf of the BMVI)*. https://bmdv.bund.de/SharedDocs/DE/Anlage/G/mid-2017-short-report.pdf?_blob=publicationFile.
Ivanova, D., Barrett, J., Wiedenhofer, D., Macura, B., Callaghan, M., & Creutzig, F. (2020). Quantifying the potential for climate change mitigation of consumption options. *Environmental Research Letters, 15*(9), 93001. https://doi.org/10.1088/1748-9326/ab8589
Ivanova, D., Stadler, K., Steen-Olsen, K., Wood, R., Vita, G., Tukker, A., & Hertwich, E. G. (2016). Environmental Impact Assessment of Household Consumption. *Journal of Industrial Ecology, 20*(3), 526–536. https://doi.org/10.1111/jiec.12371
Javaid, A., Creutzig, F., & Bamberg, S. (2020). Determinants of low-carbon transport mode adoption: Systematic review of reviews. *Environmental Research Letters, 15*(10), Article 103002. https://doi.org/10.1088/1748-9326/aba032
Kallenbach, T. (2020). Narratives of urban mobility in Germany: On the threshold of a departure from the car-centered city? *Sustainability: Science. Practice and Policy, 16*(1), 197–207. https://doi.org/10.1080/15487733.2020.1799625
Kelber, A. (2021). *On the way to a sustainable mobility system: An empirical evaluation of the automobility engagement scale.* Unpublished Bachelor's Thesis at the Faculty of Psychology, University of Mannheim.
Kivimaa, P., Laasko, S., Lonkila, A., & Kaljonen, M. (2021). Moving beyond disruptive innovation: A review of disruption in sustainability transitions. *Environmental Innovation and Societal Transitions, 38*, 110–126. https://doi.org/10.1016/j.eist.2020.12.001
Klöckner, C. A., & Matthies, E. (2012). Two Pieces of the Same Puzzle? Script-Based Car Choice Habits Between the Influence of Socialization and Past Behavior 1. *Journal of Applied Social Psychology, 42*(4), 793–821. https://doi.org/10.1111/j.1559-1816.2011.00817.x
Klosterkamp, M., Papendieck, P., & Francke, A. (2022). ÖPNV für alle? Erwartungen an das 9-Euro-Ticket vor Start der Maßnahme. *Internationales Verkehrswesen, 74*(3), 78–81.
Koller, K., Pankowska, P. K., & Brick, C. (2023). Identifying bias in self-reported pro-environmental behavior. *Current Research in Ecological and Social Psychology, 4*, Article 100087. https://doi.org/10.1016/j.cresp.2022.100087
Kronsell, A., Dymén, C., Smidfelt Rosqvist, L., Stepanova, O., & Winslott Hiselius, L. (2023). Critical masculine and feminine norms in sustainable municipal transport policies and planning. *Journal of Environmental Policy & Planning, 25*(6), 663–675. https://doi.org/10.1080/1523908X.2023.2248914
Kronsell, A., Dymén, C., Smidfelt Rosqvist, L., & Winslott Hiselius, L. (2020). Masculinities and femininities in sustainable transport policy: A focus on Swedish municipalities. *NORMA, 15*(2), 128–144. https://doi.org/10.1080/18902138.2020.1714315
Kuhnimhof, T., Wirtz, M., & Manz, W. (2012). Decomposing Young Germans' Altered Car Use Patterns. *Transportation Research Record: Journal of the Transportation Research Board, 2320*(1), 64–71. https://doi.org/10.3141/2320-08
Kuss, P., & Nicholas, K. A. (2022). A dozen effective interventions to reduce car use in European cities: Lessons learned from a meta-analysis and transition management. *Case Studies on Transport Policy, 10*(3), 1494–1513. https://doi.org/10.1016/j.cstp.2022.02.001
Lanzini, P., & Khan, S. A. (2017). Shedding light on the psychological and behavioral determinants of travel mode choice: A meta-analysis. *Transportation Research Part F: Traffic Psychology and Behaviour, 48*, 13–27. https://doi.org/10.1016/j.trf.2017.04.020
Le, H. T. K., & Carrel, A. L. (2021). Happy today, satisfied tomorrow: Emotion—satisfaction dynamics in a multi-week transit user smartphone survey. *Transportation, 48*(1), 45–66. https://doi.org/10.1007/s11116-019-10042-6
Lucas, K., & Jones, P. (2009). *The car in British society*. https://www.racfoundation.org/wp-content/uploads/car_in_british_society-lucas_et_al-170409.pdf.
Lukina, A. V., Sidorchuk, R. R., Mkhitaryan, S. V., Skorobogatykh, I. I., & Musatova, Z. B. (2023). A New Combined Model for Assessing the Perceived Accessibility of Public Transport by Consumers in the Megapolis. *Emerging Science Journal, 7*(6), 2239–2259. https://doi.org/10.28991/ESJ-2023-07-06-023
Mattioli, G. (2013). Car Dependence, Sustainability and the Transport Policy Stalemate: The Potential Trade-offs between Intra- and Inter-generational Equity. *The International Journal of Sustainability Policy and Practice, 8*(1), 45–57. https://doi.org/10.18848/2325-1166/CGP/v08i01/55416
Mattioli, G., Roberts, C., Steinberger, J. K., & Brown, A. (2020). The political economy of car dependence: A systems of provision approach. *Energy Research & Social Science, 66*, Article 101486. https://doi.org/10.1016/j.erss.2020.101486
McCarthy, L., Delbosc, A., Currie, G., & Molloy, A. (2017). Factors influencing travel mode choice among families with young children (aged 0–4): A review of the literature. *Transport Reviews, 37*(6), 767–781. https://doi.org/10.1080/01441647.2017.1354942
McGrath, A. (2017). Dealing with dissonance: A review of cognitive dissonance reduction. *Social and Personality Psychology Compass, 11*. https://doi.org/10.1111/spc3.12362
Miner, P., Smith, B. M., Jani, A., McNeill, G., & Gathorne-Hardy, A. (2024). Car harm: A global review of automobility's harm to people and the environment. *Journal of Transport Geography, 115*, Article 103817. https://doi.org/10.1016/j.jtrangeo.2024.103817
Miralles-Guasch, C., Melo, M. M., & Marquet, O. (2016). A gender analysis of everyday mobility in urban and rural territories: From challenges to sustainability. *Gender, Place & Culture, 23*(3), 398–417. https://doi.org/10.1080/0966369X.2015.1013448

