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Happy or liberal? Making sense of behavior in transport policy design

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ABSTRACT

Appropriate microeconomic foundations of mobility are decisive for successful policy design in transportation and, in particular, for the challenge of climate change mitigation. Recent research suggests that behavior in transportation cannot be adequately represented by the standard approach of revealed preferences. Moreover, mobility choices are influenced by factors widely regarded as normatively irrelevant. Here we draw on insights from behavioral economics, psychology and welfare theory to examine how transport users make mobility decisions and when it is desirable to modify them through policy interventions. First, we explore systematically which preferences, heuristics and decision processes are relevant for mobility-specific behavior, such as mode choice. We highlight the influence of infrastructure on the formation of travel preferences. Second, we argue that the behavioral account of decision-making requires policy-makers to take a position on whether transport policies should be justified by appealing to preference satisfaction or to raising subjective well-being. This distinction matters because of the (i) influence of infrastructure on preference formation, (ii) health benefits from non-motorized mobility, (iii) negative impact of commuting on happiness and (iv) status-seeking behavior of individuals. The orthodox approach of only internalizing externalities is insufficient because it does not allow for the evaluation of these effects. Instead, our analysis suggests that transport demand modeling should consider behavioral effects explicitly.

Introduction

Effective climate change mitigation necessitates, *inter alia*, the decarbonization of the transport sector (IPCC, 2014; Rothengatter et al., 2011). This challenge is arguably more difficult than the analogous transformation of the energy or the buildings sector: Mobility requires high-density fuels as opposed to electricity generation or heating (Sims et al., 2014; Pietzcker et al., 2014). Also, the emissions stemming from passenger transport result directly from the consumption decisions of the individual end-users. As such, behavioral aspects play a much more important role than, for example, in the utility sector, and, as we will argue, pose a challenge for standard welfare theory as applied to mobility.

Options for decarbonizing transportation fall into two groups, which can be delineated with a decomposition of total greenhouse gas (GHG) emissions (Schipper and Marie-Lilliu, 1999; Creutzig et al., 2011; Sims et al., 2014). Carbon and energy

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intensity can be reduced by technological options. This group was emphasized in former assessments on the decarbonization of transportation, for instance Kahn Ribeiro et al. (2007). However, transport demand and modal share also influence to global GHG emissions from transportation. A number of studies indicate that these factors can equally support the decarbonization of transportation (Banister, 2008; Creutzig and He, 2009; Kahn Ribeiro et al., 2012; Sims et al., 2014). While it has been argued that the second set of options can have substantial benefits in addition to reducing emissions (Woodcock et al., 2009; Creutzig and He, 2009; Creutzig et al., 2012; Shaw et al., 2014), the corresponding analyses are often not founded in economic models of decision-making and thus the welfare effects cannot be properly derived.

Here, we provide such a foundation for transport policy-making by addressing two questions: First, can policies based on behavioral findings regarding mobility choices substantiate behavioral change as an appealing option for decarbonizing the transport sector? Second, how do two different normative viewpoints, the satisfaction of preferences and the maximization of subjective well-being, produce diverging policy conclusions? Under the paradigm of rational choice, transport economics was freed of addressing the normative distinction between maximizing subjective well-being and satisfying the preferences of transport users. The idea of preference satisfaction was seen as unproblematic as, for instance, time-inconsistent or ill-defined preferences were deemed irrelevant, or preference satisfaction and maximizing well-being were understood to be identical. This article shows that many particular aspects of mobility behavior deviate from rational choice. Thus, our main claim is that the decision maker must take an explicit position regarding preference satisfaction or the maximization of subjective well-being: The two positions imply different transport policies.[2] We find that taking subjective well-being as a welfare criterion means that climate change mitigation policies become more closely entwined with policies addressing behavioral effects.

We proceed in three steps: (i) we comprehensively classify the choice mechanisms shaping mobility behavior, (ii) we characterize the option space of behavioral mitigation policies in the transport sector and (iii) we propose a refined and normatively explicit welfare analysis of transport policies.

First, we establish which choice mechanisms are the major explanations for mobility-specific behavior.[3] We systematically identify the main drivers of behavior in various modal choice situations, drawing from the large class of choice mechanisms that are well established in behavioral economics, such as time-inconsistency, social preferences, overconfidence, framing, focusing illusion, loss aversion and limited attention.

Second, our classification of choice mechanisms involved in mobility decisions allows us to exhaustively derive the option space for decarbonization policies addressing transport users' behavior. We pinpoint some of the choice mechanisms as the most promising for the design of such policy instruments. Key options include enhancing environmental awareness, addressing behavioral factors that may lead to a higher modal share of non-motorized transport, encouraging the purchase of more fuel efficient cars as well as exploiting the influence infrastructure has on preferences. We highlight the importance of understanding the built environment and choice architectures as crucial leverages for achieving low-carbon transport.

Third, we argue that our descriptive results indicate that understanding transport policy as internalizing the externalities of otherwise optimal behavior is insufficient. Instead, a distinction between two normative viewpoints – the maximization of subjective well-being ('happiness') and the maximization of preference satisfaction – is necessary in order to assess the merits of the potentially beneficial side effects of decarbonization policies. The reason is that the benefits, such as improved health or greater social cohesion, carry greater weight when happiness is maximized instead of preferences fulfilled, since transport users may not have preferences for the outcomes that make them happy. Finally, we delineate the differences between transport policies that follow from the two different welfare conceptions.

This article is connected to the pertinent literature in two ways: First, traditional transport demand modeling relies on the rational choice approach to explaining economic behavior. Underlying the standard disaggregate transport demand models, such as (multinomial) logit or probit models of mode choice and trip scheduling, is utility-maximization based on *revealed* preferences, often expressed as minimizing generalized costs, including time (Quinet and Vickerman, 2004; Small and Verhoef, 2007; van Wee et al., 2013). This does not allow, for instance, for an influence of the physical and social environment on preference *formation*. In contrast, while no canonical transport demand models based on behavioral economics exist; previous empirical work on mobility choices has produced a great number of findings that highlight the importance of empirical mechanisms for explaining mobility choices successfully. Examples include mass effects and conformity behavior (Abou-Zeid et al., 2013), symbolic and affective motives for car use (Steg, 2005), inertia (van Exel, 2011) or self-value of travel (Mokhtarian and Salomon, 2001). However, such research has not given an overview of which psychological effects generally identified as important for economic decisions matter specifically for explaining mobility (Markovits-Somogyi and Aczél, 2013). Moreover, empirical findings on mobility behavior have not been well integrated into the catalog of 'non-standard' choice mechanisms produced by behavioral economics (DellaVigna, 2009) that are amenable to rigorous welfare analysis (van Wee et al., 2013). An exception is Avineri (2012), who also discusses the relevance of behavioral effects in mobility choices for low-carbon transport policies. Nevertheless a systematic classification of the relevant effects on choices and the distinction between subjective well-being and preference satisfaction for drawing policy implications methodically are missing.

[2] In this article, we discuss which transport policies follow from different welfare criteria without addressing the question of how institutions should be guided by such criteria. The reason is that the policy domain of transport does not seem particularly different from other policy domains in this regard (see also section 'Two viewpoints of welfare').

[3] In this article, we only discuss behavioral effects in understanding *households'* mobility choices. Arguably, firms' transportation choices may also be subject to behavioral effects and are very important for a complete picture of mobility behavior, yet they are beyond the scope of this article.

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Second, current research in welfare theory is well aware of the distinction between preference satisfaction and subjective well-being (Loewenstein and Ubel, 2008; Fleurbaey and Blanchet, 2013), but has not addressed the consequences for the field of transportation decisions. Instead, research has focused on the applications for fields such as financial decisions, health (particularly addictions), and public good problems. By contrast, studies in transport science that explicitly deal with the welfare effects of (behaviorally construed) mobility decisions typically have not introduced a clear economic approach to welfare, but have chosen physical welfare metrics such as 'disability adjusted life years' (DALYs) (Woodcock et al., 2009; Shaw et al., 2014). To the best of our knowledge, no normative theories of transport policies exist to date that explicitly take into account the importance of behavioral findings regarding mobility. The added value of our article is thus to assemble the tools for such welfare analysis of transport policy: We examine whether behavioral economics, and its welfare theory, help better justify demand-side regulation, which has been recommended by transport research for a long time, and could lead to more effective policy instruments.

The remainder of this article is structured as follows: In the section 'Behavioral economics foundations' reviews key aspects of behavioral economics and research on subjective well-being (in which no familiarity is assumed) that matter for analyzing mobility decisions. The section 'Classifying behavioral explanations for mobility choices' explores systematically which preferences, heuristics and decision processes identified by behavioral economics are relevant for explaining and modeling mobility-specific behavior. The normative part of our analysis consists of three steps: First, in section 'Behavioral policies for mitigating carbon emissions from transportation', we characterize the option space of possible behavioral decarbonization policies. In the section we then, in section 'Two viewpoints of welfare', introduce preference satisfaction and subjective well-being as welfare criteria for evaluating transport policies. Finally, in section 'Assessing behavioral change from two distinct viewpoints', we show why the distinction between the two criteria is relevant for designing policies and highlight key differences in the resulting policy packages. The last section concludes by considering implications of our analysis for transportation research.

