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A multilevel approach to travel mode choice – how person characteristics and situation specific aspects determine car use in a student sample

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Abstract

The presented study analyses travel mode choice in a student sample on four frequent trips: to the university, to work, to the favourite leisure activity, and to the favourite shop. The decision to use the car in contrast to alternative travel modes is modelled for each individual trip using a two-level structural equation model with trip specific attributes on Level 1 and person specific attributes on Level 2. Data was gathered in an online travel survey on a student sample of the Ruhr-University in Bochum. 3560 students reported their mode choice for 26,865 individual trips. On the person level a comprehensive action determination model was applied to explain variation in person specific car preference, whereas on the situation level car availability, trip duration, day of travel, disruption in public transportation, weather, daylight, and purpose of the trip were included as predictors. The proposed two-level model is supported by the data, Level 1 predictors explain 62% of Level 1 variation, the Level 2 model explains 48% of Level 2 variance. The intraclass-correlation of car preference is .535. In a final step, interactions between person and trip specific variables were explored.

Keywords: travel mode choice, two-level structural equation model, situational influence, person attributes

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1. Introduction

Individual car use is one of the largest single contributors to CO₂ emissions in the private sector. Lorek and Spangenberg (2001) identified transportation as the third largest contributor to a household's CO₂ footprint after construction/housing and food/nutrition. They argue, furthermore, that transport related CO₂ emissions are under the control of the household itself to a large extent, by deciding for example about the travel mode to shopping and leisure activities, the distance travelled to such activities, the average energy consumption of the car used, and the number of people travelling in a car. Targeting individual car use with carefully tailored intervention programs should therefore be of high priority in travel mode psychology and related disciplines. To do so, we need a thorough understanding of the different influences on mode choice and their interaction. In fact, travel mode choice has been a frequently researched domain within sustainable behaviour analysis (see for example Gärling & Fujii, 2009, for a recent review).

Whereas travel mode psychology has a strong focus on cognitive determinants of travel mode choice and has proposed a long list of possible predictors (to be discussed in more detail, below), the non-psychological perspective on travel mode choice is very much characterized by a focus on travel mode characteristics, socio-demographic factors and features of the decisional situation. The authors of this paper understand the two perspectives not only as looking from two different angles on the same thing, but also as analyzing travel mode choice on different levels of abstraction. The psychological perspective usually tries to identify overarching patterns in travel mode choice that relate – for example – to relatively stable intentions, norms or habits and therefore to look for the stable, person specific aspects in travel mode choice (e.g., Hunecke, Blöbaum, Matthies, & Höger, 2001; Verplanken, Aarts, van Knippenberg, van Knippenberg, 1994). Consequently, in such studies,

travel mode choice is measured on an aggregated level. In contrast, the perspective on the influence of the choice situation implies analysing singular travel decisions with a specific set of situational determinants (e.g., Su, Bell, & Schmöcker, 2009; Ewing, Schroeder, & Greene, 2004).

Very few studies combined the two perspectives. For example, Collins and Chambers (2005) found interactions between situational aspects like cost relation between the car and public transportation, access to public transportation, as well as the relation between travel time by car and public transportation and psychological variables like environmental beliefs about car use. Hunecke, Haustein, Grischkat, and Böhler (2007) used both situational, socio-demographical, and psychological variables as predictors of travel mode choice and found significant predictors in all three domains. However, interactions between the domains were not analysed in that study. Furthermore, both studies did not go beyond the level of aggregated behaviour for their analysis. The present study aims to not only combine the two perspectives on travel mode choice but also the two levels of analysis by modelling travel mode choice both on the disaggregated trip level and the aggregated person level simultaneously. This is especially important when the situational influence varies constantly over time (e.g., the weather) and cannot be represented reliably as an aggregate on the person level. A combination of both perspectives allows furthermore analysing empirically how person related constructs are influenced by situational factors and how psychological factors shape the perception of varying situational aspect. A strategy of two-level structural equation modelling is applied to achieve that goal.

2. Theoretical background

2.1. The psychological determination of travel mode choice

Psychology has come a long way in analysing determinants of travel mode choice in recent years. Environmental psychology has been especially active in identifying variables that are able to explain a sustainable choice of travel modes or why people hold on to unsustainable patterns of travelling.

Only a fraction of this research can be reported here and therefore this section focuses on reporting the application of action theories like the *Theory of Planned Behaviour* (TPB; Ajzen, 1991) or the *Norm-Activation Model* (NAM; Schwartz & Howard, 1981) to travel mode choice as well as extensions of both theories that have been proposed.

The theory of planned behaviour has been successfully applied to travel mode choice (e.g., Bamberg & Schmidt, 1998). It assumes that sustainable travel mode choice is a direct outcome of *intentions* (INT) to use sustainable modes of transport and *perceived behavioural control* (PBC). The latter is a measure for the amount of control a person subjectively experiences over his/her behaviour in a given situation and the ease of performing different behavioural alternatives. Intentions in turn are generated in a maximum utility calculation, integrating the three components *attitudes* (ATT) towards the different behavioural alternatives, *subjective norms* (SN) regarding the alternatives, and perceived behavioural control. Attitudes represent a general evaluation of each behavioural alternative based on beliefs about possible outcomes of selecting the respective alternative. Subjective norms represent the perceived social expectation of relevant other people for each behavioural alternative.

Empirical work shows that in the domain of travel mode choice explained variance is increased if the theory of planned behaviour is extended with habitual processes (HAB), especially when the trip to be analysed is frequently conducted in stable circumstances (e.g., the trip to work). Verplanken et al. (1994) first introduced the construct “habit” into the theory of planned behaviour in its application on travel mode choice and were able to increase explained variation in the dependent variable travel mode choice significantly, a result that has been replicated many times since (e.g., Thøgersen, 2006; Gardner, 2009). Some of the authors were also able to show that habits moderate the relation between intentions and behaviour (Verplanken et al., 1994; Gardner, 2009). With strong habits the

influence of intentions diminishes, an effect that Ouellette and Wood (1998) also demonstrated in a meta-analysis of behaviour in several domains.

The Norm-Activation Model has been applied to travel mode choice by Hunecke et al. (2001). The basic assumptions of this theoretical approach are that behaviour in domains that are relevant with respect to normative considerations and tap on the value system of a person are under the control of personal norms to behave in accordance with the value system. *Personal norms* (PN) are a feeling of moral obligation to act in a certain way. This feeling is activated both by social norms (an equivalent to Ajzen's subjective norms) and perceived behavioural control, but also by an *awareness of need* (AN) and an *awareness of consequences* (AC). The latter two are necessary prerequisites of an activated personal norm. Awareness of need is a feeling of a necessity to act (e.g., that car use poses a threat to the environment). Awareness of consequences is the belief that the actor's own actions pose a relevant contribution to the problem.

The model has proven to be a suitable approach to travel mode choice and pro-environmental personal norms are a significant predictor of sustainable travel mode choice (Hunecke et al., 2001). Recent research has, however, questioned the direct link between personal norms and behaviour and has instead suggested a mediated relation with intentions as mediator between personal norms and behaviour (Bamberg & Möser, 2007; Bamberg, Hunecke, & Blöbaum, 2007; Klöckner & Blöbaum, 2010; Kaiser, 2006). As described above for the theory of planned behaviour, habits are also a valuable extension of the norm-activation model. Klöckner, Matthies, and Hunecke (2003) and Klöckner and Matthies (2004) have demonstrated that habits moderate the influence of personal norms on behaviour and are a predictor of travel mode choice parallel to personal norms under certain conditions.

