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COMBINED DIGITAL NUDGING TO LEVERAGE PUBLIC TRANSPORTATION USE

Research Paper

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Abstract

The urgency of global climate change is becoming increasingly evident, but prevailing mobility patterns in developed countries still cause severe environmental damage. Therefore, developed countries need to change their mobility patterns fundamentally, such as modal changes to public transportation instead of private car use. Digital nudging in digital mobility applications is a novel and promising way to influence modal changes to public transportation. In this study, we conduct an online experiment with 183 participants who are being nudged toward public transportation trip options. Our results show that combining two different digital nudges significantly affects the choice of public transportation options. By contrast, single nudges do not significantly change the choice of public transportation trips. With our findings, we contribute to the research stream of digital nudging and the transportation literature and provide insights for practice to address the adverse effects of current mobility patterns.

Keywords: Digital Nudging, Online Experiment, Public Transportation, Sustainable Mobility.

1 Introduction

The urgency of global climate change is becoming increasingly evident, and addressing its hazardous effects is part of the sustainable development goals of the United Nations (United Nations, 2021). In this regard, mobility significantly contributes to environmental damage and air and noise pollution (Hauslbauer et al., 2022; Mulley, 2017). For instance, in 2020, the transportation sector was responsible for more than 20% of global CO_2 emissions (Tiseo, 2021). One of the reasons for the adverse effects of the mobility sector is the use of environmentally harmful modes of transportation, such as driving private cars instead of using environmentally friendly alternatives like public transportation (Keller, 2022). Therefore, innovative solutions are necessary to change climate-damaging human behavior in the mobility sector.

One way to reduce the negative effects of the current mobility patterns is to make more sustainable mobility modes more efficient. For instance, mobility apps or web applications allow easier and more convenient use of public transportation by providing real-time information on occupancy rates or current delays (Zimmermann et al., 2020). In addition, as shown in other contexts, such as fitness tracking or fostering sustainable behavioral changes in companies, information technology (IT)-enabled solutions can trigger behavioral changes (Isensee et al., 2022; Sullivan & Lachman, 2017).

One of the promising IT-enabled approaches to changing individual (mobility) behavior is digital nudging. In general, nudging is defined as *"[...] any aspect of the choice architecture that alters people's* *behavior predictably without forbidding any options or significantly changing their economic incentives*" (Thaler & Sunstein, 2008, p. 6). When nudging occurs in the digital realm, such as on webpages or apps, such an event is referred to as digital nudging and defined as "*the use of user interface design elements to guide people's behavior in digital choice environments*" (Weinmann et al., 2016, p. 433). The recent information systems (IS) literature (e.g., Henkel et al., 2019; Meske & Amojo, 2019; Weinmann et al., 2016) has discussed the concept of digital nudging. It has also been examined in diverse other fields, such as psychology (e.g., Taube & Vetter, 2019), business and marketing (e.g., Grinstein & Riefler, 2015), and environmental sustainability (e.g., Tiefenbeck et al., 2019). Moreover, digital nudging promotes sustainable mobility behavior (e.g., Kim et al., 2020; Tussyadiah & Miller, 2019). For instance, digital nudges are used to promote the subscription to public transportation tickets (Hauslbauer et al., 2022) or to increase the use of public transportation in field experiments (Anagnostopoulou et al., 2020; Lieberoth et al., 2018).

In the digital realm, implementing more than one nudge at a time to increase their effects is becoming common (e.g., Camilleri et al., 2019; Loock et al., 2013), as digital nudges can be deployed with less effort than nudges in an offline setting. For instance, Loock et al. (2013) implemented a combination of default and goal-setting nudges to induce energy-efficient behaviors among study participants. However, the effects of combining different digital nudges have not been considered systematically (Meske & Amojo, 2019; Zimmermann et al., 2021), as exemplified by Guerassimoff and Thomas (2015) and Abrahamse et al. (2007). Both studies combined feedback, goal-setting mechanisms, and social comparison nudges to promote energy-efficient behavior but did not address the degree to which the achieved effects can be attributed to a digital nudge or a combination of two or more.

In addition, changing mobility behavior toward more sustainable options, such as public transportation, is a complex societal challenge (e.g., Gravert & Collentine, 2021; Hauslbauer et al., 2022; Steg, 2005). Moreover, former studies often showed mixed results regarding the effects of digital nudging to increase the use of more sustainable mobility forms, such as public transportation (Cellina et al., 2019). Therefore, we analyze the effects of digital nudging to increase public transportation use and pose the following research questions:

1) Can digital nudging increase the choice of public transportation trip options?
2) Can the effect be increased by deploying a combination of two digital nudges?

We conducted an online experiment in Germany with 183 participants to answer these research questions. We compared the effects of two digital nudges (i.e., decoy and default) and a combination of both digital nudges for choosing public transportation instead of private car options to a control group. Our results show that only combining two different digital nudges has significant effects. By contrast, single nudges do not significantly change the choice of public transportation trips. With our results, we contribute to the research stream of digital nudging and the transportation literature and provide insights for practice to address the adverse effects of current mobility patterns.

