Extending the theory of planned behavior to predict and nudge toward the subscription to a public transport ticket

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Abstract

Introduction: To reduce pollution from motorized private cars, a modal shift toward more sustainable modes, such as public transport, is desired. A first step to achieving this is the subscription to a public transport ticket. It was investigated if an extended version of the *theory of planned behavior* is suited to predict subscription to a public transport ticket, and if *environmental concern*—the channel through which many sustainable transport modes are advertised—plays a significant role. It was further examined if nudging serves as an effective measure in convincing employees to subscribe to the offered ticket. *Nudges* encourage desired behaviors by changing the information set that individuals face when taking decisions; in this paper, this includes favorable *defaults* and the manipulation of the *social norm*. Since nudges lack a coherent theory, it was tested if these nudges can be integrated into the aforementioned theory.

Method: By means of an online experiment, participants ($N = 373$) were randomly assigned to different nudging conditions or a control condition. The questionnaire mimicked a working contract, including the decision for or against a subscription to the ticket.

Results: Results of structural equation modeling revealed that the theory predicted the purchase decision well, yet the impact of *environmental concern* was surprisingly low. Most tickets were purchased in the default condition, but no nudge reached statistical significance.

Discussion and Conclusion: The limitations of nudging in the transport sector are discussed, along with the effectiveness of advertising public transport through an environmental lens.

Keywords: Nudge, Default, Social nudge, Environmental concern, Mobility behavior, Commute, Theory of planned behavior, Modal shift

1 Introduction

1.1 The need to change mobility behavior

Motor car use in urban areas is connected to numerous ramifications for the environment and human health, including greenhouse gas emissions, fine-particle and noise pollution. Cars stuck in traffic, e.g. during rush hours, emit even more of these damaging substances, and simultaneously decrease the viability of public transport [47]. One approach to overcoming these issues is achieving a modal shift, i.e., convincing private car users to switch to more sustainable means of transport, such as public transport or bicycles [32]. Strategies aimed at achieving this modal shift typically follow the push-and-pull approach: They either try to increase the attractiveness of more sustainable travel or decrease the attractiveness of car use [42, 45]. As sustainability concerns are on the rise, advertising for environmentally friendly travel is increasingly becoming part of transport marketing strategies as well. But, within the frame of a liberal society, changing behavior, especially habituated

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behavior like car use, is an ambitious and difficult task [7].

1.2 New approaches to change mobility behavior

To be able to change behavior, it is important to understand what drives said behavior. One of the most widely used and accepted model to explain behavior is the theory of planned behavior (TPB) [1], which uses attitudes, subjective norm and perceived behavioral control as predictors. A previously unexplored attempt to achieve a behavioral change, i.e. the decision to switch from private car to public transport, is addressing the predictors of this theory using nudges [44]. The concept of *nudging* [44], developed in the field of behavioral economics, has proven effective in incentivizing voluntary behavior change across numerous fields. Nudges are interventions that support or direct the choices that people make (e.g. healthy, sustainable, etc.) without restricting freedom of choice. Nudging is an umbrella term for numerous interventions, and as such, its definition suffers from lower levels of granularity, and a coherent "nudging theory" still needs to be developed [35]. A step toward resolving this could be the integration of nudges into the theory of planned behavior.

To test these nudges and evaluate the model, a mobility context is required in which a modal shift could provide a considerable impact. Thus, the commute to the workplace was chosen: for the working population, work-related travel accounts for more than half of their weekly distance traveled [34, p. 103]. Many employers in Germany incentivize the use of public transport for the commute by offering subscription tickets to public transport at a reduced price, frequently called *Job ticket*. Even though owning such a ticket is not equivalent to using public transport instead of the private car, it can be assumed that subscriptions are the first critical step to increasing the use of public transport. Thus,

the decision to subscribe to the Job ticket is the behavior central to this study.

1.3 Aim of the study

First, this study investigates if the theory of planned behavior extended by environmental concern is able to predict the decision to subscribe to a public transport ticket. Second, this study aims to test if two nudges (a default and a social nudge) aimed at enticing employees to purchase a public transport ticket could increase subscription numbers. Finally, this study analyses if the nudges can be integrated into the theory of planned behavior.

2 Literature review

2.1 The theory of planned behavior extended by environmental concern

As mentioned above, the theory of planned behavior by Ajzen [1] is one of the most widely used models to predict behavior is the theory of planned behavior (TPB) [1]. In the field of environmental psychology, studies found that the predictors of the TPB affect the intention of car use as well as the decision to use public transportation or other transport means instead of the car [8, 9, 20, 23]. Donald et al. [18] argue that the prediction of mode choice can be enhanced by environmental concern, and found that it has an indirect effect on car use. In an extended version of the theory of planned behavior [36], environmental concern [19] functions as a fourth predictor of behavioral intention as well as of the other three predictors (Fig. 1).

Attitude (AT) is defined as the extent to which a person has a favorable or unfavorable evaluation of the behavior. Subjective norm (SN) is defined as the perceived social pressure to perform or refrain from the behavior. Two kinds of social norms can be differentiated [2]: injunctive norms refer to what others (dis)approve of, while