2.2. A comprehensive action determination model

Several authors have suggested integrating the aforementioned psychological models (or parts of them) to improve prediction of environmental behaviour, and they tested such integrated models empirically (e.g., Gardner & Abraham, 2010; Harland, Staats & Wilke, 1999; Kaiser, 2006; Valle, Rebelo, Reis & Menezes, 2005). Recently, Klöckner and Blöbaum (2010) proposed an integrated model that combines all central features of the theories presented in the previous section and aims to be more comprehensive in explaining pro-environmental behaviour. The upper half of *Figure 1* visualizes the model that Klöckner and Blöbaum refer to as *Comprehensive Action Determination Model* (CADM). It assumes that variables from four different areas predict pro-environmental behaviour either directly or indirectly: Intentional processes, habitual processes, normative processes, and situational influences (represented in the lower half of *Figure 1* as they will be modelled on the situation level in this study). Whereas intentions, habits and situational influences have a direct impact on behaviour, the impact of norms is mediated by intentions and habits. This is a finding that is also supported by Gardner and Abraham (2010) and Kaiser (2006).

The intentional aspect of behaviour determination is represented by an attitude-intentions-behaviour chain which corresponds to similar processes described in the TPB. It is assumed in the model that habits are generated by pairing previous behavioural patterns with situational cues and therefore associating the two. Over time, this association becomes strong enough to elicit behavioural patterns just by encountering the same situation again – a process also described as direct-context-cuing (Neal, Wood & Quinn, 2006). The model is depicting decision making at one point in time and past behaviour (as the hypothesised antecedent of habit) is not included. Therefore, habits should be related to the more stable proximal determinants of past behaviour (perceived behavioural control) but also to the rather stable personal norms as they have a large impact on stability in behaviour according to Klöckner and Blöbaum (2010). The situational influence

on behaviour is assumed to be both indirect (filtered through perceived behavioural control) and direct. Perceived behavioural control should also impact intentions as is proposed by the TPB. Both personal and social norms should influence the formation of intentions but the influence of social norms should be mediated by personal norms, to a large extent. As predicted by the NAM, personal norms should be determined by the awareness of need, the awareness of consequences, social norms, and perceived behavioural control. The CADM assumes that the relative importance of the influences of intention, situation, habits and norms varies between different types of behaviour, between cultures and over time. The CADM has successfully been applied to travel mode choice (Klößner & Blöbaum, 2010) but also to other domains of pro-environmental behaviour (wood pellet heating: Sopha & Klößner, 2010; waste separation: Klößner & Oppedal, in press).

2.3. Situational conditions impacting travel mode choice

A lot of empirical evidence has been presented with respect to situational influences on travel mode choice, also. In the following, a selection of findings is summarized that includes the impact of car availability, the purpose of the trip, disruptions in public transportation, strikes in public transportation, the day of travel, daylight, the weather, and the duration of the trip.¹

That car availability is a powerful predictor of travel mode choice is neither new nor surprising. The easier a car can be accessed at the point in time when the decision is made, the higher – in general – the likelihood that a car is used. For example, Simma and Axhausen (2001) were able to show that car availability is a powerful predictor of both the percentage of car use and the distance travelled (car owners travel longer distances). Ben-Akiva and Boccara (1995) show that car ownership is a more binding constraint of travel mode choice than accessibility of public transportation systems. In a study by Dieleman, Dijst, and Burghouwt (2002) car ownership is strongly related to a higher likelihood of car use on trips to work, shopping and leisure. The theoretical status of car availability, however, is unclear. On the one hand it is strongly predictive of travel mode choice and is therefore

an independent variable, on the other hand car availability itself is the product of individual decision making and therefore depending on other variables. Van Acker and Witlox (2010) show that car ownership serves as a mediator between socio-economic/demographic variables, built environment characteristics and car use.

Similarly, the travel goal clearly corresponds to differences in travel mode choice. Dielemann et al. (2002) show in their analysis of data from the National Travel Survey in the Netherlands that the percentage of car use is highest for leisure trips, lowest for shopping trips and medium for trips to work. A representative German analysis of travel patterns (INFAS & GIW, 2004) shows that car use on work related trips is highest with 66%, followed by 43% on shopping related trips, 32% on leisure related trips, and only 10% on education related trips.

Disruptions of the public transportation network like delays, cancelled trains or strikes hitting the system have been also shown to impact travel mode choice. For example, van Exel and Rietveld (2009) demonstrated that an announced one-day strike in the railway system of the Netherlands lead to a major reorganization of travel patterns, including abandoning the trip, changing to car use, and rescheduling the trip to another day. Lo and Hall (2006) could show that a strike in Los Angeles transit lead to traffic speed declining by 20% and the rush period extending by 200%, even though the transit riders constituted a rather limited fraction of the population. Their results imply that a significant number of transit travellers switched to using the car for the duration of the strike. Effects of real or anticipated disruptions in the traffic network on travel mode choice might at least partly be explained by the high value of reliability of travel time in decision-making of individuals (Bogers, van Lint, & van Zuylen, 2008). The authors show in an experiment that people prefer a travel route that might be costly but has a travel time varying only within a small margin over a route that is cheap but has a highly variable travel time.

During weekends travel behaviour differs from usual working days. A representative analysis of German travel patterns (INFAS & GIW, 2004) shows that the number of trips on Saturdays is lower than on ordinary working days and the number of trips on Sundays falls even below the level of Saturdays. The modal split is also different on weekends: In a study from New Zealand alternative travel modes lose a significant part of their share of trips per day on Saturdays and especially Sundays in favour of car trips (O'Fallon & Sullivan, 2003). Both effects can be explained by the higher proportion of leisure related trips on both days (especially on Sundays) and the high proportion of shopping related trips on Saturdays (INFAS & GIW, 2004; O'Fallon & Sullivan, 2003). Chosen travel modes also differ with respect to time of day: Whereas 40% of all trips as a car driver fall between 16:00 and 05:00, the respective number for public transportation is only 28% (INFAS & GIW, 2004).

The weather on the day of travel has an impact on the number of trips and travel mode choice (INFAS & GIW, 2004). Snow and heavy rainfall increase the percentage of people not taking a trip at that day, both conditions reduce bike use significantly and use of public transport slightly, while car use is slightly stronger. The effect of the weather on the number of trips, however, is much stronger than on the modal split. Jakobsson (2004) also identified extreme weather events such as snow storms as one reason for not making a planned car trip. Al Hassan and Barker (1999) analysed the correlation between weather events and traffic activity in Scotland and found that, during weekdays, sunshine hours and temperatures above the expected level traffic activity increased, whereas higher than expected rainfall lead to lower traffic activity. Extreme events like snowfall (reducing traffic) or extremely good weather (the highest sunshine hours of the year and the highest temperatures – increasing traffic) also change traffic activities. It can be concluded from the data that people adjust their leisure activities to the weather: If there is good weather on a weekday they make additional

trips (mostly by car), if there is weather below the expectations on weekends they cancel planned activities.

The German travel study (INFAS & GIW, 2004) shows that trips with public transportation tend to take longer than trips by car, although the average distance travelled is shorter in public transport. Although there might very well be an objective difference in travel time between the car and alternative modes for the same trip, it has to be mentioned that most studies rely on self-reported travel times (even if they are recorded in travel logs). Thus, effects on the subjective perception of travel time have to be recognized. Li (2003) summarizes research on subjective time perception in commuting and proposes a model that includes, among other aspects, the objective duration, the composition of journey episodes (ride, wait, transfer), the comfort and entertaining quality of the travel environments, and expectancies by the commuter. It is thus possible that the difference in trip duration between car and public transport is overstated in a self-report procedure.

2.4. A multi-level approach

Whereas the impact of situational conditions on travel mode choice is usually modelled for individual travel decisions, the impact of psychological variables on travel mode choice is usually analysed with aggregated travel mode decisions. Against the background of both research traditions each perspective makes sense: On the one hand, the impact of constantly changing situational conditions like the weather, the goal of a trip, disruptions in travel services, etc. can only be understood meaningfully in a given situation and the impact is only valid for this specific situation. Psychological variables like intentions, habits, attitudes, norms or perceived control on the other hand have a rather high stability compared to situational conditions.² If situational variation is rather low, the impact of psychological variables can be estimated by using aggregates that treat situational variation as error variation. As multilevel analysis is more demanding on the data and sample size aggregate analysis is often preferred by psychologists not interested in the situational impact.