2 Theoretical Background

2.1 Digital Nudging

Empirical studies showed that psychological triggers could effectively change people's behavior to promote public transport use (Hunecke et al., 2010; Möser & Bamberg, 2008). Examples are nudges that influence people's behavior without changing economic incentives, relying instead on choice architecture that refers to the physical or digital environment in which decisions are made. Manipulating choice architecture affects behavior without forbidding any available options (Thaler et al., 2013). Such adaptations can influence people consciously or subconsciously and are well suited to changing habitual choices (Thaler & Sunstein, 2009), for example, people's mobility behavior. For example, Franssens et al. (2021) showed that messages in buses that positively label passengers as sustainable could increase the usage rate of public transportation. Moreover, Fyhri et al. (2021) used nudging mechanisms to increase the perceived safety of cycle lanes and promote bicycle use.

As more and more choices are being made on screen, nudging has also been transferred to the digital realm. This is then called digital nudging and is defined as "the use of user-interface design elements to guide people's behavior in digital choice environments" (Weinmann et al., 2016, p. 433). Digital nudges can be deployed, for example, on web pages, apps, or online shops. However, the implementation and underlying mechanism for behavioral change can vary widely across different digital nudges. For example, some digital nudges, such as priming or goal setting, are used before action. By contrast, other nudges, such as default settings or feedback nudges, influence user behavior during or after a decision or action. Moreover, some digital nudges are mostly combined with other incentives, such as social norms or framing nudges (Zimmermann et al., 2021).

One type of digital nudging is so-called decoys. Huber et al. (1982) were the first to research the decoy effect, which can be deployed in decision situations where individuals must choose between two options that differ along varying dimensions, such as price, sustainability, or quality, but none of the options is dominant in all dimensions. The resulting trade-off between options makes it difficult for consumers to decide on one option (Attwood et al., 2020; Momsen & Stoerk, 2014). Introducing a third option during the selection process - the decoy option - which is similar but inferior to one of the two options, can unconsciously change a consumer's preferences. The reason is that the superior option of the decoy appears relatively more appealing than without the decoy (Huber et al., 1982). This effect can be explained by the observation that consumers often consider irrelevant alternatives in their choices, influencing the decision-making process and its outcome. A decoy option includes an irrelevant alternative (Ariely & Wallsten, 1995) and makes the desired choice option more attractive.

Defaults are another kind of digital nudging. Setting defaults preselects the most desired alternative for the respective situation and influences the presentation of different choices for consumers. This nudge forces individuals who want to choose differently to invest effort in opting out of the preselected option. Deciding based on the default option requires the least time and effort (Blumenthal-Barby & Burroughs, 2012). Moreover, defaults are implicit recommendations (Johnson & Goldstein, 2003; Keller et al., 2020). This case leads to a higher probability of a favorable evaluation and of sticking to the default, particularly when the decision requires difficult considerations involving money, personal values, and societal norms (Gollwitzer, 1990; Henkel et al., 2019).

2.2 Related Literature and Hypothesis Development

Increasing sustainable mobility modes is a potential use case for digital nudging. The extant literature in IS and related research streams showed a growing number of scientific studies on this topic. For instance, former studies analyzed the effects of digital nudges applied in a flight context. The results of Székely et al. (2016) provide insights into the effectiveness of default nudges to increase carbon-offset payments on an online flight booking platform. Sanguinetti and Amenta (2022) used information nudges on flight emissions on a flight search and booking platform. Their results show that labeling low-emission flights with "Greenest Flight" could increase the participants' willingness to pay for these flights.

Within a recreational context, Jariyasunant et al. (2015) used a digital travel feedback system to enforce more sustainable travel choices, including the choice of transportation mode. Their results show that digital feedback nudges containing social norms increased the choice of sustainable choices in the experiment. Moreover, Pihlajamaa et al. (2019) used real-time information to move people from crowded nature destinations to less crowded areas using occupancy and public transportation information. Bothos et al. (2016) implemented a recommendation system within mobile apps and used route planning applications to reduce the overall CO_2 emissions of the study participants by proposing different routes. Additionally, several studies followed a technical approach and developed location-based recommendations to steer the participants' mobility behavior using tailored information (e.g., Gao et al., 2019; Zhu et al., 2017). Although such user-data-informed digital nudges show promising effects, they also raise ethical issues like privacy aspects that should be considered when designing and deploying digital nudges (Sunstein, 2015).

Several studies have also analyzed the promotion of public transportation. For instance, Anagnostopoulou et al. (2020) nudged users through recommendations, such as "Today it's sunny! Take the opportunity to combine bike with public transportation to save CO_2 emissions" (Anagnostopoulou et al., 2020, p. 171) to actively recommend pro-environmental mobility choices to app users. Hauslbauer et al. (2022) used digital nudges to promote public transport ticket subscriptions with a working contract. In their experimental study, they deployed default and social norm nudges to increase the subscription among participants. Their results show no statistically significant effects of the nudges but a positive trend for the default intervention. Lieberoth et al. (2018) tested different interventions, including gamification elements and digital nudges, to promote public transportation instead of private car use in a field experiment. Their results show that nudging can support psychological conversions to behavioral change, although the impact caused by gamification elements in their experiment showed an even bigger effect.

The literature on digital decoy nudges is still scarce. Only little empirical evidence on their effects exists (e.g., Attwood et al., 2020; Momsen & Stoerk, 2014), particularly in a mobility context. Moreover, extant literature showed mixed results regarding effect sizes from decoy nudges. In the present study, we chose to test digital decoy nudges to unravel their potential to increase the desired choice option. Considering the experimental design, the provided mobility scenarios differ in various dimensions, such as price, emissions, or duration, complicating the decision-making. Decoys can simplify such multi-dimensional choice options. Therefore, we empirically analyze whether digital decoy nudges can increase the choice rates of rail and flight options and propose the following hypothesis:

Hypothesis 1: Nudging participants with a digital decoy nudge increases the likelihood that they will choose a public transportation trip option.