Fig. 1 Extended version of the theory of planned behavior [36]
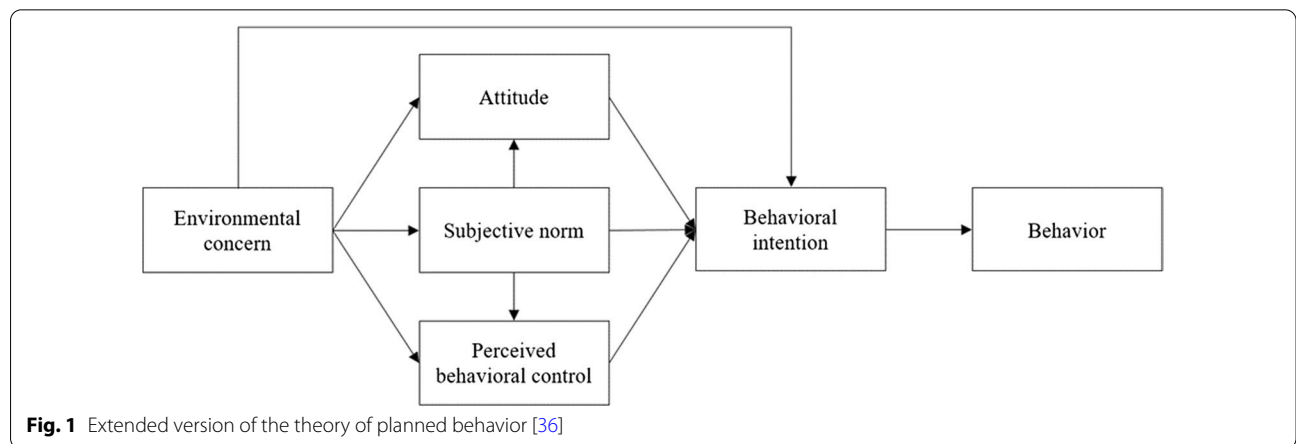
descriptive norms refer to the actual behavior of others. Perceived behavioral control (PBC) is defined as the perceived ease or difficulty of performing the behavior.

Environmental concern (EC) scales the awareness of environmental issues and the personal effort to contribute to their solution [19]. It is targeted specifically at current environmental issues regarding the transportation sector, based on the assumption that "attitudes toward specific environmental topics are ultimately reflections of a single, broad environmental attitude —what is sometimes referred to as environmental concern" [16, p. 2], [19]. Donald et al. [18] argue that the prediction of mode choice can be enhanced by environmental concern, as it provides these additional beliefs beyond the three classic TPB constructs, and they indeed found that EC has an indirect effect on car use. We thus adapted the model from Paul et al. [36], who too, found environmental concern to be of predictive value (regarding green consumption), and included environmental concern in the model used in this study. However, there is an ongoing discussion on the proper measurement of environmental attitudes in the literature. Harland et al. [23], for example, use items that are phrased very similarly to our conceptualization of environmental concern (e.g. "I am worried about the condition of the environment"), for their measurement of environmental involvement. This topic will be resumed in the discussion of this paper.

2.2 Nudging within the transport sector
Nudges [44] are interventions that direct the choices that people make (e.g. healthy, sustainable, etc.) without restricting freedom of choice. Examples include design interventions (like spatial arrangements that place healthy food in cafeterias or supermarkets at eye-level) or default settings with opt-out options (like being an organ donor by default vs. having to sign up as an organ donor) [29, 37].

The relevance of nudges with regard to sustainable transportation derives from travelers not being a rational *homo economicus:* Cost–benefit calculations alone do not determine which transportation mode travelers choose because their behavior is subject to limited cognitive resources and bounded rationality. Nudging travelers can "help them to make better decisions for themselves, to improve the performance of the overall transport system, and to reduce some of the external costs (economic, environmental, societal) associated with choices made by individual travelers" [6], p. 2. Among the most promising nudges are default settings and social nudges. While often addressed on a theoretical basis, according to Byerly et al. [13] both have been used rarely as interventions to change mobility behavior.

2.2.1 Default nudges
The default is defined as what happens when a person does not act. Defaults are thus unavoidable [12] and among the most utilized approaches in the nudging literature. The "decision" not to act can be explained by several psychological phenomena: inertia, the status quo bias, and the path of least resistance [35, 46], which can be loosely summarized as the tendency to stay put if not weightly compelled to change. Related explanations are cognitive processing limitations [12], e.g. being overwhelmed by the number and complexity of available choices, and cognitive misperceptions [39], e.g. the assumption that a default was set for a certain reason.

In an online experiment, Momsen and Stoerk [33] found that in the context of choosing an energy contract for the household (conventional energy vs. renewable energy at a higher cost) a default setting was effective. They informed the subjects that the contract entailing renewable energy was the default in their region, and that making no active choice would set them up with this default contract. This simple nudge increased the share of subjects who choose the renewable contract by 44.6% compared to a control condition. Similar results were found in an experiment regarding the default transfer of a percentage of an employee's wage to a pension scheme with an opt-out option. The number of people saving for old age was strikingly higher (50–67% increase) than in a previous opt-in system [14].

Within the context of the extended theory of planned behavior, defaults seem to be connected to perceived behavioral control, as a default setting increases the ease of performing said behavior drastically: no action needs to be taken.

2.2.2 Social nudges
Social pressure has long been known to be an effective mechanism to push others towards performing or abstaining from a certain behavior. This is included in Ajzen's [1] theory of planned behavior as the predictor subjective norm. People tend to conform to group norms, e.g. in the form of opinions and actions, because non-conformity induces fear or shame of not belonging to the group [3].

Brandon et al. [10] tested social nudges for their effectiveness in decreasing household energy consumption during peak load events. Enabling social comparisons regarding energy consumption with other households decreased energy consumption by up to 6.8% compared to a control condition. According to Ajzen's [2] differentiation of subjective norms, this can be called a descriptive social nudge, as participants were informed about what others did (as opposed to what they think).