Looking more closely on travel mode choice, however, makes it obvious that a combination of both approaches could describe travel mode choice most accurately. Travel mode decisions are made by people with a specific psychological mind set in specific situations, which means both the aggregated level of a deciding person with person specific but (relatively) situation independent psychological variables on the one hand and situation specific additional influences on the other hand should influence travel mode choice simultaneously. If a substantial amount of variance in travel mode choice can be located at both levels analysing exclusively from either the situational or the psychological perspective without considering the nested structure of travel mode decisions may lead to an overestimation of relations on the respective level.

Multilevel structural equation modelling (e.g., du Toit & du Toit, 2008) is a way to statistically separate variation in travel mode choice into one part that is specific for a person but stable over situations (referred to as “between level”, “person level”, or “Level 2” in this paper) and a remaining part that is specific for a situation (referred to as “within level”, “trip level”, or “Level 1” in this paper). Such an analysis requires nested data, which means in case of travel mode choice a large number of trips with information about trip specific situational conditions. These have to be conducted by a number of individuals big enough to analyse the person specific variables. Whereas multilevel analysis is relatively common in analysing travel mode choice with respect to geographical clustering (see for example Bhat, 2000), an application of a multi-level approach to combine psychological person characteristics with specific situational aspects in travel mode choice is unknown to the authors. Another advantage of the multi-level approach is that interactions between variables on different levels can be tested (for example if psychological variables influence the interpretation of situational conditions).

3. The present study

The present study has three goals: (1) To demonstrate that a multi-level approach can give meaningful results for the analysis of a combination of person specific and situation specific influences on travel mode choice that go beyond the standard techniques. (2) To replicate the results of the study by Klöckner and Blöbaum (2010) on psychological determination of travel mode choice on the aggregated level and to extend it by including trip specific situational predictors. (3) To present first hints how person specific variables interact with situation specific influences on travel mode choice and generate hypotheses for further research on interactions between psychological and situation specific variables.

The first goal corresponds to a methodological improvement of psychological models of travel mode choice. The authors of this study hope to show that up-to-date analysis strategies are able to extend the modelling possibilities and can answer questions that are not adequately represented in ordinary modelling techniques. The second goal aims to contribute to psychological knowledge on behaviour modelling in the domain of environmentally relevant behaviour. The third goal follows an exploratory and hypotheses generating strategy as the role of psychological variables in influencing the evaluation of situational aspects of a travel mode choice has only been addressed with respect to a limited number of combinations of person variables on the one hand, and situation variables considered on the other hand. Especially this aspect of interaction between person/psyche and situation should be of huge interest for environmental psychologists. For example, it has been shown that strong habits interfere with information search and use (Verplanken, Aarts, & van Knippenberg, 1997; Aarts, Verplanken, & van Knippenberg, 1997). People with strong habits should therefore be less sensitive to situation specific conditions and/or use simplified decision strategies highlighting selected pieces of information over others (Enste, 1998). Strong attitudes have also been shown to guide attention towards attitude-relevant information and away from attitude incongruent or

irrelevant information (see Fazio, 2007, for a summary of attitude effects). Again, an interaction between attitudes and selected situational conditions can be expected. Similar processes might be relevant for norms and perceived behavioural control.

Based on the goals of this study the following hypotheses can be derived.

- A) On the between person level the overall structure of the CADM proposed by Klöckner and Blöbaum (2010) can be replicated.
- B) Situation specific variables add to explaining variance in travel mode choice on the within person level. The results of previous studies demonstrating the relevance of these variables are replicated.
- C) At least some between person level variables interact with within person level variables. Variables proximal to a behavioural decision (habits, intentions, & perceived behavioural control) should be the most likely candidates. The more distal to behaviour variables are the less important they should be in the interaction analysis.

4. Method

4.1. Procedure and participants

The study was conducted between mid of November and end of December 2007 as an online survey among students of the Ruhr-University Bochum. The whole population of 30,215 students received a letter from the research team explaining the aims of the study. The students were informed that all participants who finished the online questionnaire *and* completed the travel log entered a lottery of more than one hundred prizes (overall value: more than 4,000 Euro; first prize: a laptop).

Furthermore, the internet address of the questionnaire and a personalized username and password were included in the letter. After two weeks a reminding letter was sent to all students to increase the response rate. 4,473 students (14.8 percent) finally participated in the study, 3,560 (11.8 percent) provided enough data to be analyzed for the purpose of this study. These students reported

26,865 individual trips in the travel diary that are the basis for the analysis reported here. The response rate is low but within the expected range for an online survey census.

The study consisted of two parts: First the students answered two online questionnaires. After that they filled an online travel diary for a period of one week starting the day after the questionnaires were answered. The first questionnaire included information about the students' living conditions with respect to travel mode choice (e.g., location of their home, distance to the next bus stop, location of their favourite leisure activity, their favourite shop, and work place) which were not analysed in this study. The second questionnaire included all psychological person variables, referred to as Level 2 variables in this paper. The travel diary recorded the students' travel mode choice for four standard trips (university, work, favourite leisure activity, favourite shop) and the situational conditions at the time of that choice, referred to as Level 1 variables in this paper.

4.2. Measures

Three different types of measures were used in this study: (1) measures that apply only to Level 1 (the trip), (2) measures that apply only to Level 2 (the person), and (3) the dependent variable travel mode choice that is modelled both on Level 1 and 2.

The dependent variable was measured as the chosen mode (car, bus, bike, walking). To limit the complexity of the analysis, the measure was dichotomized as car use vs. alternatives. Only the main travel mode (the mode that was used for the largest share of the distance) was analyzed. On Level 2 the variable is modelled as a continuous latent variable (a random intercept on the Level 1 probit/logit).

Trip related Level 1 variables were the day of the week the trip was conducted (workday vs. Saturday vs. Sunday/official holiday), the duration of the trip in minutes, disruption of the public

transportation system, German Rail strike,³ access to a car on the day of travel, the weather conditions, whether the trip was conducted during the hours of daylight, and the purpose of the trip. All those variables were recorded individually for each trip. Variables with more than two categories were dummy coded with the most frequent category as reference category. See the appendix for further information on the variables, including descriptive statistics.

Person related Level 2 variables were recorded once before the travel diary started. These variables were the intention to substitute alternative modes for the car on frequent trips, car use habits, perceived behavioural control with respect to use of alternative modes, the attitude towards using alternative modes instead of the car, personal and social norms to use alternative modes instead of the car, awareness of need to reduce car use, and awareness of consequences with respect to car use. All variables but car use habits were measured using two to three items and a seven point agreement scale. The items were developed based on the study by Klöckner and Blöbaum (2010). Please see the appendix for a list of the used items and descriptive statistics.

Car use habits were measured by two independent measures commonly used in other studies: The first is the Response Frequency Measure (RFM) developed by Verplanken et al. (1994). It measures the generalized tendency to associate a single travel mode for most travel goals when the travel situations are described only briefly. The strength of the car habit is inferred from the consistency with which the option car is associated with a variety of travel goals. For a further discussion of that measure see Klöckner et al. (2003) and Friedrichsmeier et al. (2010). The second measure is the Self-Report Habit Index (SRHI) introduced by Verplanken and Orbell (2003). The original version of the index measures the three defining elements of a habit (history of repetition, automaticity, and expression of identity) by a self report. We used an edited version of the index adapted to travel mode choice. Habit strength is computed as the mean score of the items. Both, the RFM and the

SRHI were used as indicators of a latent car use habit strength in the structural equation modelling. The items used for the RFM and SRHI are displayed in the appendix.