In contrast to the decoy literature, default nudges have been studied intensively. Default nudges create a status-quo bias toward the preselected choice option and force individuals who want to choose differently to invest effort in opting out of the preselected option. This case increases the probability of sticking to the default option (Samuelson & Zeckhauser, 1988). Extant literature showed that default nudges significantly influence behavioral choices (for an overview see Hummel & Maedche, 2019). For example, studies analyzed the effects of defaults to promote green online product purchases (Taube & Vetter, 2019) or energy savings (Loock et al., 2013). In the mobility context, defaults have been used to raise travelers' awareness of the environmental impact of their transportation choices (Froehlich et al., 2010; Sanguinetti et al., 2017), rethink their transportation habits (Anagnostopoulou et al., 2020), and reduce private car use (Lieberoth et al., 2018; Wunsch et al., 2015). Moreover, Székely et al. (2016) used default settings to encourage carbon offset payments for flight bookings successfully. Based on these promising results, we analyze the effects of default nudges to promote public transportation trip options and propose the following hypothesis:

Hypothesis 2: Nudging participants with a digital default nudge increases the likelihood that they will choose a public transportation trip option.

As digital nudges can often be implemented with less effort compared with nudges in an offline setting, combining different digital nudges is becoming more common to increase the expected effects (e.g., Camilleri et al., 2019; Loock et al., 2013). Nudges are combined because of an expected amplification of single-nudging effects. However, the extant literature still needs to systematically consider the effects of combining different digital nudges (Meske & Amojo, 2019; Zimmermann et al., 2021). In a mobility context, Anagnostopoulou et al. (2020), Bothos et al. (2016), and Lieberoth et al. (2018) deployed a combination of different digital nudges, such as recommendations, feedback, or social norms, to motivate more sustainable mobility behavior like the use of public transportation. However, these former studies often needed to address the degree to which the achieved effects can be attributed to a digital nudge or a combination of two or more nudges. Therefore, we first analyze the effects of decoy and default nudges alone and then continue to analyze the combined effect. We put forth the following hypothesis:

Hypothesis 3: Nudging participants with a combination of digital decoy and default nudges increases the likelihood that they will choose a public transportation trip option.

3 Methodology

3.1 Setting and Experimental Design

We set up an online randomized controlled trial to test our hypotheses. Moreover, we chose a between-subject experimental design to investigate the effects of digital nudging on the choice behavior of public transportation trip options over the choice of private car trip options. Creating an interactive and realistic user interface is essential when designing digital nudges, as every element of the digital choice environment can influence decisions (Weinmann et al., 2016). Hence, we decided not to use a standardized online survey tool but to program a custom web application. The website was built using Django's free, open-source Python web framework. The Django web framework offers efficiency, flexibility, and versatility in application development (Django Software Foundation, 2022). On the website, each participant is tracked by assigning an anonymous session key per participant throughout the experiment. By starting the website, each participant was randomly assigned to either one of the treatment groups (i.e., decoy, default, or combined) or the control group without any digital nudges. Each participant had to choose between public transportation or private car use in three different scenarios to test the effectiveness of the manipulations. Each scenario contained a fixed start and end point in Munich (Germany), and the participants could choose between two or three different trip options for the route. To mimic real-world mobility behavior as well as possible in the experiment, we included the statement, 'Once you have found a mode of transport for your route that best matches your real-life choice, press start route' (translated). The expected duration and the length of the trips in each scenario are based on realistic values provided by OpenStreetMap (2022), a free online map provider.

In the three scenarios of the control group, the participants were provided with the best public transportation and the best private car trip option based on the values of OpenStreetMap (2022). In each scenario, the public transportation option had a longer travel time than the private car option but was the more sustainable option. Thus, the two options have different advantages and disadvantages regarding sustainability and travel time. For the design of the decoy nudge, a second public transportation trip option was introduced with a longer travel time than the first public transportation option and mode changes. The default nudges are implemented by preselecting and highlighting the public transportation option. Finally, we combine the decoy and default nudges. Study participants in this group were shown the decoy option, and the first public transportation option was preselected and highlighted. Figure 1 depicts the design of the combined nudges. The manipulation of single nudge treatment groups consisted of the additional decoy option or the preselected and highlighted default option.

In addition to the experimental questions, the website included an additional survey. The survey included questions about the participant's demographics, their mobility behavior (e.g., which modes of transportation they use), and their use of mobility apps (e.g., whether they use mobility apps to plan trips or check for delays). As the study focuses on sustainable mobility behavior, we also included scales to assess the participants' environmental awareness. Therefore, we included two scales from the environmental attitudes (EA) measurement tool developed by Milfont and Duckitt (2010). In addition, the scales developed by Smythe and Brook (1980) are used to learn more, specifically about the EA regarding transportation.

Before launching the study, the intuitive handling and the website's functionality were tested and continuously improved in a pre-test with 10 participants. The study participants for the main study were recruited through Facebook groups and various online tools, such as SurveySwap, SurveyCircle, and Pollpool. We constrained the data collection to people living in Germany to control for country-specific effects. Germany is well suited for our study because it suffers from the negative consequences of mobility behavior based primarily on private car use. Moreover, the conditions for changing mobility behavior are good in Germany because several studies (e.g., German Federal Environmental Agency, 2019; Kuhnimhof et al., 2012) showed that the importance of private car ownership and the emotional attachment to one's car is decreasing in Germany. Moreover, we focus on cases located in a big city in Germany (Munich), considering that access to public transportation is very good.