Behavioral economics foundations

Behavioral economics

Traditionally, economics has modeled choices of households by assuming that they maximize a utility function representing their consumption preferences. Under this assumption, households' preferences can be inferred from their observable choices. Utility is *not* to be understood as subjective well-being or 'happiness' (see below and section 'Two viewpoints of welfare'), but rather as a function representing which options are preferred over other options. Transportation economics has adopted this perspective by modeling the preferences of transport users through observed mobility choices and narrowed it further by excluding that mobility itself is a part of the desired consumption as well (van Wee et al., 2013; Mokhtarian and Salomon, 2001): Transport demand is 'demand derived' from other consumption.

Laboratory and field experiments have pointed to anomalies and deviations from such 'rational' utility-maximization. Many of such forms of 'non-standard' behavior could, in principle, be 'rationalized', that is, understood as utility-maximizing behavior when the set of desired consumption goods is broadened or suitable 'costs' on some of the choice options are introduced (Gul and Pesendorfer, 2001, 2008). Most researchers on individual decision-making find larger departures from the paradigm of revealed preferences more convincing and believe they increase the explanatory power and accuracy of the predictions: The modeling of human decisions should make room for decision-makers to be both altruistic and envious, have partially incorrect beliefs, rely on heuristics, be influenced by factors unrelated to the consumption outcome and make mistakes in taking decisions (Camerer et al., 2005; Camerer, 2008; DellaVigna, 2009; Kahneman, 2011). Analyzing the economic consequences of such behavior, both in experiments and in reality, is the subject matter of the field of behavioral economics. For the purpose of examining its relevance for mobility decisions, mechanisms underlying human choices should thus be classified into three broad categories: Preferences, beliefs and decision-making (DellaVigna, 2009).

The following summary introduces the reader to the choice mechanisms standardly identified by behavioral economics. It closely follows DellaVigna (2009), with some effects deleted and others added according to the relevance for mobility behavior. It contains all choice mechanisms mentioned in the subsequent sections.

Preferences

Preferences are an ordering of possible consumption options. While they are traditionally assumed to be a rational ordering of only one's own benefit of consuming the choices, individuals display a much wider set of preferences in the real world. We discuss four major classes of broader preferences.

First, preferences regarding intertemporal choice options can be *time-inconsistent*. Standard economic theory assumes time consistency, or that individuals discount the future at a constant rate at different points in time. Empirical findings challenge this assumption (Loewenstein and Prelec, 1992; Frederick et al., 2002) and imply that discounting is steeper in the immediate future than in the further future. This is sometimes called hyperbolic discounting. Time-inconsistent preferences give rise to self-control problems: The short-term preference prevails over an existing long-term plan. Combined with naïvety, or the tendency to incorrectly believe that an activity postponed today will be completed tomorrow,

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self-control problems can lead to infinite procrastination, thereby explaining a "status quo bias". Most people are likely *partially* naïve about their self-control problems (O'Donoghue and Rabin, 2001; DellaVigna and Malmendier, 2006).

Second, with regards to uncertainty, experiments on decision-making under risk show that preferences systematically violate assumptions of expected utility theory. Such non-standard *risk preferences* are explained by Prospect Theory (Kahneman and Tversky, 1979) using the following characteristics: (i) reference dependence: The value of an option depends on the deviation from a reference point instead of absolute magnitude; (ii) loss aversion: Given a specific reference point, losses are valued greater than gains; (iii) diminishing sensitivity: Agents are less sensitive to outcomes further from the reference point, (iv) probability weighting: Decision makers tend to overweight small probabilities and underweight large probabilities (Kahneman and Tversky, 1979).

Third, preferences can extend to the needs of others, which are then called *social preferences*. Traditional utility theory assumes individuals are purely self-interested and have a utility function based entirely on their own payoff. However, decision makers often display altruistic behavior, which indicates that individuals also consider how their decisions affect the utility of others.

Fourth, individuals care about their relative position in social hierarchies, leading to *status-seeking behavior*. In contrast to altruism, people's utility may be affected *negatively* by the consumption of others, if they care about consuming more than members of their reference group. Such status-seeking behavior is well-documented for a large variety of "positional" goods (Solnick and Hemenway, 2005).

Beliefs

Beliefs concerning (future) states of the world and availability of options, particularly under uncertainty, are another major aspect of explaining choices. Beliefs may be correct or incorrect; systematically incorrect beliefs are called biases. We mention a variety of biases discussed as explanations for observed mobility choices. First, individuals are often *overconfident*, as they tend to overestimate their ability and quality of private information as well as underestimate the occurrence of negative events. Second, individuals often *anchor* their belief in the initial piece of information or cue. Adjustments may be insufficient and the anchor may have a large influence on future assessments. Third, individuals sometimes exaggerate the effect of a specific factor, such as an increase in income, on well-being, the so-called *focusing illusion* (Kahneman et al., 2006).

Fourth, *heuristics*, or simplified rules for practical approaches to problem-solving or processing information, can lead to biases[4]: For instance, people estimate the likelihood of an event based on memorable instances of that event, which may not be an accurate reflection of the true likelihood of its occurrence. This is referred to as the *availability heuristic*. Using this heuristic, individuals tend to overestimate the probability of events with large consequences, familiarity, and visibility. A similar, yet distinct, bias is judgement by the *representativeness heuristic*, which occurs when individuals estimate the likelihood of an outcome based on how similar it is compared to a 'typical' case. However, the fact that an instance is more representative of a certain type of event does not make it more likely (Tversky and Kahneman, 1974).

"*Self-serving*" is a related bias: Decision makers may discount information that challenges their beliefs and support ideas that are consistent with pre-established notions (Miller and Ross, 1975). Finally, *misprediction of adaptation* means that individuals have incorrect beliefs about their ability to adapt to various stimuli, for instance noise or additional income (Frederick and Loewenstein, 1999; Loewenstein and Schkade, 1999; Frey and Stutzer, 2014). In particular, this is one reason why humans systematically do not choose what makes them happy (Hsee and Hastie, 2006), see section "Subjective well-being".

Decision-making

Decision-making is not always based on maximizing the utility of the outcome. One reason for this is that it is influenced by factors other than preferences and beliefs, such as the way the options are presented or the obedience of social norms. Another reason is that individuals may face informational or cognitive limitations to calculate which option would maximize their utility. A number of non-standard forms of decision-making are needed to explain mobility choices, as presented below.

First, *framing effects* refer to the influence the presentation of information has on decisions, even if economic considerations are held constant (Tversky and Kahneman, 1981). Second, *limited attention* contradicts standard economic theory, which typically assumes that individuals make decisions using all information available. Empirical evidence shows, however, that individuals tend to simplify complex decisions by focusing only on a subset of information. Inattention to a specific piece of information depends on its salience and the number of competing stimuli. Third, *emotions* sometimes influence decisions directly. For instance, experiments show that mood manipulations and emotional arousal substantially impact decision-making. Fourth, *social pressure*, or the desire to conform to the beliefs of others, can strongly influence an individual's decision-making and may lead to herd behavior, that is, following what others are doing without processing information (Banerjee, 1992). Finally, *default effects* largely influence decisions. In order to simplify complex decisions, individuals may avoid making an active choice and instead favor the default option. This can be due to having a preference for the familiar and/or salient in difficult choice situations. Often, framing influences individuals' propensity to choose the default. Together with loss aversion and limited attention, this form of decision-making can, in particular, lead to choosing the status quo as the default.

[4] Heuristics affect choices both as beliefs (about probabilities of events) and as forms of decision-making (as substitutes for solving a maximization exercise).

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Fig. 1 provides a summary of the concepts from behavioral economics used in this article and how they relate to the rational choice approach, see also section 'The role of infrastructure, the built environment and the social context'.

Transportation economics has implicitly taken up the above concepts when analyzing mobility choices empirically, but often neglected to make explicit the nature of the underlying choice mechanisms that lead to specific mobility behavior (van Exel, 2011; van Wee et al., 2013). However, a precise analysis of those mechanisms achieves greater clarity for drawing normative conclusions and allows for the design of more successful transport policies. Our analysis in the next section provides such an explicit characterization of the choice mechanisms crucial for explaining mobility behavior. The subsequent sections draw the normative and policy implications and for this also rely on results from research on subjective well-being.