Mögele, M., & Rau, H. (2020). Cultivating the "car state": A culturally sensitive analysis of car-centric discourses and mobility cultures in Southern Germany. *Sustainability: Science, Practice and Policy, 16*(1), 15–28. https://doi.org/10.1080/15487733.2020.1756188

Moser, S., & Kleinhückelkotten, S. (2018). Good Intents, but Low Impacts: Diverging Importance of Motivational and Socioeconomic Determinants Explaining Pro-Environmental Behavior, Energy Use, and Carbon Footprint. *Environment and Behavior, 50*(6), 626–656. https://doi.org/10.1177/0013916517710685

Mulder, L. B., Kurz, T., Prosser, A. M., & Fonseca, M. A. (2024). The presence of laws and mandates is associated with increased social norm enforcement. *Journal of Economic Psychology, 101*, Article 102703. https://doi.org/10.1016/j.joep.2024.102703

Münsch, M., & Lell, O. (2024). Anreize zur Förderung eines nachhaltigen Mobilitätsverhaltens: Stand der Forschung zu Wirkung und Einsatzmöglichkeiten materieller, immaterieller und spielerischer Anreize. https://www.umweltbundesamt.de/sites/default/files/medien/11850/publikationen/03_2024_texte_anreize_zur_foerderung.pdf.

Nikolaeva, A., Adey, P., Cresswell, T., Lee, J. Y., Nóvoa, A., & Temenos, C. (2019). Commoning mobility: Towards a new politics of mobility transitions. *Transactions of the Institute of British Geographers, 44*(2), 346–360. https://doi.org/10.1111/tran.12287

Polk, M. (2003). Are women potentially more accommodating than men to a sustainable transportation system in Sweden? *Transportation Research Part D: Transport and Environment, 8*, 75–95.

Polk, M. (2004). The influence of gender on daily car use and on willingness to reduce car use in Sweden. *Journal of Transport Geography, 12*, 185–195. https://doi.org/10.1016/j.jtrangeo.2004.04.002

R Core Team. (2023). *R: A language and environment for statistical computing [Computer software]*. R foundation for statistical computing.

Rejeb, R., Bouscasse, H., Chalabaev, A., & Mathy, S. (2023). What is the role of active mobility habits in the relationship between self-determination and modal shift intentions? A mediation analysis. *Transportation Research Part F: Traffic Psychology and Behaviour, 99*, 289–305. https://doi.org/10.1016/j.trf.2023.10.004

Sachs, W. (1992). *For Love of the Automobile: Looking Back into the History of Our Desires* [Liebe zum Automobil. English], Reprint 2020). University of California Press. https://www.degruyter.com/isbn/9780520354739 DOI: 10.1525/9780520354739.