4.3. Analysis strategy

The analysis was divided into two parts. The first part was testing a two-level structural equation model with the CADM on Level 2 and a regression of the travel mode choice (car vs. alternative modes) on the situational influences (partly dummy coded) on Level 1. The logic behind this two level analysis is that some persons may be generally more likely to choose the car than others, but a person's behaviour may also vary between the different situations the same person encounters. In the two-level analysis, these two sources of variation are split into one part that differs across persons, but is constant across situations, and one part that varies between situations, but is constant over persons. The model estimates the predictors of the situation specific variance in car use on Level 1 controlled for variance between the people that conduct the trip. The basis for this analysis are 26,865 trips with corresponding situational characteristics. Furthermore, the differences in the mean preference for the car (called random intercepts) are modelled on Level 2 as a latent dependent variable in the CADM.

In a second step not only random intercepts are allowed but also random slopes of the Level 1 variables on car use. These represent individual differences in the effect of the Level 1 variables, and allow to model interactions between Level 2 variables and Level 1 variables (e.g., the impact of the day of the week on car use behaviour may differ between participants with weak or strong habits). Technically a latent "random slope" variable is entered on Level 2, the model variables are regressed on that variable and an interaction between this variable and a Level 1 variable is entered into the model instead of the linear influence of this variable on car use. A significant regression weight of one of the Level 2 variables on the random slope variable indicates a significant interaction between the respective Level 1 and Level 2 variables. If – for example – we find a significant impact of habit on

the random slope variable with the same sign as the main effect shown before it means that the impact of the Level 1 variable (e.g., the day of week) is increasing if people have strong habits. Unfortunately, this type of analysis creates an inflation of degrees of freedom and uses so much computer resources that a simultaneous testing of all possible level-2-level-1-interactions is impossible with today's equipment. Therefore, the analysis was divided into 14 parts, testing interactions of all Level 2 variables with one Level 1 variable at a time. A downside of splitting up the analysis of random slope effects into 14 separate analyses is that it cannot be tested if inclusion of other interaction terms changes the effects of one. All analyses were conducted with the MPLUS software package 5.2 (Muthén & Muthén, 1998-2007).

5. Results

5.1. Testing a two-level model of travel mode choice

The first part of the analysis was a test of the theoretically derived two level model depicted in *Figure 1*. Several model fit indices were used to determine if the proposed two level model describes the empirical variance-covariance matrix reasonably well. All between level relations were modelled according to the CADM proposed by Klöckner and Blöbaum (2010). All exogenous variables on the between level (AN, AC, PBC, attitudes, social norms) were modelled to covariate (not included in the figure). On the within level a regression of all situational variables (partly dummy coded – see appendix) on the choice of a car as travel mode on the respective trip was modelled. The estimation of the model parameters was conducted with a robust weighted least square estimator with a mean and variance adjusted chi² test statistic (WLSMV) as recommended by Muthén, du Toit, and Spisic (1997) for categorical dependent variables.

As the WLSMV estimator does not allow the random slopes needed for step two of the analysis the same model was fitted again as a reference for the subsequent analyses using a standard maximum

likelihood estimator (ML). *Figure 1* displays both the standardized regression weights and explained variance based on the WLSMV estimation (before the slashes) and the standardized regression weights for all model paths on the between level, the odds ratios on the within level, and explained variance in all dependent variables based on the ML estimation (after the slashes). The measurement model for the latent variables on the between level is not included in the figure. *Table 1* displays the complete results of the analysis including the measurement model, unstandardized regression weights and standard errors (WLSMV estimation). *Table 2* presents the results for the ML estimation.

The WLSMV estimated model has a satisfactory to good model fit. The following model fit indicators are within the recommended margins for acceptable fit (see Hu & Bentler, 1999, for a discussion of cutoff values for model fit indices, as well as Yo & Muthén, 2001 as cited in Muthén, 1998-2004, for an adaptation to categorical outcomes): $CFI=.941$, $TLI=.913$, $RMSEA=.014$, $SRMR_{within}=.000$, and $SRMR_{between}=.024$. One model fit indices is close to the recommended minimum values: $WRMR=.926$ (should be below .900). The Chi^2/df ratio is 6.30 which is more than the acceptable ratio of 2-5 ($Chi^2=712.355$, $df=113$, $p<.001$). However, the large sample size on both levels is most likely responsible for that deviation.

The estimated intraclass correlation is $ICC=.535$ which indicates that a rather large proportion of variance in travel mode choice can be attributed to Level 2 (i.e. is stable between situations). Together with an average cluster size of 7.546 (which is the average number of trips reported per person) a design effect of approximately 4.5 results, which is clearly above a maximum design effect of 2 where the clustered structure of the data might be ignored. That means that travel mode choice should be analysed combining person and situation specific information.

- insert figure 1 and tables 1 & 2 about here -

In the WLSMV model all but two model paths were statistically significant on the between level.

Intention fails to significantly predict car choice on the between level and social norms fail to predict intentions directly. Looking first at the predictors of model choice on Level 2, perceived behavioural control has the strongest influence on car use, meaning that people with a strong feeling that they are able to use alternative travel modes are very likely to do so across different travel situations. Car use habits also predict car use for the measured frequent trips strongly. Together the predictors explain 48.3 % of between level variance in the likelihood to choose a car for a trip. Regarding the influences on intentions to use alternative modes, perceived behavioural control, attitudes towards alternative travel modes and personal norms to use alternative modes (in descending importance) are significant predictors. Personal norms, however, show an unexpected negative influence which might be due to a suppressor effect. 80.4 % of variation in intention is explained.

Looking next at predictors of car use habits, perceived behavioural control and personal norms could be identified as significant influences, explaining 72.6 % of variation in habits. Finally, personal norms are predicted by awareness of need, social norms, perceived behavioural control, and awareness of consequences which account for 67.7 % of variation in personal norms. The influence of awareness of consequences on personal norms shows an unexpected negative sign, which, taken together with the very strong correlation to awareness of need and the large impact of awareness of need on personal norms, points at a suppressor effect. All standardized measurement model loadings are above .74 which indicates well-constructed measures.⁴ Note should be taken of the extremely high correlation between two exogenous variables: Awareness of need and awareness of consequences correlate higher than .80 which might have caused disturbance in the estimation process.

On the within level all influences but the occurrence of minor disruptions in public transportation and the goal of the trip being “shopping” (in contrast to travelling to the university) had a significant impact on the likelihood of choosing the car. Not surprisingly, the strongest influence by far is having a car available for a specific trip. The likelihood of choosing a car is also significantly higher if the trip was conducted on a weekend (Saturday or Sunday), was a trip related to leisure activities or work, if it rained, snowed or was sunny (compared to cloudy weather), if there was a major disruption in public transportation or if the trip was during the rail strike. A reduced likelihood of choosing the car could be shown for trips during daylight hours and for trips that took longer.⁵ 61.7 % of Level 1 variation in car use is explained by the predictors.

A comparison of the results of the WLSMV estimation in contrast to the standard ML estimation shows very few deviations in the standardized estimates. Most importantly, the influence of car choice habits on behaviour is estimated stronger using the ML-estimator and consequently explained variation in car choice on Level 2 is larger. Furthermore, the suspected suppressor effect between awareness of need and awareness of consequences is smaller in the ML estimation resulting in a non-significant influence of awareness of consequences. On Level 1 the small influence of icy weather on car use is not significant when ML estimation is used. The high degree of similarity between the two solutions makes the authors confident that the next step of the analysis can be taken with the ML model as reference model, even if the WLSMV estimation is recommended to get more trustworthy results (Muthén et al, 1997).