Subjective well-being

Subjective well-being ('happiness') is a general term for all approaches that seek to determine people's well-being by self-reports. Happiness studies (as a branch of social psychology) find that measurements of subjective well-being are reliable: Self-reported experience of one's quality of life and one's feelings about an activity *do* characterize people's life satisfaction and present mood accurately (Kahneman and Krueger, 2006; Frey, 2008; Diener et al., 2009; Kahneman, 2011; Layard, 2011). For instance, greater happiness in such surveys correlates with more genuine smiles, being characterized as happier by peers as well as reduced suicide rates and changes in brain activity (Kahneman and Krueger, 2006; Frey, 2008; Layard, 2011). Two approaches must be distinguished: Measuring *life satisfaction* and measuring *positive affect*. On the one hand, life satisfaction measures assess how people *think about* their life overall. For instance, the World Value Survey assesses this by the question, "All things considered, how satisfied are you with your life as a whole these days?", which is to be answered on a scale from 1 to 10. Many other large scale surveys contain similar questions (Fleurbaey and Blanchet, 2013, Table 5.1 for an overview). On the other hand, it is possible to assess people's feelings in their everyday environment in real time (using 'Experience

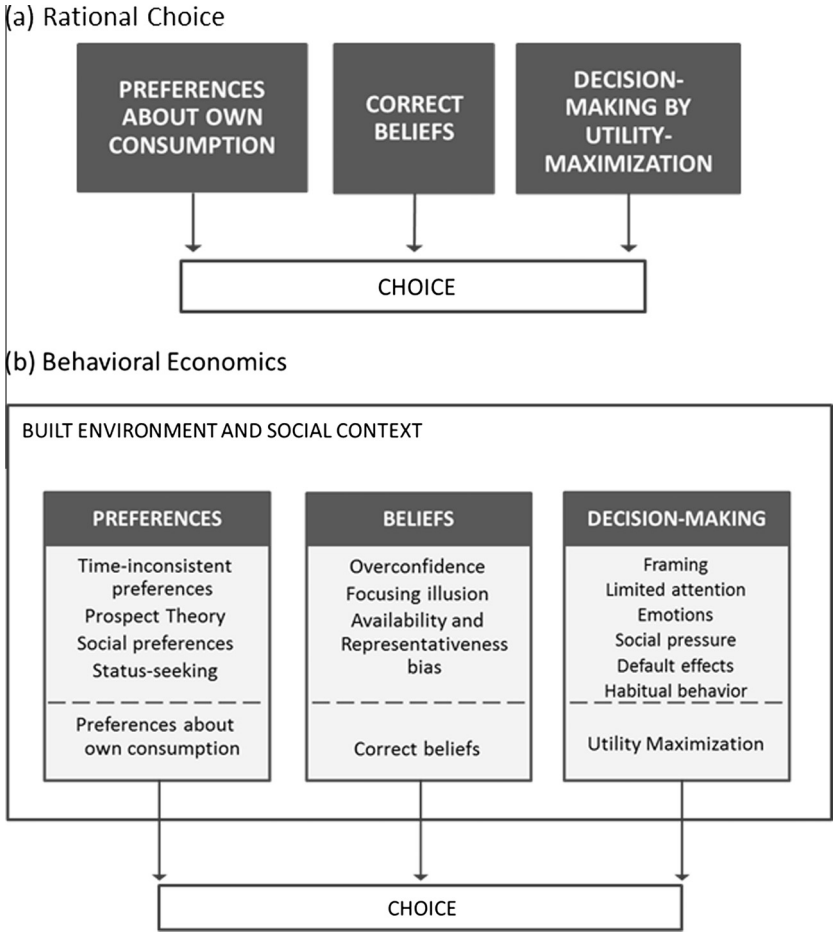

Fig. 1. The rational choice approach to decision-making (a) and concepts of behavioral economics used in this article (b). Behavioral economics is distinctively broader than rational choice models, but operates with the same categories for describing choices. The built environment and the social context may influence choice mechanisms, particularly preferences in the long-term.

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Sampling' – individuals report their well-being at fixed intervals – or 'Day Reconstruction' – individuals recollect episodes at the end of the day and indicate their feeling along nine dimensions, such as 'happy', 'worried' and 'angry', from 0 ('not at all') to 6 ('very much')). This allows for measuring how people *feel in* their life (Kahneman et al., 2004; Kahneman and Krueger, 2006). Aggregation of individual subjective well-being data into a *cardinal* welfare indicator requires two assumptions (Fleurbaey and Blanchet, 2013, Ch. 5): Individual scores must be cardinally meaningful measures and they must be interpersonally comparable. This is implausible for life satisfaction measures and has only been partially recognized by the pertinent studies. In contrast, Kahneman and Krueger (2006) propose a robust cardinal indicator, the 'U-Index', for *affect measures*: It records the proportion of the day in which negative emotions dominate (and thus would need to be minimized as a social welfare measure). Setting the difficulties of aggregation aside, measurements of subjective well-being at least allow one to study economic choices of an individual in a dimension separate from the outcomes: The impact of one's decisions on one's happiness. There is a consensus in behavioral sciences that choices often do not promote happiness: On the one hand, inaccurate predictions about the hedonic value of a choice or failure to follow correct predictions in the decision-making process (e.g. through weakness of will) lead to a deviation between actual and happiness-maximizing choices (Hsee and Hastie, 2006; Frey, 2008; Layard, 2011). On the other hand, humans do not necessarily seek happiness – instead, much behavior is driven by the need for meaning, not by the desire to be happy (Baumeister et al., 2013). In section 'Beyond emissions: Applying behavioral welfare theory to transport policy design' we discuss whether or not subjective well-being should be used as a welfare criterion and what this would imply for justifying transport policies. Below, we deliberately blur, for length restrictions, the distinction between life satisfaction and positive affect in the normative discussion to focus on the much greater contrast to preference approaches, of which we also do not discuss competing variants in detail. The empirical findings on mobility and subjective well-being we mention are mostly based on life satisfaction data.

Method of study

The overview of choice mechanisms given in section 'Classifying behavioral explanations for mobility choices' has been produced by systematically screening the literature on mobility decisions and their policy implications for precise explanations or justifications in terms of behavioral effects. The catalog of effects identified by behavioral economics produced by DellaVigna (2009) has been invoked as a standard what counts as a behavioral effect, but has been extended by including some effects too widely known to appear on it, such as status-seeking. The same applies to the presentation of the confirmed effectiveness of behavioral decarbonization measures in section 'Behavioral policies for mitigating carbon emissions from transportation'. The results on policy proposals in section 'Beyond emissions: Applying behavioral welfare theory to transport policy design' are generated by combining the general differences between subjective well-being and revealed preferences (elaborated in the syntheses of Hsee and Hastie (2006) and Layard (2011)) with all available findings about subjective well-being specific to mobility. The mobility aspects treated below are those that are most often invoked in the literature as domains in which behavior needs to be explained from a sustainability perspective. While classifying behavioral mobility aspects by importance for transport policy design would be desirable, it is beyond scope and purpose of the present article.

We emphasize that we see our contribution not as a comprehensive overview, but rather as a methodological essay designed to bridge the gap between how behavioral effects and their normative implications are treated in economic theory and transportation research, respectively.

Classifying behavioral explanations for mobility choices

In this section we identify which types of preferences, beliefs and decision-processes shape behavior for several mobility-specific aspects. Table 1 presents a non-exhaustive summary of the most important relevant behavioral effects and their explanations for each mobility aspect. Sections 'Environmental awareness', 'Mode choice', 'Safety', 'Commuting', 'Travel time', 'Car purchases and fuel economy' describe which choice mechanisms are crucial for understanding behavior regarding the mobility aspects of environmental awareness, mode choice, safety, commuting, travel time as well as car purchases and the fuel economy, respectively. For each category, relevant effects appear in the order of preferences, beliefs and decision-making. Section 'The role of infrastructure, the built environment and the social context' summarizes what is known about the influence of infrastructure, or the physical environment more generally, and the social context on mobility choices. Notably, physical and social context matter for the *formation* of preferences, which is very different from explaining mobility outcomes by preferences, as in the other subsections (see also Fig. 1). van Exel (2011, Chapter 2) also gives a comprehensive summary of the building-blocks of behavioral economics as applied to aspects of mobility, on which we draw for sections 'Mode choice', 'Safety' and 'Travel time'.

Environmental awareness

The level of awareness and concern for the environment of individuals can influence their travel behavior, such as mode or route choice. Significant behavioral factors that affect an individual's awareness and concern for the environment include social preferences and framing.

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Table 1
Mobility aspects, transport-specific phenomena exemplifying behavioral effects and their behavioral explanations in terms of preferences, beliefs and decision-making processes, as used in section 'Classifying behavioral explanations for mobility choices'.

Mobility aspects	Particular Effects	Behavioral Explanations
Environmental awareness	Willingness-to-pay for fewer emissions	Social preferences, framing
Mode choice	Habitual car use	Time-inconsistent preferences, representativeness, status quo, default effects
Safety	Safety valuation across modes, safety-compromising behavior	Prospect theory, overconfidence, emotions, social pressure
Commuting	Commuting time lowers subjective well-being	Adaptation, focusing illusion, status quo effect
Travel time	Average constant travel time, travel time valuation	Direct utility of travel, prospect theory
Fuel economy	Undervaluation	Prospect theory
Car purchases	Lower-than-expected-search effort	Status-seeking behavior, limited attention, emotions, social pressure
Infrastructure and social context	Self-selection	Default effects, context shapes preferences

Social preferences play an important role in observed behavioral shifts to sustainable mobility, which cannot be explained purely by self-interest. In some segments of the population (Anable, 2005), people's attitudes towards the environment are positively related to their willingness to reduce car use (Salomon et al., 1993; Steg and Vlek, 1997; Nilsson and Küller, 2000), as well as to their attitudes towards public transportation (Murray et al., 2010) and could be used to motivate a change in travel behavior (Anable, 2005). Indeed, some experiments indicate the existence of a "value of green", or willingness to pay for fewer emissions (for example, see Gaker et al. (2010, 2011)).