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Table 1 Descriptive statistics

Complete sample	DSN	D	SN	Control	Total
N	87	113	92	81	373
Age in years	33.93 (9.90)	35.05 (9.90)	33.01 (10.07)	35.90 (10.57)	34.47 (10.10)
Female	60.70%	63.60%	48.30%	58.40%	58.10%
Education: University degree	70.20%	74.50%	77.0%	63.60%	71.80%
Economic status of household. *Scale 1–5 (very low-very high)*	3.32 (1.20)	3.08 (1.13)	2.95 (1.21)	3.34 (1.05)	3.16 (1.15)
Car availability: anytime	47.60%	60.00%	56.50%	68.80%	58.10%
Residing within the city (vs. outside the city)	79.76%	87.27%	88.51%	80.52%	84.36%
Satisfaction with public transport connection at home. *Scale 1–6 (very low-very high)*	4.68 (1.15)	4.64 (1.16)	4.90 (.89)	4.66 (1.22)	4.72 (1.11)
Attitude toward using public transport. *Scale 1–4 (neg-pos)*	2.80 (.93)	2.74 (1.0)	2.76 (.95)	2.97 (.97)	2.81 (.98)
Subsample	**DSN**	**D**	**SN**	**Control**	**Total**
N	48	66	52	46	212
Age in years	38.98 (9.68)	39.03 (9.28)	36.10 (10.00)	37.67 (9.72)	38.01 (9.64)
Female	56.30%	54.50%	42.30%	54.30%	51.90%
Education: University degree	68.90%	74.60%	77.60%	61.90%	71.40%
Economic status of household. *Scale 1–5 (very low-very high)*	3.68 (.94)	3.41 (1.02)	3.41 (1.00)	3.38 (1.05)	3.46 (1.01)
Car availability: anytime	57.80%	71.40%	71.20%	71.40%	68.30%
Residing within the city (vs. outside the city)	73.33%	85.71%	83.67%	78.57%	80.90%
Satisfaction with public transport connection at home. *Scale 1–6 (very low-very high)*	4.60 (1.18)	4.56 (1.13)	4.96 (.89)	4.38 (1.34)	4.63 (1.14)
Attitude toward using public transport. *Scale 1–4 (neg-pos)*	2.53 (.99)	2.35 (.94)	2.46 (.98)	2.55 (.99)	2.46 (.97)

N = 373 and subsample N = 212. Mean (SD)

Economic household status was calculated as suggested in *Mobilität in Deutschland* [34] to reduce bias for families with young children

A classic example for injunctive social nudges are Asch and Guetzkow's [5] conformity experiments, revealing that participants will verbalize a clearly wrong assessment of displayed line lengths in the attempt to comply with the social norm exhibited by other (fake) participants.

As described, social nudges can be closely linked to both descriptive and injunctive social norms of the theory of planned behavior.

2.3 Combining the theory of planned behavior and nudging

The effectiveness of some nudges is explained with generic theories (e.g. dual process theory [30]; reflective-impulsive model [41]), but a coherent "nudging theory" still needs to be developed [35]. This paper tries to connect the two nudges mentioned above to the theory of planned behavior, thus hoping to contribute to the development of a more coherent nudging theory. This derives from the assumption that setting a default is expected to simplify the perceived ability to perform the behavior, and that adding information of the social norm acts as a manipulation of the predictor subjective norm in the extended TPB.

The nudging concentrates on the purchasing process; consequently, the model targets the decision for a public transport ticket, and not the intention to use it. To be consistent, this also includes the PBC predictor, but we recognize that PBC is, perhaps even more than other predictors, also strongly related to the use of public transport. This paper focuses on the specific case of the *Job ticket* offered in a German city (names blinded for peer review) (ca. 550,000 inhabitants) by the local transport association in collaboration with the local university (ca. 8,000 employees). The Job ticket is a price-reduced monthly subscription to the local public transport and offers several advantages over a comparable monthly subscription ticket, e.g. by being 20% cheaper and usable as a family ticket. In 2018, only 16% of university employees used the Job ticket to ride public transport [48]. There is room for improvement, defined as higher subscription rates.

3 Methods
3.1 Participants

The target population contained any adult either working at the university or likely to soon start working there (i.e. Master students). An invitation to the experiment's web link appeared in student newsletters and was emailed via the administrative board. Participants were unaware of the aim of the study and were led to believe that it

focused on the feasibility of digital working contracts. 373 people participated in the study (58.1% female; age $M = 34.47$, $SD = 10.10$), out of which 161 participants indicated that they already owned the Job ticket or a similar subscription ticket. To be able to identify the effectiveness of the nudges on those that did not yet possess such a ticket, we separately analyzed the subsample of $N = 212$ (51.9% female; age $M = 38.01$, $SD = 9.64$). For more descriptive data, see Tables 2 and 3 in the analysis and results section.

3.2 Design
Participants were randomly and unknowingly assigned to one of four between-subject conditions. Following the data security information, they were asked to imagine that they had just received their working contract and to click through it as if they are just about to start working at the main campus (which offers relatively good public transport connections). After a few unrelated standard contract paragraphs to increase realism, participants encountered the Job ticket paragraph. The ticket information was identical to the actual Job ticket arrangements. Depending on the condition, this page either contained both the default and social nudge (condition DSN), only the default (condition D), only the social nudge (condition SN), or no nudge at all (control).

In conditions in which the default nudge was active, the information about the Job ticket came with the notice that the participant, as a future employee, was automatically subscribed to it. If he/she wished to unsubscribe, he/she had to un-check the preselected "Yes, I want to subscribe to the Job ticket" and instead select the "No, I do not want to subscribe". In conditions in which the default was not active, this information stated that, if the participant wished, he/she could subscribe to the Job ticket by checking the respective button. In conditions in which the social norm nudge was active, a bright yellow banner at the top-right corner of the webpage informed the participant that 76% of future colleagues had already subscribed to the Job ticket. In conditions in which no social norm nudge was active, this information was missing. The investigated behavior was the subscription decision regarding the Job ticket at the bottom of the page. The layout of the webpage with the example condition DSN can be found in "Appendix 1".