5.2. Exploring interactions between Level 2 and Level 1

Unlike the analysis presented in the previous section the second analysis is exploratory in nature: Possible interactions between Level 2 and Level 1 variables are analysed systematically in 14 separate analyses, each modelling interactions between all Level 2 variables and one of the 14 Level 1 predictors (see *Figure 2* for a visualization of the model test). It should be mentioned again that

testing the between level interactions one by one does not allow for modelling the effect the inclusion of one interaction has on other interactions. This might to a certain degree distort the results as some of the variation that is captured in one interaction might also be simultaneously captured by another interaction that was not tested at the same time. However, technical limitations caused by the exponentially increasing complexity of model estimation when including several between level interactions made it necessary to go back to the one by one approach.

A ML-estimation had to be chosen for this analysis, as weighted least square estimation does not allow for the inclusion of random slopes on Level 1. Therefore, the ML-estimated model described in *Table 2* is used as the reference model for all model tests. *Table 3* displays the regression weights of the random slope on the level two variables for the tested Level 1 variable.⁶ Furthermore, the difference in relative model fit (BIC) compared to the ML model presented in Section 5.1. is reported. A negative number indicates an improvement in model fit. As there is no difference test for BIC available, a decreasing BIC does not automatically imply that the improvement of model fit is significant. Burnham and Anderson (2002) recommend to consider decreases of more than 10 points indicating substantial improvement. Modelling interactions leads to such a substantial improvement in model fit with four out of 14 Level 1 variables (gray shading in *Table 3*). The other significant interaction terms will only be interpreted with extreme caution because their inclusion did not improve the model fit. Furthermore, high correlations between some of the variables on Level 2 should lead to extra care in interpreting opposing interaction effects for two closely related Level 2 variables.

Strong car use habits, weak intentions to use alternative travel modes, weak personal norms, strong perceived behavioural control, weak positive attitudes towards alternative travel modes, and strong social norms lead to a stronger negative impact of the trip duration on car choice (note that the sign

of trip duration was negative).⁷ Taking the reversed effect of attitudes into account, the effect of the closely related perceived behavioural control might be overestimated. The same could be true for personal and social norms. What remains as a result is that strong habits, strong perceived control, and weak intentions seem to make people more perceptive for trip duration differences. Strong car choice habits strengthen the relation between “leisure”, “shopping”, and “work” as purpose of the trip and car use. Strong perceived behavioural control enhances the impact of the purposes “shopping” or “leisure” on car use. Strong intentions to use alternative travel modes reduce the impact of the purpose “shopping” on car use. Strong personal norms positively interact with the influence of the purpose “leisure” on car use, although this could have been caused by the moderate negative relation between personal norms and car use habits. Several further interaction terms are significant, but should be interpreted with extreme caution, as their inclusion does not improve the overall model fit: An interaction term between a trip on Saturdays and strong habits, a trip on Sundays and strong perceived behavioural control, and significant interactions between habits, personal and social norms and minor disruptions of public transportation. Furthermore, intentions, habits, perceived behavioural control, personal norms, social norms and attitudes interact with car access, personal norms and awareness of need with rainy weather, and attitudes with daylight.

- insert table 3 and figure 2 about here -

6. Discussion

The presented data shows that a two-level approach to car use including person specific variables and situation specific variables can broaden the knowledge about travel mode choice and paint a more precise picture of mode decisions. In the given dataset a rather large proportion of variance in car use was located at the person level which indicates that it makes sense to include person specific psychological predictors of travel mode choice as they explain a significant proportion of variance in people’s mode preferences across situations. This person specific influence should not be ignored by researchers of travel mode choice even where the primary focus is on the situational impact. At the

same time the analysis shows that psychology's approach to aggregate behaviour and exclusively analyse the person specific factors is also sub-optimal. Ignoring the situational influence neglects that people (no matter how stable their preferences are) have to decide on a travel mode in very specific situations. A car might be available or not, it might be extremely good or bad weather, different trip purposes might imply different demands, etc. In this study, the variance in car use is about evenly divided between the situation and the person level, which means both levels have approximately the same importance for modelling travel mode choice.

Looking at the two levels separately the hypotheses one and two can be confirmed. The comprehensive action determination model proposed by Klöckner and Blöbaum (2010) could overall be replicated as a promising model structure for the person specific influence on travel mode choice. There are, however, some important differences in the standardized regression weights of central model paths between the study presented by Klöckner and Blöbaum (2010) and this study: First of all, intentions do not significantly predict the person specific variation in car use. This surprising result might have been caused by a combination of statistical effects and specificities of the analysed sample in this study. The statistical explanation could be a rather strong suppressor effect of perceived behavioural control on the relation between intention and behaviour. Intention and PBC are closely related and the relation between PBC and behaviour is unusually strong (the estimated bivariate correlation between the two latent constructs is .90). Together with the unexpected positive sign of the insignificant regression weight of intention on behaviour it is possible that the influence of PBC is overestimated and the influence of intention compensates for that by switching the sign. There might, however, also be several meaningful interpretations of the lack of influence of intention on behaviour in this specific analysis: (1) It might be that within the sample we analysed here (students) and the restricted sample of travel mode decisions (everyday trips) intentions are not that relevant because perceived behavioural control and habit already determine behaviour

sufficiently. (2) Behavioural control in a single level analysis integrates both objective features of the choice situation on the aggregated level and the subjective evaluation of those situational conditions. In this study we disentangled the objective situational features on Level 1. Behavioural variance on Level 2 is only the between person variation without disturbance by within person variation. Perceived behavioural control in the current operationalization might have a stronger relation to this measure of interpersonal differences in car preferences and might be closer to intentions. (3) The missing significant influence of intentions on behaviour might finally be due to a masking effect of not included variables. Several studies have demonstrated for example that both habits and perceived behavioural control moderate the relation between intentions and behaviour (e.g., Klöckner & Blöbaum, 2010; Ajzen & Fishbein, 2005; Verplanken et al., 1994). If we assume that within the restricted sample we analysed the variance of either habit, perceived behaviour control or both is restricted to that margin of the scale where the influence of intentions would be smaller in a study based on a population sample, a combination of a restricted sample and the non-inclusion of the interaction effects might have produced the unexpected effect. However, due to already high model complexity this hypothesis was not tested.

Another difference between the model presented by Klöckner and Blöbaum (2010) and the model presented here is, that personal norms show an unexpected negative influence on intention. This can again be explained as a suppressor effect. Including attitudes as predictor of intention that was missing in the original study might have caused that effect. Also the lack of a significant influence of social norms on intentions can be attributed to the inclusion of attitudes as an additional predictor. Awareness of consequences and awareness of need have shown to be statistically inseparable in their current operationalizations in several studies (e.g., Matthies, Selge, & Klöckner, 2010; Klöckner & Blöbaum, 2010; Klöckner & Oppedal, in press). It is therefore not surprising that it is usually either awareness of need or awareness of consequences that predicts personal norms, but not both of

them. In this study we find a suppressor effect in the WLSMV estimation that disappears in the ML estimation.

On the trip level predictors from all areas influence car use significantly. Firstly, car access is the strongest predictor of car use in a given situation, by far. This replicates the results presented by Simma and Axhausen (2001), Ben-Akiva and Boccara (1995), and Dieleman et al. (2002). If a car is available in a given situation, it is much more likely that it is used for a trip. However, an interesting question was raised by van Acker and Witlox (2010): Is car availability just an ordinary predictor of car use as other predictors or does it have special characteristics as car availability is most likely a result of a decision making process itself. People create the situational conditions with respect to car availability themselves, thus car availability is at the same time expression of an evaluation of situational and psychological conditions and a predictor of actual car use. Especially in a population of students where car ownership is less likely than in the general population car availability might not always be a predictor of car use but the outcome of a decision to use the car for a certain trip: For example, if a car has to be borrowed from friends or the parents you have to make the decision first, that you want to or need to use the car, and make arrangements how to have access to one afterwards. Disentangling both aspects is a worthwhile research topic for the future.