This suggests that people may alter their travel decisions when provided with information regarding the environmental impacts of their behavior. However, Tertoolen et al. (1998) observed that environmentally-conscious regular car drivers adjusted their attitudes, rather than behavior, and placed the blame on others in order to reduce cognitive dissonance – or the mental stress caused by conflicting attitudes, beliefs, or behaviors (Festinger, 1962) – associated with driving a car. Due to the potential of drivers to adjust their attitudes instead of behavior when provided environmental information, pro-environmental social norms are argued to be essential for the provision of information about the negative environmental effects of driving to effectively encourage more sustainable behavior (Tertoolen et al., 1998).

Framing may affect how individuals perceive the impacts of alternative travel choices. For instance, when presented a comparison of travel modes, individuals perceive the difference in CO_2 emissions to be larger if framed in a negative manner, that is, in terms of potential environmental damage (mode A is worse than mode B), rather than in a positive manner, or the potential benefit for the environment (mode B is better than mode A). Furthermore, the perceived difference between CO_2 emissions of the modes is amplified when presented in larger scales – for instance, a comparison of yearly outputs as opposed to a trip-by-trip presentation (Avineri and Waygood, 2013). Considering that a "value of green" may exist for some travelers, information about the impacts of alternative modes on the environment can be presented in a way that further enhances awareness.

Mode choice

Understanding how individuals make decisions regarding mode choice is vital in order to enhance the long-term sustainability of global transportation systems. choice mechanisms that are particularly relevant for mode decisions include time-inconsistent preferences, heuristics, status quo and default effects as well as social norms and emotions.

Time-inconsistent preferences may explain the existence of potential self-control problems related to mode choice. This is particularly relevant for health and search costs and should be further investigated as self-control problems have not been elucidated specifically with regard to mode choice, only regarding physical exercise more generally (Sniehotta et al., 2005; DellaVigna and Malmendier, 2006). For instance, active travel modes have significant positive effects on health as they reduce obesity-related diseases, as well as depression and dementia (Woodcock et al., 2009; Creutzig et al., 2012; Shaw et al., 2014). Individuals that prefer to use healthier forms of transportation in the long run could face self-control problems in the short-term, which leads them to choose a form of transportation that requires less immediate physical effort despite their long-term preference for good health and normal weight.[5]

Self-control problems might also arise when people are faced with the search costs of investigating alternative modes. Even if the costs of searching for an alternative mode or other travel information may be more beneficial in the long run (for instance, if a former car user saves time and money by taking public transportation), agents might "underinvest" in searching for alternatives because they inconsistently value their present time more than their future time. Although such behavior has not been described in terms of time-inconsistent preferences for the specific case of mode choices, the experimental results of Bamberg et al. (2003b) point towards such an explanation, see also section 'The role of infrastructure, the built environment and the social context'.

[5] An individual may further exacerbate the effects of self-control issues by showing naïvety towards the problem and falsely anticipating that they will make healthier travel decisions in the future.

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An individual's beliefs may influence absorption of information, and subsequently behavior, regarding mode choice. In particular, the heuristics of judgment by representativeness and by availability as well as the self-serving bias have been invoked to explain habitual car-use. The presence of these biases in mobility choices necessitates a distinction between the transportation alternatives (modes and routes) available to an individual and the alternatives the individual considers to exist (labeled as the objective and subjective choice sets (van Exel, 2011)). For instance, car drivers could erroneously believe that public transport is not an option for many of the trips for which it could be a viable alternative. In fact, research has identified a considerable gap between subjective (50–80%) and objective (10–30%) car-dependence (Goodwin, 1995, 1997).

The focusing illusion is a different bias that may also hinder car users from making correct predictions about future satisfaction with public transport. Drivers focus too much on the negative aspects of public transit, such as waiting on the platform and overlook the positive ones, like reading on the train (Pedersen et al., 2011b).

Contrary to standard economic theory, people may not analyze travel decisions on a trip-by-trip basis, but rather keep the status quo derived from past evaluations, experiences, or prior commitments (Mondschein et al., 2006) which elicits a "mindless and habitual" (van Exel, 2011) approach to travel decisions. Limited attention, default effects and loss aversion contribute to habitual travel behavior (Kitamura, 2000; Verplanken et al., 1994; van Exel, 2011). The relatively low-scale commitments of holding a drivers license, owning a car or owning a season ticket (Simma and Axhausen, 2001, 2003) as well as the higher-scale commitments of residential and employment location (Ben-Akiva and Lerman, 1985; Domencich and McFadden, 1975) amplify habitual mobility behavior and can explain decisions favoring the status quo. Even when alterations make a particular route less efficient, e.g., a new construction site, repetition causes drivers to overlook these deviations and insufficiently reevaluate travel alternatives, i.e., drivers stick to the old route out of habit despite the existence of better alternatives (van Exel, 2011; Kitamura, 2000; Mondschein et al., 2006; Salomon et al., 1993). Furthermore, the degree of familiarity to a transportation mode influences attitudes about the mode (Diana and Mokhtarian, 2009), contributing to a reliance on the status quo.

Social norms and perceptions regarding different transportation modes can have a large influence on individual's decision-making. For instance, perceived social support plays a considerable role in the willingness to use public transportation (Tertoolen et al., 1998; Bamberg and Schmidt, 2001; Murray et al., 2010). Similarly, motivation to drive a car is influenced by status and role beliefs (Bamberg and Schmidt, 2003).

Car driving can also generate intense feelings of identity, power, independence, ownership, etc. (Steg, 2005). These symbolic and affective aspects justify arguments against viewing car use simply as derived demand and can create barriers to behavioral changes (Steg, 2005; Anable, 2005).

Safety

Safety varies across different transportation modes (Dolan et al., 2008). Three choice mechanisms help explain decisions related to safety: Non-standard risk preferences, overconfidence and emotions. Moreover, for the more specific cases of wearing seatbelts and bicycle helmets, individuals' decisions are also illuminated by considering a variety of behavioral factors roughly similar to those discussed in section 'Mode choice'.

First, travelers tend to inaccurately estimate the risk of transport-related accidents occurring (de Blaeij and van Vuuren, 2003), focusing primarily on outcomes rather than probabilities, which is particularly relevant for small probabilities of large catastrophes. The actual valuation of transport-related losses is well represented by aspects of prospect theory (de Blaeij and van Vuuren, 2003) and may explain, for instance, a higher value placed on air transportation safety compared to road safety.

Second, emotional factors, such as feelings of "dread" (Chilton et al., 2006; Sunstein, 1997; Dolan et al., 2008) "lack of control" (Dolan et al., 2008) and "ambiguity" (Bach et al., 2009), may cause perceived risks to deviate from objective risks (Slovic, 1987; Loewenstein et al., 2001). This may enhance people's willingness to pay to prevent an accident from occurring (Slovic et al. (1980), Carlsson et al. (2004) as cited in Dolan et al. (2008)). Such a higher willingness to pay has also been explained as the avoidance of "mental suffering" evoked by the image of a catastrophic plane crash (Carlsson et al., 2004).

Furthermore, individuals display overconfidence regarding their own driving and safety behavior. The majority of people believe they are more skillful than the average driver and therefore underestimate the risk of being involved in an accident (Svenson, 1981; McCormick et al., 1986). The level of overconfidence varies by age group and gender (Gosselin et al., 2010; Harre and Sibley, 2007; Ulleberg, 2001; White et al., 2011), with young males exhibiting the most overconfidence. Individuals who are more overconfident and underestimate personal transportation safety risks may be less likely to respond to efforts oriented at changing safety behavior (Ulleberg, 2001).

Moreover, behavioral effects have been invoked to explain the use (and non-use) of seatbelts and bicycle helmets. For example, it has been discussed whether seatbelt wearing leads to increased risk-taking due to a change of the reference point, that is, individuals engage more in risky behavior due to the perceived safety gained from wearing a seatbelt (Evans et al., 1982; Janssen, 1994). Furthermore, Goudie et al. (2014) show that happier individuals are more conscientious to wear a seatbelts.

Regarding bicycle helmets, a sizeable amount of literature discusses behavioral factors that may be exploited to promote helmet wearing: Findings from the literature suggest that, similar to the mechanisms that explain persistent car use, overconfidence, biases, non-standard risks preferences as well as limited attention and social pressure prevent a higher share of helmet-wearing among cyclists (Thompson et al., 2002; Rezendes, 2006; O'Callaghan and Nausbaum, 2006).

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Commuting

Making a decision about how far to commute involves balancing its costs with the benefits derived from work or housing. Rational decision-making regarding commuting choices would thus imply that agents compensate the burden of commuting with the greater utility obtained through it: An individual drives a longer distance to a higher paying job or purchases a home further away from her place of work for the sake of more space (Stutzer and Frey, 2008). However, recent research finds that people with longer commutes report systematically lower subjective well-being (see section 'Subjective well-being') as demonstrated by Stutzer and Frey (2008) using life satisfaction data. This is due to the negative effects on people's social life (Pocock, 2003; Flood and Barbato, 2005), sleeping time, family and interpersonal relationships (Sandow, 2011) and health (Costal et al., 1988; Kluger, 1998; Evans et al., 2002).[6] Insights from behavioral economics, therefore, may help explain this seemingly paradoxical behavior regarding commuting decisions.