After clicking through this Job ticket paragraph, the mock-up contract ended and participants encountered a questionnaire. The questionnaire items provided information on participants' demographic data, their mobility-related behavior, and on the extended theory of planned behavior.

3.3 Demographic data and descriptive statistics
Demographic, geographic, and mobility related descriptive data (adapted from *Mobilität in Deutschland*; Nobis and Kuhnimhof [34]) is presented for the complete sample ($N = 373$) and for the subsample of participants ($N = 212$) in Table 1, who reported that they already possess a Job ticket or a similar public transport subscription ticket. After scanning this data, it was concluded that there are no substantial differences between the four experimental conditions (DSN, D, SN, Control) in the complete sample, nor in the subsample. This impression was supported by test statistics (see Appendix 2).

3.4 Questionnaire
The questionnaire's design followed Ajzen's [2] recommendations and included adapted items from Paul et al. [36], who established the extended TPB. The questionnaire measured attitude and injunctive as well as descriptive norm towards the purchase of public transport tickets, perceived behavioral control of purchasing a public transport ticket, and environmental concern with a focus on the environmental issues caused by motor car use, with 5 to 7 items on a 7-point Likert scale each (see Appendix 3). Items regarding purchase intention were omitted, as our experiment was designed to record purchase behavior within the scenario directly.

Scale reliability was ensured through computation of Cronbach's α using SPSS 26. Two items (PBC5 and EC6) did not meet the threshold value of 0.50 [16] in the corrected item-to-total correlation and were thus removed from further analysis. After exclusion of these two variables, Cronbach's α of all constructs was greater than the optimal 0.80 [43] (Table 2).

4 Analysis and results
4.1 Test of model
To check if purchase behavior could be predicted with the extended version of the theory of planned behavior, a two-step analysis comprised of a confirmatory factor analysis (CFA) followed by structural equation modeling (SEM) using maximum likelihood estimation was performed. CFA was used to determine if the questionnaire adequately measured the four latent constructs, and therefore to assess the reliability and validity of the measurement model. SEM was used to determine the causal relationships between these constructs and the outcome variable, and therefore to assess the validity of the structural model.

To evaluate the goodness-of-fit of the measurement model as well as the structural model, a range of

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Table 2 Scale reliability

Variable	Item	Corrected item-total correlation	Cronbach's α
Attitude	AT1	.767	.923
	AT2	.839	
	AT3	.833	
	AT4	.784	
	AT5	.809	
Subjective norm	SN1	.834	.916
	SN2	.829	
	SN3	.839	
	SN4	.551	
	SN5	.715	
	SN6	.827	
	SN7	.602	
Perceived behavioral control	PBC1	.810	.908
	PBC2	.749	
	PBC3	.839	
	PBC4	.785	
	PBC5[a]	*.250*	
Environmental concern	EC1	.767	.865
	EC2	.671	
	EC3	.655	
	EC4	.682	
	EC5	.698	
	EC6[a]	*.485*	

[a] Deleted due to low item-to-total correlation. Cronbach's α reported without these

Table 3 Pearson correlations of constructs

	AT	**SN**	**PBC**	**EC**
Attitude	1.00			
Social norm	.66**	1.00		
Perceived behavioral control	.48**	.34**	1.00	
Environmental concern	.40**	.28**	.28**	1.00

**p < .01 (2-tailed)

Table 4 Convergent validity

Variable	Item	λ	AVE	Composite reliability
Attitude	AT1	.811	.718	.927
	AT2	.876		
	AT3	.868		
	AT4	.828		
	AT5	.852		
Subjective norm	SN1	.925	.794	.939
	SN2	.909		
	SN3	.934		
	SN4[a]	–		
	SN5[a]	–		
	SN6	.788		
	SN7[a]	–		
Perceived behavioral control	PBC1	.872	.720	.911
	PBC2	.790		
	PBC3	.903		
	PBC4	.824		
Environmental concern	EC1	.852	.560	.863
	EC2	.717		
	EC3	.653		
	EC4	.716		
	EC5	.788		

[a] Excluded due to factor loadings < .70. *AVE* average variance extracted

recommended indicators was used. A good model fit was considered when χ^2/df was between 2 and 3; when goodness of fit indicators (GFI (goodness-of-fit index), CFI (comparative fit index), and TLI (Tucker-Lewis-Index)) > 0.90; and when RMSEA < 0.07 [21, 28].

4.1.1 Test of measurement model
On a range from 1 (lowest) to 7 (highest), four constructs were assessed: attitude, consisting of 5 items ($M = 5.64$, $SD = 1.42$); subjective norm, consisting of 7 items ($M = 3.93$, $SD = 1.64$); perceived behavioral control, consisting of 4 items ($M = 5.93$, $SD = 1.10$); and environmental concern, consisting of 5 items ($M = 5.38$, $SD = 1.49$).

CFA assumes normality of distribution and linearity among constructs. Visual screening of Q-Q plots for all items suggested no deviation from the normality assumption and the skewness and kurtosis values were below $+/-2$ and $+/-4$, respectively [31]; only the kurtosis value for perceived behavioral control of 3.58 can be regarded as relatively high, indicating that this data is rather peaked. The relationships among constructs were linear, as depicted in Table 3.