Trip duration is another rather strong influence on car use, showing that trips undertaken by car tend to be shorter. This replicates the results presented in a German travel survey (INFAS & GIW, 2004). Again, the question can be raised if the duration of the trip in minutes is a predictor or the outcome of travel mode choice. Both effects might be interfering: Longer trips call for travel modes like the car or the train, whereas for a given travel distance trips take longer when undertaken with alternative travel modes than the car.

The purpose of a trip is another significant predictor. Both trips to work and trips to a leisure activity have a higher likelihood of car use, a result that replicates the study by Dieleman et al. (2002). Trips on a weekend are a little more likely to be conducted by car than on ordinary working days, most likely because leisure activities and work make up a larger share of trips on weekends (this is a student sample and working is often during evening hours or on the weekend). Trips during daylight hours are a little less likely to be conducted by car than trips during the night. This replicates patterns from the German travel survey (INFAS & GIW, 2004) and may be attributed to more leisure and work related trips in the evening combined with less frequent public transportation and reduced subjective safety during night (see Loewen, Steel, & Suedfeld, 1993 for a study on the effect of lighting on subjective safety).

In addition the study showed small but significant effects of the weather on the preference for the car. If it rained at the day of the trip the likelihood of car use was increased compared to the normal cloudy weather which served as a reference category, which can be explained by a significant reduction of bike use or walking as was also shown in the German travel survey (INFAS & GIW, 2004). Ice or snow also led to a slight increase in car preference. Interestingly, also unusually nice weather (sunshine) increased car use slightly, most likely because extra leisure trips by car were undertaken to use the good weather, an effect that was shown before in a Scottish sample (Al Hassan & Barker, 1999).

Finally, major disruptions in the public transport network and the rail strike during the period of data collection significantly affected car use positively. Minor disruptions did not have any effect.

Unfortunately, it was not defined in the questionnaire what minor and major disruptions were, so the result is a subjective evaluation, and what is considered to be minor or major disruptions may vary a lot between participants. It seems that both the strike (which was announced in advance) and

major disruptions (which at least partly are known before the trip is started) lead to a reorganizing of travel behaviour including a switch of public transport users to the car. This has also been shown by van Exel and Rietveld (2009) in the Netherlands.

The probably most interesting but also most preliminary results of this study are the significant interactions between person variables on Level 2 and situation variables on Level 1. Only in four out of 14 analyses an improvement of relative model fit compared to the reference model without interactions could be shown. The other significant interaction terms should therefore only be interpreted with great care. Possible suppressor effects on the interaction level further weaken the validity of some of the significant interactions. For some variables, however, a meaningful pattern emerges that merits further research in more controlled settings. First, we would like to focus on the proximal predictors of car preference on Level 2: Intention, habits and perceived behavioural control. It seems reasonable to assume from the pattern of results that both habits and perceived behavioural control strengthen the impact of easily accessible situational cues (purpose and length of the trip, probably also day of the week) in disfavour of information that is more difficult to acquire and to anticipate (probably car access at a given point in time). The opposite seems true for intentions, but also personal norms and attitudes. Social norms seem to diminish the impact of hard to get trip related information without increasing the effect of simple information like purpose or day of week.

Theoretically, all these effects make sense. It has been shown before that strong habits reduce the intensity of information search and use (Verplanken et al., 1997; Aarts et al., 1997). Furthermore, Enste (1998) discussed heuristics as a possible theoretical explanation for the effects of habitual behaviour. This means that simplified decision rules (e.g., “whenever I want to do a trip to a leisure activity I take the car”) instead of more complex decision rules might be active in case of strong

habits. For perceived behavioural control, which was measured on the person level, low specificity of PBC in case of weak control might explain the results: If a person perceives generally low control over the use of alternative travel modes, this low control should be generalized across situations (“I am not able to use the bus”). In contrast, if a person perceives a high level of control this should be linked to experience with very specific trips (“I know how to use the bus for my trip to university”). Thus, people with a high level of perceived control should respond more to cues related to trips (purpose and duration), whereas people with low control should be rather irresponsive to these cues. Put in other words: perceived behavioural control might be stored generalized and activated rather automatically when a certain travel purpose is anticipated or generated each time a decision is made, including more of the available information.

High levels of intention to use alternative modes (as well as high levels of attitude and personal norms) seem to result in a stronger motivation to make deliberate decisions based on more than simple cues. This involves a complex decision strategy considering for example trip length or car availability more thoroughly. Strong social norms, finally, seem to be an influence that has the power to override individual evaluations of some trip specific attributes. Making a decision under a relatively high level of social pressure seems to make less receptive for situation specific information.

7. Conclusion

The presented study confirms that a multilevel approach to travel mode choice is a promising alternative to conventional modelling on either the person level with aggregated travel mode choice as dependent variable or the trip level neglecting the stability of person variables over situations. The analysis shows that the multilevel approach is able to replicate previous results on both levels but adds information about interaction between both levels and the amount of variance located on each level. A comprehensive action determination model based on established psychological action theories performs reasonably well as a model on the person level, a selection of situational variables

showed to allow a rather good prediction of Level 1 variance. Adding interaction terms to the model in an exploratory manner contributed to improved model fit in some cases and offers interesting insights into how psychological variables shape perception of situational attributes. However, these results are preliminary and understanding of the effects would benefit from a more sound analysis. We hope to encourage other researchers to focus more on this interesting interface between person and environment. Hopefully, the fast methodological progress in multilevel structure equation modelling can stimulate such development.

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10. Notes

¹ Popular determinants often tested in choice models such as economical aspects (e.g., the relative monetary or time costs structure of different alternatives) or social-demographic characteristics are explicitly left out of the presentation as the present study is not focussing on them.

² It has to be acknowledged that psychological constructs vary in their stability over time. Compared to rapidly changing situational conditions, however, their stability is high.

³ On Thursday, November 15th, and Friday, November 16th 2007 – a few days after most students participating in this study started their travel diary – the train drivers' union went on strike. They announced the strike in the days prior to November 15th. The strike affected both long distance and short distance train services. About 50% of the trains were affected by the strike and especially in short distance travel in the area around Bochum the strike reduced the train density by about two thirds. The short distance trains in the region are especially important for the student population for two reasons: First, their annual ticket is valid only for short distance trains. Second, most students that do not reside in Bochum live within a rather short distance that makes slow trains the most likely connection to Bochum. However, the strike did not lead to a complete breakdown in train service. For the purpose of this study all trips conducted on the two days of strike were coded 1 for "potentially affected by the strike" in the rail strike variable.

⁴ Of course, a high loading is not the only indication of a good measurement model, and potential cross loadings on other latent constructs are not tested. However, all measures have been used and tested in previous studies and extensive analysis has indicated an item structure without significant cross loadings.

⁵ It is very likely that the causal relation in the last result is reversed: it seems reasonable that trips undertaken with alternative travel modes tend to be reported as taking a little bit longer than trips by car.

⁶ The authors decided not to report a full set of 14 result tables with all model estimates to keep the paper brief and readable. The full results of the analyses may be obtained from the first author on request.

⁷ Or vice versa, see footnote 5.

Table 1:

Results of the multilevel model test with WLSMV-estimator (Level 1: $N_{trips}=26,865$; Level 2: $N_{persons}=3,560$; Model fit: $\chi^2=712.36$, $df=113$, $p<.001$; $CFI=.941$; $TLI=.913$; $RMSEA=.014$; $SRMR_{within}=.000$; $SRMR_{between}=.024$; $WRMR=.926$).