First, in contrast to the ability to adapt to different levels of income, people are much less able to adapt to high levels of commuting (Frey and Stutzer, 2014). Agents tend to *mispredict* the utility derived from large external rewards, such as a bigger house and a higher salary, and give less attention to other aspects that play a significant role in subjective well-being, such as reduced time for social life due to longer commutes and the stress caused by the commute itself (Frederick and Loewenstein, 1999; Loewenstein and Schkade, 1999). Hence individuals misleadingly focus on the utility derived from the "extrinsic" aspects of a decision, such as its impact on their income, and neglect their "intrinsic" needs, such as time spent socializing (see Frey and Stutzer (2014)).[7] Recent research suggests, more specifically, that the negative effect of commuting on subjective well-being is greatest when using a car instead of choosing an active travel mode (Martin et al., 2014), yet the details of this distinction remain unexplored.

Second, the focusing illusion is another bias well documented to be relevant to income and hence relevant in the context of commuting: People are highly motivated to increase their income – and often justify decisions based solely on economic concerns (Frey and Stutzer, 2014) – despite the weak relationship to their subjective well-being (Kahneman and Deaton, 2010).

Furthermore, due to the repetitive nature of commuting, individuals are likely to form habits and rely on the status quo when choosing a commute mode and route (Verplanken et al., 1997; Fujii et al., 2001; Verplanken and Wood, 2006). Past commuting decisions are good predictors of current behavior since people do not re-evaluate all alternatives for routine trips – rather, they rely on prior assessments of alternative mode and route choices (Salomon and Mokhtarian, 1998; Mondschein et al., 2006). Limited self-control and naïvety about it further enhance the status quo effect and may lead to the 'infinite procrastination' of decisions that might reduce commuting time, such as searching for a job closer to home or an apartment closer to work (Stutzer and Frey, 2008).

Travel time

A common assumption in transportation economics is that travel demand is derived from other activities. The time spend traveling is therefore considered a cost, or disutility, that individuals seek to minimize (van Wee et al., 2013; Mokhtarian and Salomon, 2001). Several empirical findings, however, challenge this standard assumption and suggest that the direct utility derived from traveling, prospect theory and a constant average time budget need to be invoked to explain the amount of time spent on travel.

Individuals may not engage in travel merely for instrumental purposes, but also pursue the act of traveling itself (Mokhtarian et al., 2001; Brouwer and van Exel, 2005). The direct value of travel arises from fundamental human needs for motion, freedom or independence (Mokhtarian et al., 2001; van Exel, 2011). This means that people may not try to minimize the total time traveled as standard economic theory indicates, particularly regarding travel for recreational purposes (Mokhtarian and Salomon, 2001). Consequently, measures aimed at reducing travel demand may not be as effective as expected if they do not consider the positive utility of traveling for some trips (Salomon and Mokhtarian, 1998).

Furthermore, as predicted by Prospect Theory, travel time delays are valued higher than time savings (Rietveld et al., 2001; Avineri and Bovy, 2008; Parthasarathi et al., 2011; van Exel, 2011, for an overview), as is reliability, or low variability of travel time (Bogers et al., 2008; Asensio and Matas, 2008; Tseng et al., 2009). However, it is important to note that losses refer to deviations from a specific reference point, such as a "desired" commute time (see Avineri and Bovy, 2008), arrival time, or public transportation schedule see (van Exel, 2011), which may not reflect all objective choice sets. Considering the existence of loss aversion in terms of travel time, the occurrence of a one-time, yet substantial delay in public transportation could have long-lasting effects on the daily mode choice of an individual, even if time savings by public transportation are actually more common. Much like the distinction between subjective and objective travel choice sets, people can establish false beliefs about the reliability of a certain mode of transportation based on past experiences or attitudes (Bogers et al., 2008; Tseng et al., 2009; van Exel, 2011, for an overview).

Moreover, instead of minimizing the amount of time spent traveling (according to its dis-utility), the population is observed to have, *on average*, a fairly static daily travel time budget of approximately 70 min (Schaefer and Victor, 2000;

[6] For a detailed overview of the private and social costs of commuting, see Koslowsky and Kluger (1995).

[7] Nevertheless, it is of course possible that some individuals deliberately choose to decrease their happiness through a longer commute in order to strive for other goals sought for themselves, such as meaning, power or fame through particular career options (Baumeister et al., 2013).

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Hupkes, 1982; Mokhtarian and Chen, 2004, for a more skeptical view). The existence of a daily travel time budget indicates that individuals will continue to spend the same amount of time traveling despite changes in income or improvements to the availability of technology and infrastructure (Metz, 2004, 2008; Schaefer et al., 2009). This undermines the standard reasoning that providing additional transport infrastructures, for instance, by constructing highways, high-speed rail or additional airports, leads to travel time savings (Metz, 2008). In the long-run, people do not shift time savings to pursue other economic activities, but rather to reach farther destinations. Some claim that a constant travel time budget is an anthropological invariant (Marchetti, 1994), while, in general, no encompassing explanation (whether related to behavioral effects or not) has been given how the aggregate constant time budget arises from individually varying travel times (Schaefer et al., 2009).

Car purchases and fuel economy

As a major source of greenhouse gas emissions, the type of vehicles purchased by consumers is a focus of climate policy. Throughout the article our analysis is limited to behavioral effects of households; however, for the structure of car markets, firms' decisions are particularly important, as for example in the EU around 50% of new cars bought are company cars (Copenhagen Economics, 2010). Firms' car purchase decisions may indeed be more sophisticated regarding financial aspects than those of households, yet are possibly also influenced by the symbolic motives attached to cars by the employees. Here we only focus on household's purchase decisions because only those matter for the welfare considerations below.

Concerning the decision-making process of car purchases of households. It is well-established that car purchases of households are subject to a variety of behavioral factors – particularly regarding the evaluation of fuel economy – that influence the automobile market. Research suggests that factors such as loss aversion, status-seeking behavior, social pressure, limited attention as well as emotions can affect how consumers evaluate automobile alternatives.

Under expected utility theory, a rational economic consumer consistently discounts (uncertain future) fuel costs over the entire lifetime of a vehicle when making a purchase decision (Greene, 2010). Econometric evidence is inconclusive as to how consumers value fuel economy when selecting an automobile, but many such studies are conducted within the framework of rational utility maximization (Greene, 2010). For instance, Busse et al. (2013) find little evidence of unusually high discount rates with respect to fuel economy valuation. However, others claim that there could be undervaluation of fuel economy in the automobile market due to loss aversion because of the uncertainty about future fuel prices (Greene et al., 2009). Consequently, gains in fuel savings may have to be greater than what standard utility theory would predict in order for consumers to be willing to pay a premium for automobiles with better fuel economy. Consumers may require a short payback period in order to invest in such cars.

Furthermore, insights from Turrentine and Kurani (2007) call into question models for estimating the undervaluation of the fuel economy that assume rational individuals. They conclude, based on in-depth interviews, that "households do not have access to the basic building blocks of information regarding their fuel use and costs" (Turrentine and Kurani, 2007), that they are unable to carry out the required calculations or do not apply them. Instead, they defend the hypothesis that consumers are simply inattentive to fuel economy because their decisions about purchasing cars are driven by "high value meanings, some of which have important but non-quantifiable [...] value" (Turrentine and Kurani, 2007). This is broadly confirmed by Peters et al. (2011) who find that the purchase of fuel efficient cars is directly or indirectly influenced by a person's evaluation of less power and smaller size of cars, perceived ability to perform respective behavior, altruism, perceived response efficacy, social pressure, symbolic motives and awareness of environmental problems. Together these factors explain 29% variance of the fuel economy. Peters et al. (2015) point to a gap between intention and behavior with regards to the importance of fuel economy in purchase decisions, as stated intention is to a larger degree derived from a sense of adhering to what is socially desirable and influenced by symbolic motives.

Moreover, social influence plays a considerable role in consumption decisions more generally, including automobile purchases: In particular, status consumption (Layard, 2006; Clark et al., 2008; Solnick and Hemenway, 2005) may motivate buyers to purchase an automobile based on attributes such as appearance, speed or reputation (Johansson-Stenman and Martinsson, 2006; Winkelmann, 2012). Car buyers are also influenced by the distribution of ownership choices of their peers (Gaker et al., 2010) and, in particular, the recent automobile purchases of neighbors, which may, however, be due to information transmission rather than envy (Grinblatt et al., 2008).

Rather than making automobile purchase decisions based on all available information, consumers simplify their decision-making by not optimizing their utility over all available information, but using non-standard forms of decision-making. Several cases of limited attention in the decision-making of car buyers can be observed (Furse et al., 1984; Peters et al., 2006; Turrentine and Kurani, 2007).