The goodness of fit statistics of the confirmatory factor analysis were nearing acceptable thresholds ($\chi^2 = 748.17$; df = 183; p < 0.001; $\chi 2/\text{df} = 4.088$; GFI = 0.823; TLI = 0.893; CFI = 0.907; RMSEA = 0.09). To improve these statistics, minor modification steps were taken based on Hair et al. [21]. Items with standardized factor loadings λ < 0.70 were considered as low and thus deleted (SN4 (0.522), SN5 (0.644), and SN7(0.521)). Based on modification indices > 10.0, paths for indicated

Table 5 Discriminant validity

Constructs	AT	SN	PBC	EC
Attitude	**.718**			
Subjective norm	.436	**.794**		
Perceived behavioral control	.230	.116	**.720**	
Environmental concern	.160	.078	.078	**.560**

Numbers indicating squared correlations of constructs; average variance extracted in bold

error covariance within constructs were made available. These steps produced a very good fit of the measurement model ($\chi 2 = 289.63$; df = 124; p < 0.001; χ^2/df = 2.336; GFI = 0.923; TLI = 0.962; CFI = 0.969; RMSEA = 0.06).

Construct validity was assessed by following the guidelines of Hair et al. [21] rules of thumb. First, standardized loading estimates are > 0.70 (Table 4). Second, convergent validity was confirmed through average variance extracted (AVE) > 0.50 and composite reliability > 0.7 (Table 6). Third, discriminant validity was confirmed through AVE estimates exceeding the square of the correlation between factors (Table 5).

4.1.2 Test of structural model

A good fit of the measurement model was recognized and, therefore, a reliable and valid basis to test the structural model (Fig. 2). Using structural equation modeling, a very good model fit ($\chi^2(142) = 382.4$, p < 0.001; χ^2/df = 2.69, GFI = 0.90; TLI = 0.95; CFI = 0.96; RMSEA = 0.07) (Table 6) was obtained. Perceived behavioral control did not statistically significantly predict the decision, and environmental concern did so only indirectly by affecting the other predictors. Apart from that,

Table 6 Standardized and unstandardized beta-coefficients, and significance levels for the structural model

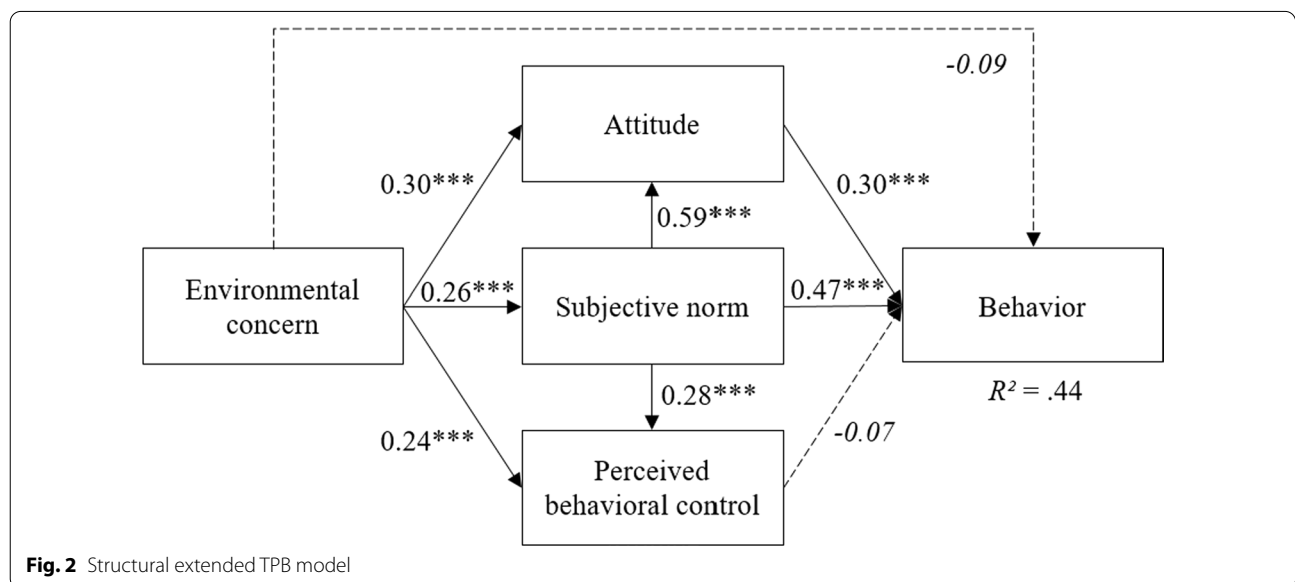| Parameter estimated	Unstandardized (error)	Standardized	Significance
EC → SN	.31 (.07)	.26	***
EC → Attitude	.27 (.04)	.30	***
EC → PBC	.16 (.04)	.24	***
SN → Attitude	.45 (.04)	.59	***
SN → PBC	.17 (.03)	.28	***
Attitude → Decision	.10 (.02)	.30	***
SN → Decision	.12 (.02)	.47	***
PBC → Decision	− .03 (.02)	− .07	.149
EC → Decision	− .03 (.02)	− .09	.076

Standard errors in parentheses, N = 374

$\chi^2(142) = 382.4$, p < .001; χ^2/df = 2.69, GFI = .90; TLI = .95; CFI = .96; RMSEA = .07, *** = p < .001

all expected beta-coefficients were statistically significant (p < 0.001). Overall, the decision to purchase the Job ticket was well predicted by applying the extended theory of planned behavior. The coefficient of determination (R^2) of 0.44 describes moderate explanatory power [27].

4.2 Effectiveness of nudges

To check if the nudges affected purchase behavior, a binomial logistic regression with dummy variables was performed for the complete sample (N = 373). The raw choice data per condition is displayed in Fig. 3. The least tickets were purchased in the conditions in which the social nudge was active (54.0% and 54.3%). The most tickets were purchased in the default condition (61.9%).