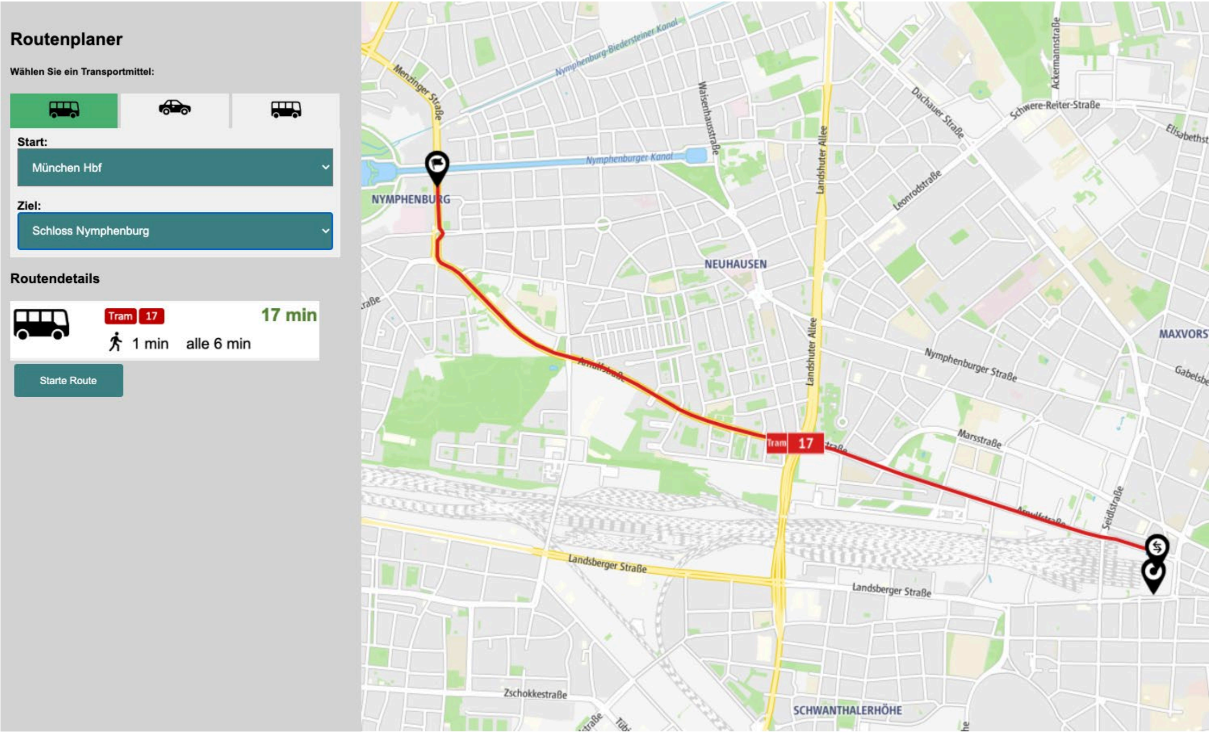

Figure 1. Deployment of the decoy and default nudge on the experimental website

3.2 Data Collection and Analysis

The experiment was conducted over 13 weeks, from May to August 2022. A total of 219 participants started the survey, and 188 completed it. The 29 participants terminated the study immediately after the start or before the demographic information was filled out. Moreover, two attention checks were included in the survey to ensure data quality, and five participants were removed because of failed attention checks. Thus, we have a final sample of 183 participants.

We apply a mixed-effects logistic regression to analyze whether the digital nudges increase the choice of public transportation trip options. Moreover, we cluster the answers and introduce a random intercept per participant to control for the several answers per participant. Following Sommet and Morselli (2017), our model is given as follows:

$$\Pr(Y_{ij}) = logit - 1(\alpha + \beta * treatment_i + \gamma * controls_i + u_i + \varepsilon_{ij}).$$

The result of the regression $Pr(Y_{ij})$ reflects the probability that the public transportation option that was targeted by the nudge(s) is chosen by the participants of the treatments groups (or the respective option for the control group), whereas i is the index for the participants, and j is the index for the three different scenarios. α refers to the fixed intercept, and β contains the fixed effects for the different treatment groups (i.e., decoy, default, combination). $Treatment$ is coded as 1 when a participant chooses the nudged public transportation trip option and 0 if otherwise. γ contains the fixed effects for the different control variables, u_i is the random effect that accounts for the correlation of the decisions per subject, and ε_{ij} represents the residual. The control variables include the participants' age, gender, EA, number of children, individual monthly income, place of residence, and the ownership of a car or public transportation ticket. For the data preparation, we used Python. The data analysis was performed with the statistical software R using the integrated development environment RStudio. For the mixed-effects regression, the package lme4 with the glmer function was used.