First, people tend to utilize a two-stage decision process when purchasing an automobile (European Parliament, 2010). In the first stage, alternatives are eliminated using intuition followed by a second stage in which the person rationally weighs the alternatives. Such decision-making process could explain large evidence for the fact that automobile buyers search effort is lower than expected (Furse et al., 1984). Evidence suggests that in the first stage, buyers decide on the car class based on characteristics such as price, safety and style followed by the second stage in which they consider factors such as environmental impact and fuel economy (Peters et al., 2006; European Parliament, 2010). Since the environmental impact and fuel economy is relative to car class, which was decided in the first stage, these factors may not have as large an influence on purchasing decisions as standard theory would suggest. Furthermore, 40% of Swiss car buyers take less than two weeks

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for making a purchase decision, while a majority stated to have only considered one brand (and then only one model) pointing to strongly limited attention in decision-making (Peters et al., 2006).

Second, car buyers also have a strong partial inattention to mileage in the used car market, which causes irregular drops in the sale prices of used cars at the 10,000-mile and 1000-mile odometer thresholds (termed left-digit bias) (Lacetera et al., 2012).

Third, transaction costs and information barriers prohibit people from understanding fuel economy correctly when it is presented in complicated frames, leading to an "MPG illusion" (Larrick and Soll, 2008): Car users systematically misunderstand miles per gallon (MPG) as a measure of fuel efficiency. A false linear instead of a correct hyperbolic reasoning about MPG leads car drivers to undervalue small improvements on inefficient vehicles. If expressed as gallons per mile consumers would intuitively understand their petrol use and carbon footprint.[8]

Moreover, the emotional state of a person can have a large impact on consumption decisions. Car manufacturers not only sell cars based on technical features, but also tap into the emotions of potential buyers (Sheller, 2004) by emphasizing the type of lifestyle or community the car symbolizes, making it more appealing and seductive to their target market. The emotional association people have to cars (Steg, 2005) creates a barrier to reducing automobile use despite efforts to raise awareness and enhance access to public transportation (Banister, 2008).

The role of infrastructure, the built environment and the social context

Infrastructure design and urban form are variables within the scope of policy design that influence individual user behavior and should thus be part of an overarching behaviorally explicit policy framework (Næss, 2006; Sims et al., 2014). Important examples include the provision of cycling networks, tram lines or highways (Ewing and Cervero, 2010). Nevertheless, there is surprisingly little research that explicitly analyzes the links between infrastructure and mobility choices based on behavioral effects. Infrastructure can influence mobility choices through two independent channels. First, it may impact behavior through default effects in the decision-making process (as suggested by the finding of Goodman et al. (2014), see section 'Behavioral policies for mitigating carbon emissions from transportation'). Although this influence is a special case of the general ubiquity of "choice architectures" in shaping decisions (Thaler and Sunstein, 2008), there is, to the best of our knowledge, no substantial transportation research on this effect. An exception may be the finding of Bamberg et al. (2003b): Individuals moving to a new city with an excellent public transport system were given information material and a free day ticket for public transport. The modal share of public transport more than doubled as a result, compared to a control group moving to the same city. This may indicate the presence of default effects (and/or limited attention and time-inconsistent preferences) when individuals make mobility decisions in a new environment (see also Bamberg et al., 2003a). Second, infrastructures are stocks that are effective for long time scales,[9] constituting the template for preferences and user behavior. Infrastructure could thus influence the *formation* of preferences on a longer time-scale. Traditional transport demand modeling, however, is based on the idea that preferences (for instance, for modes) are fixed, while only attributes of modes change. Descriptively, this rules out the idea that preferences themselves are impacted by changing physical and social environments, which may be important for understanding residential self-selection (see below; for normative implications of this assumption, see section 'Assessing behavioral change from two distinct viewpoints').

A recent strand of literature on social learning in transportation, however, puts pressure on this approach. Results indicate that individuals who move from city A to city B tend to have modal choice preferences that co-align with the infrastructure of city A, even if city B provides infrastructure that is more suitable for a different mode (Weinberger and Goetzke, 2010, 2011). The built environment one grows up with hence shapes one's modal preferences – preferences are not exogenous but endogenous to one's physical environment. Similarly, one's social environment may also shape individual preferences[10] (Weinberger and Goetzke, 2011; Goetzke and Weinberger, 2012).

Moreover, there is a two-way relationship between the built environment and behavioral preferences. As described, the built environment can impact travel behavior (Næss, 2006; Ewing and Cervero, 2010), but the individual preference for a specific built environment, given specific mobility habits, also plays a substantial role that is not easy to quantify (Cao et al., 2009): After controlling for such residential self-selection, several studies nevertheless indicate that there is a distinct influence of the built environment on travel behavior. However, few studies have attempted to quantify the relative size of the two components' influence (see Cao et al., 2009, for an overview).

In summary, mobility preferences are revealed conditional on the availability of infrastructures; a different set of infrastructures thus would also lead to different revealed preferences. Normative implications of this finding are explored in the subsequent sections. In general, it can be expected that not only the built and social contexts influence preference formation, but that introducing policy instruments unlinked to altering those contexts directly may induce preference changes. For instance, traffic control policy might be expected to have an influence on preference formation regarding mode choice in

[8] Kahneman (2011, p. 372f) notes that the Obama administration has partially corrected for this.

[9] Infrastructures alone might induce emissions in the order of the remaining carbon budget under ambitious climate protection goals (Davis et al., 2010). On a city scale, the housing sector induces inertia in long-term transport behavior and ensuing GHG emissions (Gusdorf and Hallegatte, 2007). Crucially, transport prices are causally most relevant in determining housing locations and, in turn, long-term GHG emissions from commuting (Creutzig, 2014).

[10] It may, however, be difficult to determine whether the social environment influences the decision-making or the preference formation, similar to the case for the built environment.

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the same way as changes to infrastructure have. The reason we limit our discussion of preference formation to the influence of infrastructure and social context is that we could not find empirical research on the influence of policy measures separate from altering built and social contexts (although one may hypothesize from the strand of urban planning research synthesized in Ewing and Cervero (2010) that this is likely the case).

Behavioral policies for mitigating carbon emissions from transportation

In this section, we characterize the option space for mitigation policies based on the above overview of the major behavioral factors relevant for mobility choices. Table 2 summarizes potential behavioral policy measures that foster low-carbon transport. Behavioral measures and demand reduction have long been discussed as options for emission reduction in transportation research (van Wee et al., 2013; Sims et al., 2014) and are generally seen as complementing pricing options, which alone would be insufficient. To our knowledge, however, little attempt has been made to connect an evaluation of their effectiveness to research on the choice mechanisms isolated by behavioral economics.[11] The purpose of this section is to sketch what additional insights one may hope to gain from informing demand-side transport policies by results on choice mechanisms related to mobility. We proceed as follows: For each category of mobility-specific behavior, there are many potentially successful policy instruments to consider that may reduce emissions. Policy-instruments are typically classified in three categories: (i) bans and direct regulations, (ii) monetary incentives, (iii) education and information – sometimes lightheartedly labeled "sticks, carrots and sermons" (Bemelmans-Videc et al., 1998). To these three categories, "context" must be added for the case of transport policy (Shaw et al., 2014): Changing the built environment through construction or modification of the transport infrastructure also alters decision-making. For each category, Table 2 gives examples of specific policy measures that may be useful for changing mobility behavior towards low-carbon options. The following list provides a summary of those measures whose effectiveness can be deduced from extant transportation research.

Regarding **environmental awareness**, providing the accumulated yearly emissions from car use compared to more sustainable modes of transportation is more effective at encouraging a change in behavior compared to daily emission savings. Also, a negatively framed comparison of emissions from different modes is more effective than a positively framed comparison (Avineri and Waygood, 2013).[12] Furthermore, policies will be more effective if they identify attitudinal differences among segments of the population and frame information accordingly. For instance, population segments that show a high sense of environmental moral obligation should require less persuasion to use alternatives, such as public transportation or cycling, whereas information regarding traffic congestion or reliability may be more persuasive for segments that are less concerned with environmental effects (Anable, 2005).

Concerning **mode choice**, the tendency to favor the status quo provides opportunities for policymakers to influence long-term travel behavior by motivating individuals to break undesirable habits. Policy measures so far tested successfully include:

- Distributing a free bus ticket to regular car users for one month. Attitudes towards the bus improved, and even one month after the end of the intervention, the frequency of car use was decreased while subjects used the bus more often and made it a habit (Fujii and Kitamura, 2003), see also Bamberg et al. (2003b).
- A temporary decrease in car use was observed after subjects with a strong habit of car use were induced to deliberate travel mode options by answering questions before beginning a trip (Garvill et al., 2003).
- A change of residence may be the most promising opportunity to alter mode choice since individuals are then forced to form new habits (Bamberg et al., 2003b; Weinberger and Goetzke, 2010).
- The establishment of social norms that are pro low-carbon transportation modes can be an effective mechanism to encourage more sustainable behavior on an individual level (Banister, 2008, for an overview).
- Finally, it is generally assumed that better infrastructure for walking and cycling promotes a higher modal share of non-motorized mobility. However, research is only beginning to examine the determinants of the efficiency of various possible changes in the infrastructure (Ogilvie et al., 2012): One tentative outcome is that new infrastructure promoting active travel may chiefly attract individuals who are physically active anyway and potentially merely displacing physical activity (Goodman et al., 2013). Over longer time-scales, however, additional active travel is generated by such infrastructure (Goodman et al., 2014).