Sandberg, M. (2021). Sufficiency transitions: A review of consumption changes for environmental sustainability. *Journal of Cleaner Production, 293*, Article 126097. https://doi.org/10.1016/j.jclepro.2021.126097

Schuster, H., van der Noll, J., & Rohmann, A. (2023). Orientation towards the common good in cities: The role of individual urban mobility behavior. *Journal of Environmental Psychology, 91*, Article 102125. https://doi.org/10.1016/j.jenvp.2023.102125

Schwartz, S. H. (1977). Normative influences on altruism. In L. Berkowitz (Ed.), *Advances in experimental social psychology* ((10th ed.).). Academic Press.

Semenescu, A., Gavreliuc, A., & Sârbescu, P. (2020). 30 Years of soft interventions to reduce car use – A systematic review and meta-analysis. *Transportation Research Part D: Transport and Environment, 85*, Article 102397. https://doi.org/10.1016/j.trd.2020.102397

Sheeran, P., & Webb, T. L. (2016). The Intention-Behavior Gap. *Social and Personality Psychology Compass, 10*(9), 503–518. https://doi.org/10.1111/spc3.12265

Sierra Muñoz, J., Duboz, L., Pucci, P., & Ciuffo, B. (2024). Why do we rely on cars? Car dependence assessment and dimensions from a systematic literature review. *European Transport Research Review, 16*(1). https://doi.org/10.1186/s12544-024-00639-z

Silvestri, A., Foudi, S., & Galarraga, I. (2022). How to get commuters out of private cars? Exploring the role of perceived social impacts in mode choice in five European countries. *Energy Research & Social Science, 92*, Article 102811. https://doi.org/10.1016/j.erss.2022.102811

Simons, D., Clarys, P., de Bourdeaudhuij, I., de Geus, B., Vandelanotte, C., & Deforche, B. (2013). Factors influencing mode of transport in older adolescents: A qualitative study. *BMC Public Health, 13*(323), 1–10.

Smart, M. J., & Klein, N. J. (2020). Disentangling the role of cars and transit in employment and labor earnings. *Transportation, 47*(3), 1275–1309. https://doi.org/10.1007/s11116-018-9959-3

Sovacool, B. K. (2017). Experts, theories, and electric mobility transitions: Toward an integrated conceptual framework for the adoption of electric vehicles. *Energy Research & Social Science, 27*, 78–95. https://doi.org/10.1016/j.erss.2017.02.014

Sovacool, B. K., & Axsen, J. (2018). Functional, symbolic and societal frames for automobility: Implications for sustainability transitions. *Transportation Research Part a: Policy and Practice, 118*, 730–746. https://doi.org/10.1016/j.tra.2018.10.008

Steg, L. (2005). Car use: Lust and must. Instrumental, symbolic and affective motives for car use. *Transportation Research Part a: Policy and Practice, 39*(2–3), 147–162. https://doi.org/10.1016/j.tra.2004.07.001

Stern, P. C., Dietz, T., Abel, T., Guagnano, G. A., & Kalof, L. (1999). A value-belief-norm theory of support for social movements: The case of environmentalism. *Human Ecological Review, 6*(2), 81–97.

Temenos, C., Nikolaeva, A., Schwanen, T., Cresswell, T., Sengers, F., Watson, M., & Sheller, M. (2017). Theorizing Mobility Transitions: An interdisciplinary conversation. *Transfers: Interdisciplinary Journal of Mobility Studies, 7*(1), 113–129. https://doi.org/10.3167/TRANS.2017.070109

Thaller, A., Posch, A., Dugan, A., & Steininger, K. (2021). How to design policy packages for sustainable transport: Balancing disruptiveness and implementability. *Transportation Research Part D: Transport and Environment, 91*, Article 102714. https://doi.org/10.1016/j.trd.2021.102714

Thaller, A., Wicki, M., Fleiß, E., Maier, R., & Posch, A. (2024). Pushing low-carbon mobility: A survey experiment on the public acceptance of disruptive policy packages. *Climate Policy, 1–14*. https://doi.org/10.1080/14693062.2024.2302322

United Nations Economic Commission for Europe. (2024). *Gender and transport*. https://unece.org/transport/gender-and-transport.

van den Bijgaart, I., Klenert, D., Mattauch, L., & Sulikova, S. (2024). Healthy climate, healthy bodies: Optimal fuel taxation and physical activity. *Economica, 91*(361), 93–122. https://doi.org/10.1111/ecca.12497

van Eenoo, E., Fransen, K., & Boussauw, K. (2022). Perceived car dependence and multimodality in urban areas in Flanders (Belgium). *European Journal of Transport and Infrastructure Research, 22*(1), 42–62. https://doi.org/10.18757/ejtir.2022.22.1.6044

Webb, T. L., & Sheeran, P. (2006). Does changing behavioral intentions engender behavior change? A meta-analysis of the experimental evidence. *Psychological Bulletin, 132*(2), 249–268. https://doi.org/10.1037/0033-2909.132.2.249