3.3 Descriptive Statistics

Table 1 summarizes the descriptive statistics of the participants for each treatment group. The participants in our study are between 17 and 78 years old, with an average of 29.6 years. Of the participants, 59.0% are female, and 41.0% are male. Moreover, among the 183 participants, 22 have one or more children. On average, the participants have a personal net income of €1,800 per month, whereas 25.7% have an income below €1,000 per month, 43.2% have an income of €1,000–€2,000, and 30.6% have an average net income of more than €2,000 per month. Most (69.4%) live in a large city in Germany, whereas 16.4% live in medium cities, and 14.2% live in small towns or rural communities.

Demographic Data	**Control** (n = 44)	**Decoy** (n = 46)	**Default** (n = 49)	**Combined** (n = 44)
Age (SD)	27.9 (8.79)	30.4 (10.56)	30.7 (10.88)	29.4 (10.71)
Gender (in %)				
Female	45.5	58.7	65.3	65.9
Male	54.5	41.3	34.7	34.1
Diverse	0.0	0.0	0.0	0.0
Children (SD)	0.1 (0.39)	0.4 (0.86)	0.2 (0.48)	0.1 (0.44)
Net income per month (in €)	1980.2	2079.5	2118.7	1752.1
Place of residence				
Large city	79.5	63.0	69.4	65.9
Medium city	9.1	21.7	16.3	18.2
Small town	11.4	10.9	6.1	13.6
Rural community	0.0	4.3	8.2	2.3
Score environmental attitude (SD)	5.3 (1.08)	5.4 (0.98)	5.7 (0.86)	5.6 (0.96)
Car ownership (in %)	56.8	50.0	49.0	56.8
Public transportation ticket (in %)	61.4	43.5	63.3	70.5
Mostly used transportation mode (in %)				
Public transportation	36.4	41.3	40.8	40.9
Car	22.7	30.4	20.4	25.0
Bicycle	31.8	17.4	24.5	27.3
Others	0.0	2.2	2.0	2.3
None (only walking)	9.1	8.7	12.2	4.5

Table 1. Descriptive statistics of the demographic data of the participants grouped by the treatment group

For the scores of the EA based on the scales of Milfont and Duckitt (2010), we find an average score of 5.52 among all participants with scales ranging from 1 to 7. Our study will use this average score to classify a below-average EA score as neutral-EA and an above-average score as pro-EA. Of the respondents, 97.8% have a driving license for passenger cars, and 53.0% own a car. Moreover, 59.6% have a permanent ticket for public transport. Local public transport is also the most used mode of transportation by the respondents, with 39.9%. Notably, the survey was conducted during the introduction of the "nine-euro ticket" in Germany. The German parliament passed the nine-euro ticket on May 19, 2022, a one-time, time-limited special offer. The nine-euro ticket was valid throughout Germany on local and regional public transport for June, July, and August 2022 (Müller 2022). Ninety-three people participated in our study before introducing the nine-euro ticket and 90 people afterward. Notably, only 51.61% of the respondents had a ticket for local public transport before the introduction, and 67.78% were after.

4 Results

We start with an initial graphical analysis following the approach of Meske et al. (2020) to gain an overview of the data. Figure 2 depicts the percentage of participants choosing public transportation and car options, grouped by control and treatment groups. The initial graphical analysis shows that the public transportation option is often selected among all control and treatment groups with median values of 80% or higher. Hence, participants who did not experience digital nudging already have a high willingness to choose public transport in our sample. By adding the nudging interventions, we can observe that participants select public transportation more often.

The graphical analysis shows a trend for the treatment groups, with higher medians for all three groups of 83% and up to 97%. Among the treatment groups, we find the smallest effect for the manipulation in the decoy group regarding the median value and the dispersion among the participants, which can be deducted from the quantiles in Figure 2. The default and combined nudges lead to a significantly higher increase in the choice of public transportation options for the medians, whereas the combination of both nudges is the highest. Moreover, we find that the dispersion among the participants decreases considerably, meaning that the increase in the median can be ascribed to a large share of the participants in these two treatment groups.

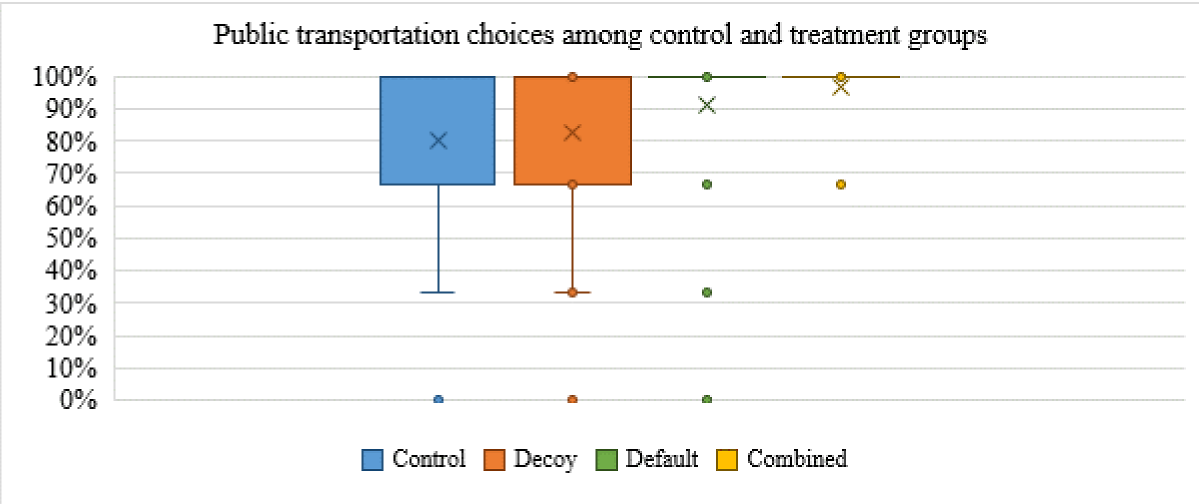

Figure 2. Public transportation choices among control and treatment groups (in %)

Next, we apply different mixed-effects logistic regression models. Table 2 presents the results. First, we present the Null model, an intercept-only model with a random intercept for each respondent. Model 1 contains the treatment group added as a fixed effect, and Model 2 has the control variables as fixed effects. Models 3 and 4 contain the results for additional analyses: They are similar to Models 1 and 2 but are restricted to participants with an EA score below average.