Fig. 2 Structural extended TPB model

Fig. 3 Raw choice data of N = 373 and N = 212: percent of people who decided for the ticket
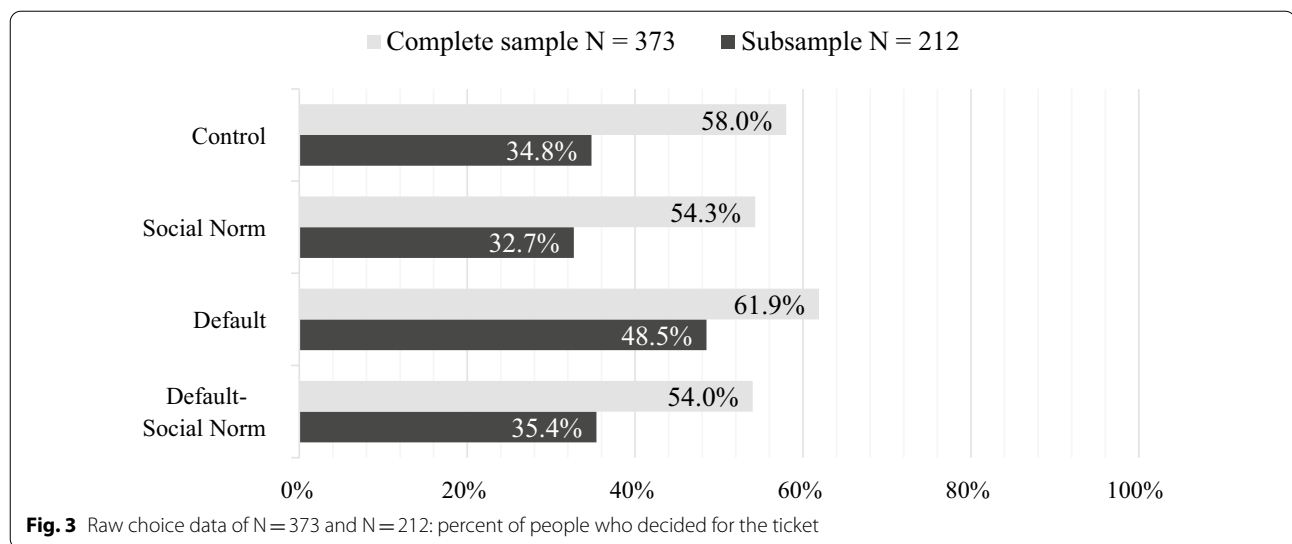
Table 7 Average effect of condition on purchasing decision for the complete sample (N = 373) and the subsample (N = 212)

Condition	Beta-coefficient (s.e.)	p-value	t-statistic	Odds ratio
Complete sample				
Default-social norm	− .163 (.311)	.602	− 0.524	.850
Default	.164 (.297)	.582	0.552	1.178
Social norm	− .149 (.307)	.627	− 0.485	.861
Subsample				
Default-social norm	.028 (.432)	.949	0.065	1.028
Default	.568 (.396)	.151	1.434	1.765
Social norm	− .094 (.428)	.827	− 0.220	.911

In the control condition, 58.0% of people purchased the ticket.

To gain insight into the effect of the nudge on those that had not previously purchased a Job ticket or a comparable public transport subscription ticket (and were thus the main target for this study), the participants who indicated they already owned such a ticket were excluded. With the resulting subsample of $N = 212$, the analysis was performed again. In these results, the trend visible for the complete sample intensified (Fig. 3).

To see if there are any statistically significant differences, a logistic regression with dummies for each variable (the control condition being omitted) was performed

for both the complete sample and the subsample. Results are reported in Table 7. No condition had a significant effect on purchasing behavior. The model explained 0.06% (Nagelkerke R^2) of the variance in purchasing behavior and correctly classified 57.4% of cases in the complete sample. In the subsample, too, no condition had a significant effect on purchasing behavior. Here, the model explained 2.5% (Nagelkerke R^2) of the variance in purchasing behavior and correctly classified 61.3% of cases.

5 Discussion

The goal of this study was to nudge commuters toward a public transport subscription ticket and thus to make commuting more sustainable on a voluntary basis. It was first investigated if the theory of planned behavior, extended by environmental concern, could predict the subscription decision regarding the ticket. Second, a default nudge and a social nudge were tested to determine their effectiveness regarding increasing subscription numbers, with these nudges ultimately being integrated into the aforementioned model. An experiment with four nudge conditions and a questionnaire revealed that the theory is well suited to predict the decision, but surprisingly, environmental concern did not add direct predictive value.

Interestingly, more than half of the participants (57.4%) purchased the Job ticket, which is significantly more than the true number of tickets purchased (16% of employees purchased a ticket in 2018). This effect could be partly

explained by the "nudge" of confronting everyone with the ticket, even in the control condition. This would explain why even in the subsample which excluded those who had not previously owned such a ticket, purchase numbers were quite high (38.7%).

5.1 Extended theory of planned behavior
The extended theory of planned behavior [36] predicted the purchasing decision well. It did, however, not prove to be of higher utility than the original theory of planned behavior by Ajzen [1]. Commonly, subjective norm is described as the weakest predictor of behavior [2, 38]. In this experiment, however, subjective norm was the strongest predictor of the subscription decision. If a subject believed others appreciated the ticket (injunctive) and would purchase it as well (descriptive), he/she was likely to purchase the ticket, too. As expected, attitude toward purchasing a ticket predicted the subscription decision as well. Perceived behavioral control, however, had no statistically significant influence on purchasing decision. This is likely due to the questionnaire items revealing slight skewness and kurtosis, meaning that most participants found it similarly easy to purchase the ticket in this study. After all, it took only a simple mouse click to decide for or against the ticket. Undoubtedly, perceived behavioral control still plays a significant role when it comes to *using* public transport, as shown in several studies (e.g. Donald [18, 24, 25]), however, this was not investigated in the present study.