To reduce **commuting** time, correcting misguided perceptions of certain modes of transportation (e.g., by increasing actual experience with public transportation) could strongly influence long-term commuting behavior. This effect was seen after habitual drivers were given a 30-day trial period public transportation ticket – their reported satisfaction with the mode increased after using it more often (Pedersen et al., 2011a).

Issues of **travel time** need also to be taken into account for well-designed, low-carbon transport. A first aspect is congestion: As providing more road infrastructure does not translate into reduced time traveled (see section 'Travel time'),

[11] Even if one comes from a macroeconomic perspective holding that the ultimate solution to decarbonize the transport sector is through carbon pricing, for instance by including it in national cap-and-trade-systems, behavioral arguments make sense if one is concerned either that high modal shares of non-motorized transport options cannot be reached by pricing instruments or doubts the political feasibility of high carbon prices at a national level.

[12] This effect may also be applicable for other information provided i.e., calories burned, time saved waiting in traffic, etc.

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Table 2
The option space for decarbonization policies concerning behavioral effects. "PT": public transport, "NMT": non-motorized transport.

	Sticks (bans, regulations)	Carrots (monetary incentives)	Sermons (education, information)	Context (infrastructure, culture)
Environmental awareness	–	Crowding in social preferences	Salient information about emissions; provision of comparison to others	Change of cultural norms: campaigns, first adopter circles
Mode choice	Ban on cars in some parts of cities	Active choosing, free initial PT tickets	Promoting self-control; lower PT search costs; encouraging social learning about NMT	Change of built environment
Commuting	–	Commuting tax, incentives for moving close to work	Education on adaptation, personalized travel planning	Promote more efficient use of infrastructure: car pool lanes, ...
Travel time	Ban on fast travel options	–	Inform about expected delays and alternative routes	Road diet
Fuel economy and car purchases	Fuel efficiency standards	Taxation of status aspect of cars	Active choosing in purchases, more salient information	Change cultural norms

additional carbon-intensive infrastructure can only be justified by improved accessibility (and ensuing beneficial effects for the economy), not by travel time savings. However, this well-known aspect of transportation planning can be turned into a potentially effective strategy for climate change mitigation: As people spend a constant fraction of their time traveling on average, banning or reducing speed of carbon-intensive travel options will decrease carbon emissions. Of course, this option is only sensible if the economic costs of reduced accessibility are inessential compared to the environmental benefits, as may be the case for publicly-funded, but uneconomic local airports.

A second issue is to mitigate the negative effects travel delays may have on the travelers view of the (low-carbon) public transportation system. Loss aversion regarding travel time may increase the need for measures such as informational campaigns for planned construction. This is because travelers take their preferred commuting or arrival time as well as a public transport time schedule as the reference point (see section 'Travel time').

Finally, regarding **fuel economy** of cars, one policy implication is particularly salient in the literature. If loss aversion explains why consumers do not value fuel economy highly (see section 'Car purchases and fuel economy'), this provides a major behavioral rationale for fuel efficiency standards, even in addition to carbon pricing (Greene et al., 2009; Greene, 2010). An alternative suggestion is to provide shorter payback periods for automobiles with better fuel economy, for example by instant rebates instead of expecting consumers to take into account long-term fuel savings (Greene et al., 2005). Peters et al. (2008) discuss the success of various feebate schemes on behavioral grounds, exhibiting a trade-off between the range of consumers reached and limited efficiency of schemes.

Beyond emissions: Applying behavioral welfare theory to transport policy design

In this section, we first introduce the impact of behavioral findings on current welfare theory. Two plausible candidates for defining welfare as a policy-goal emerge: A revision of the orthodox preference satisfaction approach and the maximization of subjective well-being. This is essential for evaluating the implications of behavioral economics for transport policy design beyond correcting externalities. In the second part of this section we then outline the major differences in the policies that follow from the two different welfare conceptions, for example, regarding commuting and infrastructure provision.

Two viewpoints of welfare

The behavioral account of how humans make economic choices renders the traditional normative approach in economics, which underlies most methods of evaluating transport policies, unconvincing (Kahneman and Sugden, 2005; Bernheim and Rangel, 2007; Loewenstein and Ubel, 2008). Several alternative approaches for evaluating economic choices, and thus welfare, are currently explored. The most important two are (i) revising the orthodox (*liberal*) preference-satisfaction approach that maintains the idea that welfare consists in having people obtain what they want; (ii) evaluating choices by their impact on *subjective well-being* (see section 'Subjective well-being').

It has been so far unexplored what these approaches mean for the evaluation of transport policy. The subsequent analysis adopts a 'social welfare perspective', that is, we analyze the consequences of different normative criteria as an input for public debate (Broome, 2008). The question which (independent) institutions are entitled to base their policies on subjective well-being (Loewenstein and Ubel, 2008) is a separate normative question to which we believe there is little specifically to be said about mobility. In the following, we present the two approaches and describe how they are to be understood in the context of transportation. We then state the main arguments for and against them.

Standard economic welfare analysis assumes that "whatever people choose makes them better off" (Loewenstein and Ubel, 2008). More generally, it is postulated that the goal of public policy, social welfare, is the (weighted) sum of the degree

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to which citizen's preferences are fulfilled. This normative position is called the preference-satisfaction view of welfare (Hausman, 2012): The optimality of policies is judged from this viewpoint in standard transportation economics. Research in behavioral economics and social psychology highlights two main difficulties for this normative theory: (i) preferences may be ill-defined or inconsistent, (ii) preferences may be systematically influenced by factors that one would not want to have any normative significance, notably the framing of a choice, the choice environment (such as infrastructure or the built environment in the context of transportation) or herd behavior.

Given these two difficulties, modifications to the standard preference-satisfaction (or: liberal) approach have been proposed. Revised versions try to save the idea that welfare is determined by how far human preferences can be fulfilled: They assume that preferences exist in most contexts and that it is possible to detect them. But the attempted revisions acknowledge that preferences sometimes need to be "laundered" (Hausman, 2012): Not only because people may make errors in decisions or base their decisions on false beliefs, but also because of the factors highlighted in (i) and (ii) above. "Purification" would thus be required if choices happen in a context in which individuals are no good judges of what is beneficial to themselves, thus when people are ill-informed or preferences are distorted by the context (Hausman, 2012). In this way, a distinction is introduced between people's actual choices and their 'true' preferences: These are not simply revealed by the choices, but only emerge through 'purification' (Thaler and Sunstein, 2008; Bernheim and Rangel, 2009; Hausman, 2012) – with disagreement how exactly the purification should be carried out. With regards to evaluating transport policy, the challenge of determining the 'true' preference of mobility-users can be particularly intricate: The effect of infrastructure and the built environment on the formation of preferences is not fully explored, but it must be assumed that the built environment shapes people's modal choice (see section 'The role of infrastructure, the built environment and the social context'). Moreover, current culture shapes mobility decisions in favor of private motorized transportation (and so creates large externalities that cause harm in all metrics of welfare usually considered). It seems therefore unclear whether it will ever be practically possible to purify preferences about mobility of such influences and whether they should be counted as welfare.

A different approach to policy evaluation is the viewpoint that subjective well-being should be maximized. Its starting point is the well-established finding of happiness studies that human beings make decisions that fail to maximize their subjective well-being (Hsee and Hastie, 2006), see section 'Subjective well-being'. Welfare is taken to be subjective well-being as measured in happiness research (Kahneman, 2011, Part V; Layard, 2011). Difficulties with inconsistent or undefined preferences over potential choices do not exist for this approach. However, the idea that maximizing subjective well-being is often criticized as 'paternalist', because a regulator adopting this viewpoint would base its policies on what makes people happy even if they have preferences for something else. Nevertheless, it should be emphasized that freedom is an important determinant of happiness (Helliwell, 2003; Layard, 2011, ch. 5) – so in practice, any policy that curtails freedom is unlikely to promote subjective well-being. There is to date little research that determines the direct impact of transportation choices on happiness or the impact of happiness on mobility choices. Exceptions, however, include Stutzer and Frey (2008) on commuting as a factor of unhappiness, Abou-Zeid et al. (2012) on the impact of temporary mode switching and Ettema et al. (2012) on the impact of in-vehicle activities on subjective well-being as well as Goudie et al. (2014) on happiness as a driver of seatbelt wearing.

We now briefly summarize the main arguments for preferences-satisfaction and subjective well-being as welfare criteria. The debate has been typically framed around whether the maximization of subjective well-being is a good criterion for welfare because preference satisfaction is the received orthodox approach in economics (Kahneman and Sugden, 2005; Kahneman, 2011; Loewenstein and Ubel, 2008; Loewenstein, 2009; Fleurbaey and Blanchet, 2013; Layard, 2011, Part III).