The results show no significant effects for Model 1, indicating that none of the digital nudging mechanisms (i.e., decoy, default, and combined) could statistically significantly increase the choice of public transportation options compared with the control group. However, as in the graphical analysis, the coefficients for the treatment effects show a positive trend, with the most significant effect for the combined nudging mechanism. When adding all the control variables in Model 2, we find that the combination of the two nudges, default, and decoy, has a statistically significant effect on the choice of the public transportation option. As the coefficients are reported as changes to the log odds ratio, the coefficient of 3.04 of the combined nudge indicates an approximately 20.9 times higher chance of selecting the public transportation option than the control group. In addition to the effects based on the nudging effects, we find that the control variable EA is highly significant, with a coefficient of 1.72. This result indicates that the score deducted from the EA scales has explanatory power for choosing sustainable, that is, public transportation options. All other control variables are not statistically significant.

Based on our findings in Model 2, we run additional analyses to examine the effects based on the EA scores in more detail. Participants with a pro-EA are more likely to choose the more sustainable transportation alternative than individuals with an EA below the average EA value. Thus, we focus on the latter sub-sample with 71 participants to optimize digital nudging from a practical perspective, as it can be expected that the group with higher EA scores already acts more sustainable. Again, we start with a graphical analysis of the results for the below-average EA score group (Figure 3).

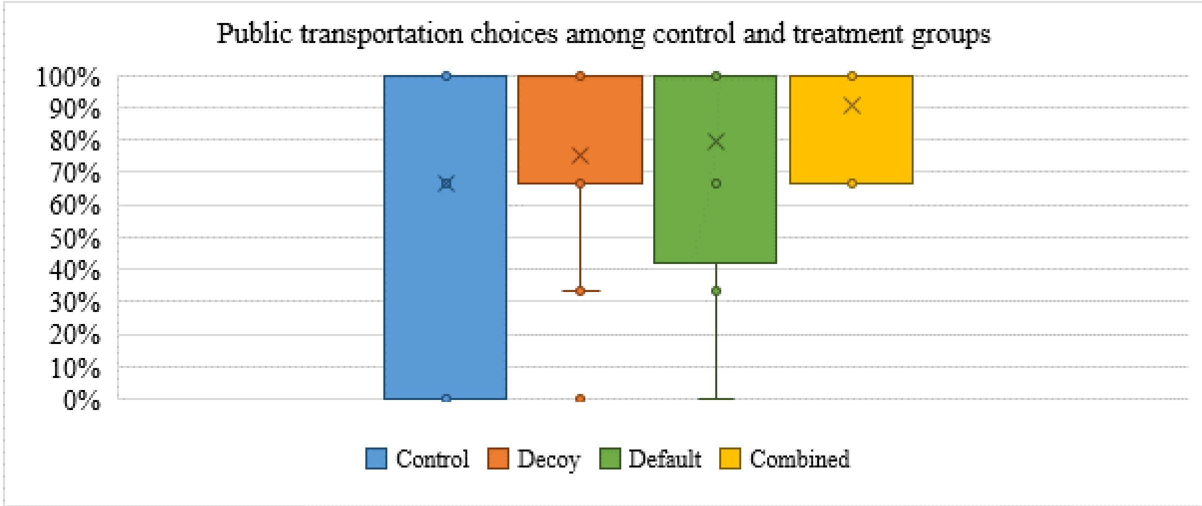

Figure 3. Public transportation choices among control and treatment groups for participants with under-average EA scores (in %)

The graphical analysis shows that all median values for the public transportation choices are lower (67% for the control and 75% - 90% for the treatment groups) and are more dispersed among all groups. Again, by adding the nudging interventions, we can observe that participants select public transportation more often. Among the treatment groups, we found the smallest effect for the manipulation in the decoy group and the highest effect for the combined nudges. The default manipulation leads to a higher median increase in the public transportation choice option than the decoy nudges. However, the results are more dispersed, unlike those discussed above for the sample with all participants.

Table 2 shows the regression analysis results for the sub-sample of participants with EA scores below the average. In Model 3, only the treatment effects for the different nudging manipulations are considered, which leads again to no significant effects for the coefficients. However, notably, values show a positive trend, and the effects are higher than those of Model 1. When considering the regression analysis of Model 4, again, a significant effect of combining the default and decoy nudges can be observed. Notably, the individual decoy and default nudges have a more substantial yet statistically insignificant effect than in Model 2. Finally, although the results for the sub-sample analysis show similar trends, the effects are similar or stronger, although the regression model contains only 71 participants.