Lastly, environmental concern had an indirect effect on behavior which was mediated by each of the other predictors of the TPB, but had no direct effect on the subscription decision. On the one hand, this finding is in line with Heimlich and Ardoin [26], who summarize that pro-environmental attitudes rarely lead to actual behavioral changes. In the traffic sector (and numerous others), behavior change is often induced by marketing/advertising for the environmental benefit or sustainability of a transport mode. However, according to our results, sustainability concerns did not drive the decision to buy the ticket on its own, so it might be worthwhile to interlock environmentally-focused marketing with subjective norms. On the other hand, the lack of a direct effect on behavior could, in part, be explained by the use of environmental concern as opposed to other constructs measuring environmental attitudes. For example, personal (environmental) norm, as found in Schwartz's [40] norm-activation theory, targets self-expectations based on internalized values and might have yielded different results.

5.2 Effectiveness of nudges
We investigated whether the effectiveness of nudges stretches to the transport sector. While trends were observed, statistically significant results were not obtained, which provides an important understanding of the limits of the effectiveness of nudges in the transport sector.

The results presented here fall in line with the summarized findings of Byerly et al. [13], i.e., that in changing the environmentally relevant behavior of transportation choice, defaults and norms (as well as education) have no effect whatsoever—even though it was established with the structural equation modelling, that subjective norms do have a strong effect on the purchase decision. It seems, thus, that it is very hard for interventions to influence this predictor. Interventions targeting sustainable transportation using commitments, salience, and finances did previously show mixed to promising effects. Still, it is claimed that "the nudging of travelers could be one of the most promising approaches to deal with the need for a radical and urgent behavioral change" ([6], p. 15). If this is the case, social nudges and defaults, as designed in the presented experiment, do not seem to be the appropriate choice.

Even though subjective norm was the strongest predictor in the model, the social nudge was not at all effective, producing even less subscriptions than the control condition. There has previously been evidence that people display reactance to social nudges [4]. Considering that the social nudge used here was quite obvious (a bright yellow banner), and mentioned a high number of purchased tickets compared to the real numbers (73% vs. 16%), reactance might be an explanation. Since social nudges were not effective in other transport studies as of yet, one can assume reactance cannot be the sole factor. Social nudges do work, on the contrary, in the sector of reducing waste [22] and water use [11]. These studies focused on refraining from "bad" behavior (using less water, reducing paper waste), while this experiment focused on incentivizing "good" behavior (buying a ticket, using public transport). The social nudge used here further targeted highly habituated behavior and involved monetary costs, which probably increased the cost of changing behavior.

The involvement of habituated behavior and monetary costs might also explain the results of the default nudge. Even though there was a trend following our expectations, the result was not robust. First, commuting is highly habituated. Commuters have traveled this route countless times and changing the mode or route is thus connected to possibly uncomfortable alterations

and mental workload. The targeted behavior in successful nudging studies using the default (e.g. choosing an energy contract, Momsen and Stoerk [33] is typically not routine behavior. Why should subjects invest in changing something that already works, and potentially lose money while doing so?

These significant monetary costs could have led to bigger resistance toward purchasing the ticket. Losses weigh higher than gains [46], which might have activated conscious thinking (system 1 of the dual process theory), and nudges are believed to attack system 2 (i.e. unconscious processing). On top of that, opportunity and comfort costs may arise. If various leisure activities are planned for after work, a car is a symbol of freedom, it provides flexibility and spontaneity which people might think public transport cannot offer. Our default might have been designed too softly to consider all factors.

In addition, the effort to *not* subscribe was kept very low (compared to e.g. the opt-out of organ donation, which is a lot of paperwork) on purpose to keep it realistic. This can be seen clearly in the results of the perceived behavioral control items: participants found it similarly easy to purchase the ticket. Defaults might need to connect the undesired behavior with more hurdles than the design of this study provided.

As previous studies found, nudges can be effective. In this experiment, where there was monetary cost involved, switching the default was simple, the social nudge was quite obvious, and the targeted behavior was very habituated, nudging seemed to hit its limit, and these limits still require systematic analysis. In future studies, it seems worthwhile to investigate exactly how harsh nudges should be designed to ensure their impact in the transport sector.

Since the nudges themselves were not effective, they could not be tied to the predictors of the model. We therefore urge that connecting nudges to model predictors should be retested with effective nudges to facilitate the search for a comprehensive framework regarding nudging theory. However, in light of these results, it is debatable if there is a good enough reason to keep using the general term of nudging or if it is more promising for future research to revert back to looking at interventions and their mechanisms individually.

5.3 Limitations
When interpreting the above-mentioned results of the structural equation model, it is important to remember that the questionnaire was targeted at simply the purchase of the ticket, in line with Paul et al. [36], who targeted the purchase of green products. However, the purchasing decision of a public transport ticket would naturally be influenced by attitude, social norm, and self-efficacy toward *using* public transport, as well. To get a more holistic picture of the issue, it would be valuable to consider this in future studies.

Another suggestion for future studies is taking the experiment out "on the road". Participants were asked to imagine the scenario and to act accordingly. While this procedure offers great feasibility and is fairly common, it can obviously not be guaranteed that it would produce the same results as in a field study.

While promoting public transport seems like a good idea to increase sustainability, it entails an important drawback: instead of attracting car drivers, promotions tend to entice walkers and bikers, who are already moving sustainably. In the city of Hasselt (Belgium), 16% of public transport users stated that they had left a car at home, while 21% would have walked or biked instead [15]. To avoid this, ways to target such strategies especially and directly at car drivers need to be found.