WITHIN LEVEL (Level 1; trips):				
	<i>Beta</i>	<i>S.E.</i>	<i>p</i>	<i>β</i>
CAR USED ← Saturday	.210	.040	<.001 ***	.037
CAR USED ← Sunday	.202	.053	<.001 ***	.026
CAR USED ← trip duration	-.014	.000	<.001 ***	-.238
CAR USED ← rail strike	.181	.037	<.001 ***	.044
CAR USED ← minor disrupt.	.048	.035	.176	.012
CAR USED ← major disrupt.	.398	.045	<.001 ***	.076
CAR USED ← car access	2.208	.034	<.001 ***	.669
CAR USED ← sunny weather	.109	.041	.007 **	.021
CAR USED ← rainy weather	.209	.028	<.001 ***	.057
CAR USED ← icy weather	.307	.106	.004 **	.019
CAR USED ← daylight	-.113	.024	<.001 ***	-.034
CAR USED ← trip to work	.337	.028	<.001 ***	.075
CAR USED ← trip to leisure	.691	.026	<.001 ***	.169
CAR USED ← trip to shop	.030	.027	.266	.007
BETWEEN LEVEL (Level 2; person):				
	<i>Beta</i>	<i>S.E.</i>	<i>p</i>	<i>β</i>
INT1 ← intention	1.000	-	-	.894
INT2 ← intention	.962	.034	<.001 ***	.853
SRHI ← car use habit	1.000	-	-	.825
RFM ← car use habit	.626	.022	<.001 ***	.789

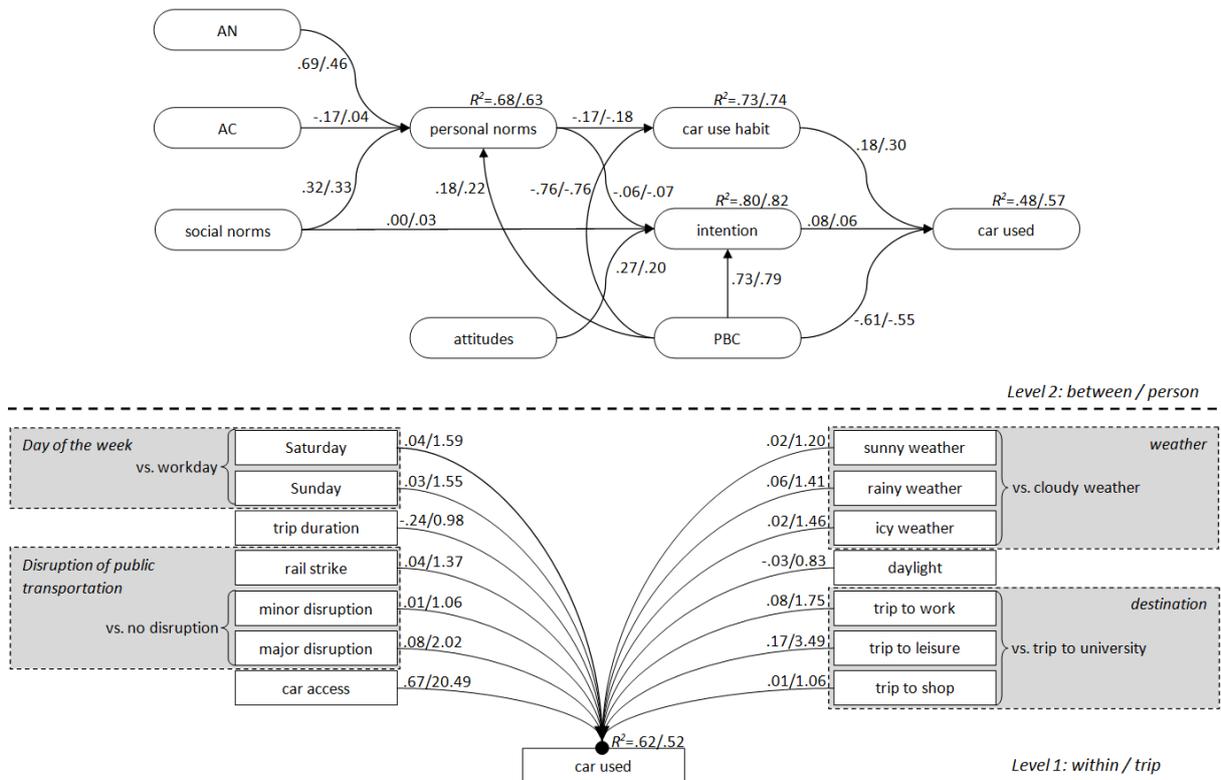
PBC1 ← PBC	1.000	-	-	.748
PBC2 ← PBC	1.027	.045	<.001 ***	.822
SN1 ← social norms	1.000	-	-	.838
SN2 ← social norms	1.106	.039	<.001 ***	.858
PN1 ← personal norms	1.000	-	-	.887
PN2 ← personal norms	.896	.025	<.001 ***	.852
PN3 ← personal norms	.914	.025	<.001 ***	.841
AN1 ← AN	1.000	-	-	.829
AN2 ← AN	.911	.025	<.001 ***	.765
AC1 ← AC	1.000	-	-	.829
AC2 ← AC	.992	.030	<.001 ***	.812
ATT1 ← attitudes	1.000	-	-	.792
ATT2 ← attitudes	.978	.034	<.001 ***	.766
CAR USED ← intention	.044	.045	.328	.083
CAR USED ← car use habit	.122	.049	.012 *	.179
CAR USED ← PBC	-.407	.088	<.001 ***	-.609
intention ← attitudes	.342	.037	<.001 ***	.266
intention ← personal norms	-.072	.022	.001 **	-.060
intention ← social norms	-.001	.027	.982	.000
intention ← PBC	.913	.043	<.001 ***	.727
car use habit ← personal norms	-.161	.017	<.001 ***	-.174
car use habit ← PBC	-.740	.033	<.001 ***	-.758
personal norms ← social norms	.395	.022	<.001 ***	.322
personal norms ← AN	.863	.063	<.001 ***	.691
personal norms ← AC	-.203	.050	<.001 ***	-.172
personal norms ← PBC	.194	.019	<.001 ***	.184
social norms ↔ PBC	.512	.055	<.001 ***	.230

AN↔PBC	.761	.059	<.001 ***	.348
AN↔social norms	.747	.051	<.001 ***	.397
AC↔PBC	.537	.054	<.001 ***	.232
AC↔social norms	.744	.051	<.001 ***	.373
AC↔AN	1.681	.070	<.001 ***	.860
Attitudes↔PBC	1.700	.105	<.001 ***	.672
Attitudes↔social norms	.993	.064	<.001 ***	.456
Attitudes↔AN	1.287	.067	<.001 ***	.603
Attitudes↔AC	1.088	.065	<.001 ***	.481

*** p<.001; **p<.01; *p<.05

Figure 1:

The tested multilevel model of travel mode choice without interactions between Level 2 and Level 1.