	Null Model	Model 1	Model 2	Model 3	Model 4
Intercept	7.85^{***}	6.89^{***}	3.86^{**}	1.82	3.57^{**}
	(0.88)	(1.19)	(1.26)	(1.08)	(1.38)
Decoy		0.10	−0.04	0.96	0.72
		(1.19)	(0.93)	(1.34)	(1.06)
Default		1.11	1.11	1.65	1.53
		(1.29)	(1.01)	(1.45)	(1.27)
Combined		1.95	3.04^{*}	2.63	2.94^{*}
		(1.61)	(1.29)	(1.46)	(1.38)
Age			−0.17		−0.68
			(0.80)		(0.96)
Gender = Female			−0.26		−0.15
			(0.53)		(0.50)
EA			1.72^{***}		1.87^{**}
			(0.49)		(0.69)
Children			0.52		0.74
			(0.55)		(0.72)
Individual income mth.			0.49		0.97
			(0.73)		(0.79)
Small town			−1.12		−0.07
			(1.24)		(1.40)
Rural community			−0.77		0.34
			(1.72)		(2.18)
Medium city			0.59		0.12
			(1.12)		(1.18)
Public transport ticket = Yes			0.60		1.04
			(0.84)		(0.96)
Car Owner = Yes			−0.42		−0.90
			(0.86)		(1.02)
AIC	299.23	302.95	303.79	197.78	199.25
Log Likelihood	−147.62	−146.47	−136.89	−93.89	−84.62
Num. Observationen	549	549	549	213	213
Num. User	183	183	183	71	71
Var. User (Intercept)	70.60	60.30	9.25	10.57	5.13

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 2. Coefficient estimates and standard deviations for the five different logistic regression models. Null Model: Intercept-only model with random intercept per respondent; Model 1: Treatment group added as fixed effect; Model 2: Control variables added as fixed effects; Models 3 and 4; Similar to Models 1 and 2 but restricted to participants with an EA score below-average.

5 Discussion

In this study, we have analyzed whether the digital nudges decoy, default, and a combination of both can increase the choice of public transportation options with three different route planning scenarios in Munich. Our results show that despite a positive trend, the digital nudges decoy and default did not significantly increase the likelihood of choosing public transportation options. Therefore, hypotheses 1 and 2 are not supported. However, combining both nudges leads to a statistically significant increase in our experimental study when other control variables are considered in the regression model. Therefore, hypothesis 3 is partially supported. Table 3 presents the findings for the hypotheses.

Hypotheses	Findings
Hypothesis 1: Nudging participants with a digital decoy nudge increases the likelihood that they will choose a public transportation trip option.	Not supported
Hypothesis 2: Nudging participants with a digital default nudge increases the likelihood that they will choose a public transportation trip option.	Not supported
Hypothesis 3: Nudging participants with a combination of digital decoy and default nudges increases the likelihood that they will choose a public transportation trip option.	Partially supported

Table 3. Summary of the hypotheses and study results

5.1 Theoretical Contributions

Our findings contribute to the (IS) literature in several ways. First, we present empirical findings on digital decoy and default nudges in the mobility context. Our results show that the digital decoy nudge did not increase the choice of public transportation trip options in the regression model. The trend identified in the graphical analysis of the nudging effects is relatively small. Our analysis of the relevant literature and former literature reviews shows that no other research study could be found in which decoy nudges were applied in the digital mobility service providers' field to influence sustainable mobility choices (Zimmermann et al., 2021). Considering the superordinate field of digital nudging research on pro-environmental behavior changes, we find consistent results with Momsen and Stoerk (2014), who tested decoy nudges to reduce energy consumption and did not find significant results. A potential explanation for our findings might be that decoys are too complex to catch users' immediate attention on a website when they are in a decision-making process. By contrast, other digital nudges, such as defaults, are very prominent and simplify the decision-making process tremendously.

The insignificant findings for the default nudges are rather contradicting when considering the extant literature. For instance, Hummel and Maedche (2019) reported that default nudges are one of the most promising behavior change mechanisms in the extant nudging literature. Moreover, former studies in the mobility context successfully deployed default nudges. For instance, Székely et al. (2016) used default settings to encourage carbon offset payments for flight bookings, and Stryja and Satzger (2019) increased the choice of battery-powered rental cars with default settings in an experimental study. However, evidence that default nudges might not be as effective in digital realms as offline settings also exists "*because people in online environments are confronted much more often with default options and so have become more cautious*" (Meske and Amojo 2019, p.413). Moreover, increasing the use of public transportation options requires more individual commitment than other contexts that might not demand such big behavioral changes.

Second, we provide systematic findings on the effect of a combination of two different digital nudges. To date, the effects of combining different digital nudges have often not been considered systematically in the extant literature (e.g., Anagnostopoulou et al., 2020; Lieberoth et al., 2018), which leads to limitations in terms of the transferability of the findings as why a combination of different digital nudges lead to behavioral changes is unclear (Meske & Amojo, 2019; Zimmermann et al., 2021). In our study, the combined digital nudge provides significant results for public transportation options. More specifically, when adjusting the control variables, participants in the combined group were approximately 21 times more likely to choose public transportation than participants not exposed to a digital nudge. However, the individual nudges did not show a significant effect, illustrating that the interaction between the digital default nudge amplifies each other's effects. By contrast, most observed effects seem accountable to the default nudge.