5.4 Conclusion
While the theory of planned behavior could predict the purchasing decision toward the Job ticket well, environmental concern did not directly affect it. This is an important finding regarding the advertisement of sustainable transport while also implying considerations regarding the measurement of environmental attitudes. The lack of effectivity of the nudges provides insights into the limitations of nudging theory for the transport sector. Here, nudging is different to—and apparently more difficult than in—the fields of behavioral economics, in which the concept initially boomed. Rather than a single or once in a lifetime decision, transport mode choice is habituated behavior, enforced daily, and monetary costs are involved. For policy makers, it is important to consider that social nudges could potentially trigger reactance in people, and that softly designed nudges might only have very slight effects in the transport sector, which needs to be weighed against the (typically low) cost of implementing them.

Appendices
For the originals in German language, please do not hesitate to contact the authors.
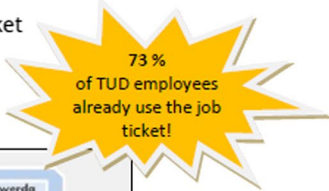
Appendix 1: Condition DSN

Condition DSN.

§ 5
Jobticket

State employees automatically receive a Job ticket based on their home address. You are free to unsubscribe from the Job ticket at any time.

The Job ticket is a monthly subscription ticket at a 20% discount for the local public transport and is offered as part of the environmental management of TU Dresden.

- Personal use from Mondays till Fridays from 6 am - 6 pm. During other times the ticket is transferable to any other person
- During weekends the Job ticket can be used as a family ticket
- Taking a bike is free at any time

Prices and fare zones

73 % of TUD employees already use the job ticket!

Territorial validity	Usual price for a monthly subscription ticket	Retail price monthly job ticket
Fare zone Dresden	€51,90	€41,50
Fare zone Dresden + 1 neighboring fare zone	€76,60	€61,30
Fare zone Dresden + adjacent fare zones	€114,20	€91,40
Whole operating area	€151,60	€121,30

- ◉ Yes, I would like to purchase the job ticket.
- ○ No, I would like to request the documents to unsubscribe from the job ticket.

Appendix 2: Group differences in the sample and subsample

The conclusion that there are no substantial differences between the four experimental conditions (DSN, D, SN, Control) in the complete sample or in the subsample was supported by test statistics: Kruskal–Wallis H tests on the complete sample (N = 373) (IV = condition), using the dependent variables education level ($\chi 2(3) = 4.884$, p = 0.181), economic status ($\chi 2(3) = 5.922$, p = 0.115), car availability ($\chi 2(3) = 5.967$, p = 0.113), geographic living region (inside the city vs. surrounding villages; $\chi 2(3) = 2.989$, p = 0.393), satisfaction with public transport ($\chi 2(3) = 1.552$, p = 0.670) and attitude toward public transport ($\chi 2(3) = 3.248$, p = 0.355) confirmed that there were no substantial group differences. The same was true for the subsample of N = 212 (IV = condition) and the same dependent variables: education level ($\chi 2(3) = 2.674$, p = 0.445), economic status ($\chi 2(3) = 2.207$, p = 0.531), car availability ($\chi 2(3) = 3.182$, p = 0.364), geographic living region ($\chi 2(3) = 4.036$, p = 0.258), satisfaction with public transport ($\chi 2(3) = 5.048$, p = 0.168) and attitude toward public transport ($\chi 2(3) = 1.335$, p = 0.721).

Appendix 3: Items of the extended theory of planned behavior

Item	Phrasing	Answer scale 1–7
Attitude		
AT1	My attitude toward purchasing the Job ticket is…	Negative–positive
AT2	I find purchasing the Job ticket is…	A bad idea–a good idea
AT3	I find purchasing the Job ticket is…	Disadvantageous–advantageous
AT5	I find purchasing the Job ticket is…	Not desirable–desirable
AT4	I find purchasing the Job ticket is…	Not reasonable–reasonable
Subjective norm		
SN1	Most people who are important to me would find it good if I purchased the Job ticket	Unlikely–likely
SN2	Most people who are important to me would want me to purchase the Job ticket	Unlikely–likely
SN3	The people who are important to me would find it desirable that I purchase the Job ticket	Unlikely–likely

Item	Phrasing	Answer scale 1–7
SN4	My colleagues would support my decision to purchase the Job ticket	Unlikely–likely
SN5	Most people in my situation purchase the Job ticket	Unlikely–likely
SN6	The people who are important to me would purchase the Job ticket if they were in my place	Unlikely–likely
SN7	Most of my future colleagues possess a Job ticket	Unlikely–likely
Perceived behavioral control		
PBC1	For me, purchasing the Job ticket is…	Complicated–simple
PBC2	Buying the Job ticket is not very complex	Disagree–agree
PBC3	For me, purchasing the Job ticket is…	Laborious–easy
PBC4	If I wanted to purchase the Job ticket, it would be easy for me to do so	Disagree–agree
PBC5	Whether I purchase the Job ticket or not is completely up to me	Disagree–agree
Environmental concern		
EC1	I am worried about CO_2 emissions caused by motor car use	Disagree–agree
EC2	I would be willing to use my car less if that helped the environment	Disagree–agree
EC3	Substantial political change is necessary to increase the sustainability of the traffic and transportation sector	Disagree–agree
EC4	Substantial social change is necessary to increase the sustainability of the traffic and transportation sector	Disagree–agree
EC5	Anti-emission laws should be implemented more strictly	Disagree–agree
EC6	If more employees would purchase the Job ticket, the environment would profit	Disagree–agree

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equation modelling; GFI: Goodness-of-fit index; CFI: Comparative fit index; TLI: Tucker–Lewis index; RMSEA: Root mean square error of approximation; AVE: Average variance extracted.

Availability of data and materials
Please contact the author for the original (German) material and data.

Declarations

Ethics approval and consent to participate
Participants freely decided to participate in the online survey and consented to the use of the anonymized data. The need for ethics approval was waived.

Consent for publication
Not applicable.

Competing interests
There are no competing interests to declare.

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