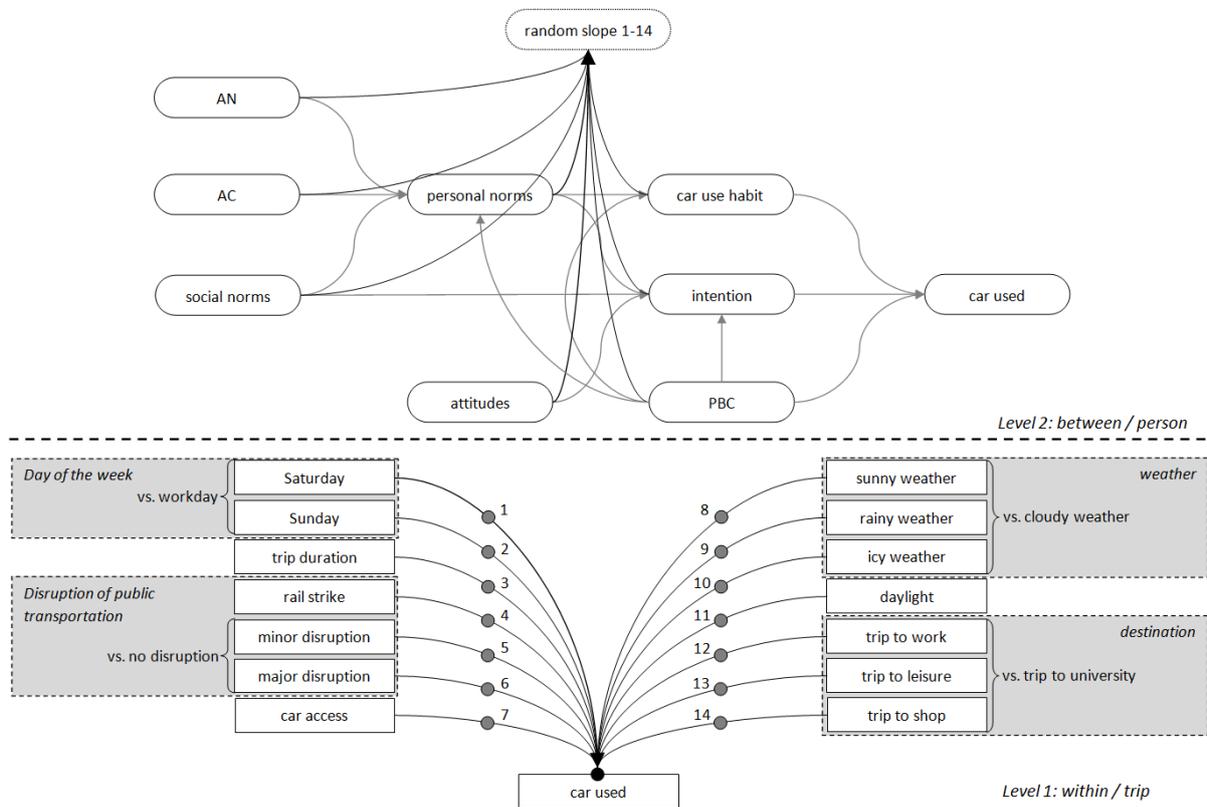


Notes:

The Figure shows standardized regression weights and explained variance for the WLSMV estimation before the slashes and standardized regression weights (Level 2), odd ratios (Level 1) and explained variance for the ML estimation behind the slashes. Rectangles represent observed variables, rounded forms represent latent variables. The circle on “car used” on Level 1 represents random intercepts (the latent variable “car used” on Level 2). For unstandardized regression weights, covariations of exogenous variables, and the measurement model on Level 2 refer to Tables 1 and 2.

Figure 2:

The tested multilevel model of travel mode choice with interactions between Level 2 and Level 1.



Notes:

Rectangles represent observed variables, rounded forms represent latent variables. The circle on “car used” on Level 1 represents random intercepts (the latent variable “car used” in Level 2). The grey circles on the arrows on Level 1 indicate random slopes (the interaction with Level 2). For the results of the stepwise between levels interaction test consider table 3.

Appendix

Level 1 items (trip level):

- A) *Car used*: Was the car used as main travel mode for this particular trip? (1=yes, 0=no) Obtained in the travel diary. Car used on 35.0 % of all trips.
- B) *Day of the week*: Was the trip conducted on a working day, a Saturday or a Sunday? Obtained in the travel diary. Dummy coded into two variables (Saturday/Sunday) with working day as the reference category. (9.1 % of the trips on a Saturday; 4.7 % of the trips on a Sunday)
- C) *Duration of the trip*: Self report of the total duration of the trip in minutes, including for example walking to the bus stop. ($M=31.1$ minutes; $SD=28.5$).
- D) *Rail strike*: Was the trip conducted on one of the days during the strike of German Rail? (1=yes, 0=no). Inferred from the date in the travel diary. 19.5 % of the trips conducted on a strike day.
- E) *Disruption in public transportation*: Self reported severity of disruptions in public transportation on the day of the trip (no disruption, minor disruption, major disruption). Dummy coded into two variables (minor/major disruption) with “no disruption” as the reference category. (20.4 % of the trips on days with minor disruption; 10.6 % of the trips on days with major disruption)
- F) *Car access*: Self reported car access for each particular trip. (1= car was available, 0=car was not available). Car available on 60.1 % of the trips.
- G) *Weather*: Self reported weather condition when the trip was conducted (cloudy, sunny, rainy, icy/snowy). Dummy coded into three variables (sunny, rainy, icy/snowy) with cloudy as the reference category. (10.4 % of the trips in sunny conditions; 26.8 % of the trips in rainy conditions; 1.0 % of the trips in icy/snowy conditions).
- H) *Daylight*: Was the trip conducted during daylight? (1=yes, 0=no). Inferred from the reported travel times in the travel diary and the daylight statistics for Bochum, Germany, at that day.
- I) *Destination of the trip*: Self report from travel diary. Four categories were recorded: university, work, favourite leisure activity, favourite shop. Dummy coded into three variables (work, leisure, shop) with university as the reference category. (15.3 % of the trips to work; 19.3 % of the trips to a leisure activity; 20.0 % of the trips to a shop).

Level 2 items (person level):

- A) *Intention (INT)*:

INT1: My intention to use public transportation instead of the car for my frequent trips (university, shopping, leisure, work) in the next seven days is strong. ($M=4.7$; $SD=2.3$)

INT2: I intend to use public transportation instead of the car for my frequent trips (university, shopping, leisure, work) in the next seven days. (M=4.7; SD=2.3)

B) *Car use habit (HAB):*

Self report habit index (SRHI)

"Taking the car for frequent trips is something that..."

SRHI1: ... gives me a strange feeling when I don't do it.

SRHI2: ... I do totally automatically.

SRHI3: ... I do without thinking about it.

SRHI4: ... is part of my routine.

SRHI5: ... is typical for me.

SRHI6: ... does not require any active thought.

Total SRHI score: $M=3.3$; $SD=1.9$

Response frequency measure (RFM)

"Assume you want to do the following things. Which travel mode are you most likely to use? Please answer spontaneously. (Habit strength equals the times "car" was chosen)"

RFM1: Visiting a friend in a nearby town.

RFM2: Taking a stroll in the city centre.

RFM3: Visiting a pub in the evening.

RFM4: Taking an excursion in nice weather.

RFM5: Shopping daily needs.

Total RFM score: $M=1.3$; $SD=1.2$

C) *Perceived behavioural control (PBC):*

PBC1: I am sure that I can use public transportation instead of the car on my frequent trips during next week. (M=5.0; SD=2.1)

PBC2: It would be easy for me to use environmentally friendly modes of transportation for my frequent trips. (M=4.8; SD=2.0)

D) *Personal norm (PN):*

PN1: Due to my values/principles, I feel personally obliged to use environmentally friendly means of transportation such as a bike, bus or train. (M=3.8; SD=1.9)

PN2: The aspect of environmental protection in travel mode choice is solidly anchored in my value system. (M=3.9; SD=1.8)

PN3: When I have to make a decision about a travel mode I feel obliged to take the environmental impact into consideration because of my values. (M=4.0; SD=1.8)

E) *Social norm (SN):*

SN1: People who are important to me expect that I will use environmentally friendly means of transportation. (M=2.6; SD=1.7)

SN2: People who are important to me insinuate that I should consider environmental protection when selecting a mode of travel. (M=3.0; SD=1.8)

F) *Attitude (ATT):*

“It would be ... if I used public transportation instead of the car for my trips next week.”

ATT1: ... enjoyable ... (M=4.1; SD=2.0)

ATT3: ... useful ... (M=4.0; SD=2.0)

G) *Awareness of need (AN):*

AN1: It is urgent to do something against the ecological destruction caused by using the car. (M=5.0; SD=1.6)

AN2: I believe that using the car causes many environmental problems. (M=5.0; SD=1.6)

H) *Awareness of consequences (AC):*

AC1: My personal car use is affecting the quality of life for future generations. (M=4.7; SD=1.7)

AC2: My personal decision to use the car has consequences for global ecological damage. (M=4.4; SD=1.8)