Third, we additionally considered a subgroup of subjects with a below-average EA score based on the scales of Milfont and Duckitt (2010) and Smythe and Brook (1980). Our results show that environmental attitude significantly impacts the choice of sustainable mobility options. By contrast, other control variables (e.g., participant's age, gender, number of children, or monthly income) did not significantly influence the decision. Therefore, our results show that the scales are well-suited to predict sustainable mobility choices. Moreover, we find that the effects of the digital nudges for this sub-sample are more robust than for the overall sample. This result complements former findings, for instance, of Hunecke et al. (2010) and Schulz et al. (2021), who pointed out the relevance of mobility target groups based on attitudinal factors, such as environmental attitude.

5.2 Practical Implications

Our findings are also important for practitioners, such as public transportation companies, city managers, or designers of mobility apps and other digital platforms used to plan and navigate trips. First, our results show that the combination of decoy and default can increase the choice of public transportation in cities. For instance, the findings can be used to integrate these nudges into mobility apps (e.g., Google Maps or apps offered by public transportation companies) to increase the use of more sustainable modes of transportation, such as public transport. Moreover, policymakers could use these insights to increase the effects of political measures, such as promoting the sales of subsidized public transportation tickets with digital nudging mechanisms. Second, the effects of the nudging interventions in such applications can differ based on the EA scores of the users, as shown in our results. This finding indicates that although digital nudging is a promising approach to induce behavior change in individuals' mobility behavior (e.g., Franssens et al., 2021; Fyhri et al., 2021), such interventions must be tailored carefully to the targeted users.

Third, the design of our experimental website can be used as a blueprint or starting point for the further development of digital nudges. For example, designers of digital mobility service providers can use the study results to adapt environmental decision-making, improve decision quality, and develop more effective interventions. The interventions present only minor changes to the existing user interface. Therefore, digital nudges can be implemented with low implementation and development costs. However, designers must be aware that applying digital nudges can raise ethical issues, including privacy, as nudges are often related to manipulating decisions (Schneider et al., 2018). In general, (digital) nudges should always be deployed in a way that represents the interest of the persons involved to avoid malicious manipulation, following the guidelines of Thaler and Sunstein (2009). One way to overcome this issue in practice is, for instance, to make interventions more notable to users so that they can decide more consciously whether to follow a nudge or to choose a different option. Particularly with default nudges, designers should consider factors such as the visibility of automatic enrollment and the ease with which users can opt out (Caraban et al., 2019).

5.3 Limitations and Future Research

This study had several limitations that should be addressed in future research. First, we only collected data in Germany. Considering that the importance of private car ownership and the emotional attachment to one's car is decreasing among the younger generation (e.g., German Federal Environmental Agency, 2019; Kuhnimhof et al., 2012) in Germany, the conditions are promising to change current mobility patterns. However, as attitudes toward public transport use vary significantly across countries and cultures (Kuhnimhof et al., 2012), future studies should examine how these attitudinal differences influence people's mobility choices. Moreover, our sample consists of a moderate number of 188 participants. Although we found statistically significant results for the combined nudging interventions, our sample might not represent larger populations, which should be examined in future research with larger sample sizes.

Second, the experimental design can only mimic real-world situations without completely reflecting them. In our experimental study, we implemented only simple user interface elements to distract the study participants as little as possible and limited the choice options to private cars and public transportation use. Thus, our findings might only partially be transferable to actual choice decisions, for instance, when more design elements, such as the price or the date of a trip, are also displayed to users, or additional mobility options like biking are available. In addition, the availability and accessibility of public transportation alternatives are prerequisites for behavioral change in the mobility sector. The fictitious trips the participants were asked to plan were all within or started from Munich in Germany. In this city, the prerequisite for switching to more sustainable modes of transportation is present. However, this may be different in other locations. Therefore, the results should not be directly generalized to other regions with less diverse transportation options but rather taken as a foundation for future examination of the specific factors that may influence public transportation in more rural areas.

Third, the timing of the study might have influenced the results found and limited the generalization of the statements. The experiment was conducted in Germany during the spring and summer of 2022. This period included summer vacations, the COVID-19 pandemic, mandatory masks in public transport, the relief measure with fuel discounts for gasoline and diesel, and the nine-euro ticket. Therefore, the results may differ from one experiment to another during the year when there is no pandemic, or other political measures are taken. Therefore, future studies should examine how political decisions and the restrictions owing to the COVID-19 pandemic influence public transportation choices.

6 Conclusion

Digital nudging can be a solution to support behavioral change and encourage people to switch to more environmentally friendly modes of transport. In this study, we conducted an online experiment with a custom and interactive web application to analyze the effects of decoy and default nudges. We also addressed the lack of systematic evaluation of combined digital nudges by testing a combination of the two digital nudges to increase public transportation use. We tested the nudges within a route planning scenario in a big city in Germany, which offers very good access to public transportation options. Our results show that the combination of decoy and default nudges could statistically significantly increase the choice of public transportation options when additionally including control variables. Moreover, our results show that using decoy and default nudges influences our study participants, indicating that even small design changes of mobility service providers can influence their mode choice. However, the individual nudges lack statistical significance, thereby limiting the conclusions related to the general population.

This study contributes to the theory by providing a deeper understanding of the digital nudging mechanisms for pro-environmental mobility behavior. For practitioners, our study provides design implications for implementing digital nudges in web or mobile applications. It provides guidelines for optimizing the deployment of digital nudges in terms of geographical aspects and target users. Our study results show that digital nudging in mobility applications can represent another step toward more sustainable mobility patterns to address urgent environmental challenges worldwide.

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