There seem to be two main arguments in the literature by which authors advocating preference satisfaction theories of welfare criticize subjective well-being as an alternative criterion: (i) happiness neither should be nor is de facto the only thing people care about in life. Other important life goals that are sought for themselves and not to reach greater happiness include achievements, meaning or wisdom (Loewenstein, 2009; Fleurbaey and Blanchet, 2013). (ii) Happiness is not a good criterion for welfare because it is no good representation of (material) deprivation: There can be 'happy peasants and miserable millionaires' (Sen, 1985, 1999; Frederick and Loewenstein, 1999). Scholars advocating the maximization of well-being typically do so because they are skeptical that procedures for 'laundering' preferences can be successful in practice. Against the two criticisms of subjective well-being as a welfare criterion, it is argued, regarding (ii), that the fact that material deprivation is not decisive for happiness implies a revision of our intuitions about welfare: Curing depression should be a primary concern when mitigating inequality (Layard, 2011), and fighting poverty only in as far as it produces bad feelings. Regarding (i) advocates of subjective well-being as a welfare criterion are very skeptical about the prospect of detecting 'true' preferences. This doubt is combined with judging the idea that people want to make themselves unhappy to achieve other goals as secondary or far-fetched (Krueger et al., 2009). Alternatively, they argue that although happiness is not the only intrinsic value which makes life worthwhile (for example, meaning in life might also matter, see Baumeister et al. (2013)), it is certainly the most important one for practical purposes and thus a good first approximation for welfare in policy design (Greene, 2013).

While differences between policies aiming at maximizing subjective well-being and those aiming at preference satisfaction have been explored for the case of the health sector (Dolan and Kahneman, 2008; Loewenstein and Ubel, 2008), an analysis of the differences is lacking for the transport sector. To apply the viewpoints to transport policies, it is, first of all, crucial that both viewpoints endorse the regulation of the main externalities of motorized transportation (such as local air and noise

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Table 3
Transport policies for various mobility aspects that can be justified by either maximizing subjective well-being or satisfying preferences (liberalism). "NMT": non-motorized transport.

	Subjective well-being	Liberalism
Env. awareness	Rewards for individual altruistic behavior	No particular rewards
Mode choice	Incentives for NMT, change in social norms and cues against biases	Degree of incentivizing NMT depends on type of liberalism
Safety	Disincentives for risky behavior	No disincentives for risky behavior unless: others at risk or preferences about risk inconsistent
Commuting	Disincentives for commuting	No disincentives for commuting
Car purchases	Vehicle tax according to status component of car	Imposition of 'status tax' depends on type of liberalism
Infrastructure	NMT priority, urban planning for short commutes	Not directly applicable, alternative: elicit preferences in simplest context

pollution, congestion and greenhouse-gas emissions).[13] Instead, the differences between these viewpoints concern policies that are not targeted at externalities.

Assessing behavioral change from two distinct viewpoints

The classification of behavioral effects introduced in the section 'Classifying behavioral explanations for mobility choices' suggests that even in a transport system in which the main externalities of road transport are internalized there are many important policy choices to be made regarding the specifics of mobility – in particular concerning mode choice. We substantiate this claim by discussing four important cases in which the behavioral account of mobility choices yields different policy recommendations from the two different viewpoints on welfare: (i) the influence of infrastructure and the built environment, (ii) health benefits from non-motorized transportation, (iii) the fact that commuting causes significant unhappiness and (iv) status-seeking behavior about mobility choices. Table 3 provides a summary.

First, transport infrastructure and the built environment shape people's preferences and influence how their preferences translate into choices (see section 'The role of infrastructure, the built environment and the social context'). For liberalism, this implies that people's *actual* preferences are no sound basis for transport project appraisal. This is because if transport infrastructures influence preferences and decisions *subconsciously*, as is mostly the case, one would not want to count them as normatively relevant. Potentially, liberal approaches could circumvent this difficulty by eliciting preferences over hypothetical residential choices or designing experiments that uncover people's true preferences over the built environment. If, alternatively, one takes subjective well-being as a welfare criterion, this difficulty does not arise: Changes to the built environment would be beneficial if they raise subjective well-being, regardless of whether or not preferences are influenced by these changes. While no research on this exists, it seems conceivable to determine the influence of various different possible transport infrastructures on the population's subjective well-being by field experiments.

Second, assessing the health benefits from non-motorized transport (see section 'Mode choice') depends crucially on the normative viewpoint chosen. For the view that welfare consists in subjective well-being, improvements in health through more physical exercise can be straightforwardly counted in terms of a subjective well-being metric, but also in terms of increased life span.[14] For the view that welfare consists in the satisfaction of preferences, an assessment of such health benefits depends strongly on the normative treatment of time-inconsistent preferences (Bernheim and Rangel, 2007): Is people's 'true' preference regarding modal choice in cities to opt for a comfortable drive that is adverse to their health in the long-run or is their 'true' preference to stay healthy while they are unsuccessful in getting themselves to travel by other options?

Third, should the negative impact of commuting on subjective well-being influence project appraisal or not? Commuting is a non-negligible cause of human unhappiness (see section 'Commuting') as people systematically choose larger houses and higher salaries over more leisure time for socializing. From the viewpoint of liberalism, this effect is not relevant for transport policy. For the viewpoint of subjective well-being, one should curtail commuting (for instance, Kahneman and Krueger (2006) suggest to tax it) and also take the finding into account when assessing the merit of infrastructure projects.

Finally, the effect that there exists status-seeking behavior regarding vehicle ownership means that, for the purpose of raising subjective well-being, one would regulate such behavior because it creates an efficiency loss in subjective well-being (Layard, 2006). On the contrary, whether regulating status-seeking behavior would be mandated from the viewpoint of liberalism depends on whether one judges status-seeking as a proper externality or believes that people engage willfully in it.

[13] For liberalism, correcting an externality increases welfare by the first fundamental theorem of welfare economics. Although it is not true in principle that from the viewpoint of maximizing subjective well-being correcting externalities always enhances welfare, it is true in practice for the main externalities of the transport sector due to their adverse impact on a (longer) happy life.

[14] Measures of the burden of disease such as 'disability adjusted life years' (DALYs) or 'quality adjusted life years' (QALYs), which are widely used in public health research, implicitly and partially take the view that welfare is subjective well-being. Although these are not based on state-of-the-art happiness measurement, this is so because these metrics count welfare improvements through better health in terms of greater quality and greater length of life. They do so independently of whether individuals have a preference for living longer and healthier when confronted with a range of healthier or less healthy options, for instance, regarding drug use and dietary choices.

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Beyond the four cases described above, there may also be minor differences regarding environmental awareness, because altruism generally leads to greater happiness (Post, 2005), and safety (overriding preferences for risky behavior – or not).[15]

Conclusion

This article presents a descriptive and normative analysis of behavioral effects in mobility decisions to improve the design and justification of transport policies. The main descriptive conclusion is that the preferences, heuristics and forms of decision-making identified by behavioral economics are indispensable to explain mobility behavior methodically. A particularly policy-relevant class of effects arises from the influence of transport infrastructures on decision-making through framing and the formation of preferences regarding mode choice. We argue that our descriptive analysis necessitates a revision of the standard approach to policy evaluation in transportation. Either the orthodox economic understanding of welfare as preference satisfaction must incorporate differences between actual and 'true' preferences of transport users. This matters particularly when the infrastructure influences decisions and for time-inconsistent preferences yielding health benefits of non-motorized transport. Or, transport policies can be grounded in the aim of maximizing subjective well-being. Key differences to the preference approach concern status-seeking behavior and commuting, as agents systematically do not choose what makes them happy when traveling.

There are potential applications of our analysis to transport modeling and policy design. First, standard transport demand modeling, based almost exclusively on the rational choice approach, may be enhanced by incorporating the behavioral effects that are particularly relevant for the given context, such as mode choice or trip scheduling, which may vary widely across levels and world regions. Notably, *dynamic* models (with long time horizons) would need to consider the issue of the influence of the physical and social context on preference *formation*. In other words, preferences should be, to some degree, endogenous in such models. Second, behavioral effects in the decision-making of firms likely matter for explaining mobility – particularly with respect to car purchases, but these are typically neglected in discussions of behavioral approaches to transport policy and should be taken into account. Third, our analysis of the possible justifications for transport policies may lead to a more consistent policy design according to policy-makers' tastes. It sharpens the debate concerning trade-offs in transportation, for instance, between better health and shorter commutes as opposed to greater individual liberties. Fourth, a systematic understanding of the available behavioral policy options to decrease emissions emerges from our work.

Beyond the specific details of our analysis for the field of mobility, some more general lessons may emerge for behavioral economic approaches to climate change mitigation: For instance, the behavioral effects explaining why individuals have a propensity to maintain the status quo may be suspected to present obstacles for decarbonizing emissions from buildings. Further, preference formation may play an important role not only for understanding mobility, but also for dietary choices. Altogether, whenever end-user behavior is particularly relevant, the design of mitigation policy packages likely benefits from taking behavioral effects into account.

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[15] A potentially further important reason for distinguishing the two viewpoints in transportation is the argument that reduced geographical mobility and quieter urban quarters lead to greater social cohesion and better mental health and thus greater happiness (Layard, 2011), despite individual preferences for car-friendly road design and anonymity. We exclude it here, because the arguments have not (yet) been based on specific behavioral effects.

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