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D I S S E R T A T I O N

Mobility biographies:
Linking life events, travel behavior and attitudes

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As I write this, France is confined to stay at home to limit the spread of the coronavirus (Covid-19), a health crisis that has also affected transportation research and planning. The social and environmental impact of traveling inspired my interest to work in the transport sector and will always make it a fascinating field to work in.

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Julia Janke

Abstract

This thesis consists of three research papers analyzing the relationship between life events, travel attitudes and behavior. It contributes to the mobility biography literature that considers daily travel behavior to be to a large extent habitual and observes that life events may trigger travel behavior change. The first article analyses the causal mechanisms that explain why life events change the level of bicycling and attitudes towards bicycling based on 54 interviews conducted with residents of a small college town (Davis, California, US). This analysis identifies four mechanisms: Life events trigger a deliberation process that lead individuals to scrutinize their travel routines. Second, life events change social norms that favor or disincentivize bicycling and attitudes towards bicycling. Third, life events may unleash a latent demand as for instance bicycling infrastructure changes after relocation. Fourth, life events may change interest in destination and activities. The results also provide evidence for a bi-directional relationship between bicycling attitudes and the level of bicycling. Although the results relate to bicycling attitudes and the level of bicycling they may also apply to other transport modes. The second article quantitively assesses the effect of life events on travel behavior change and analyses the role of life stage in these processes based on a panel university travel survey of the same college town (Davis, California, US). Using a Manifest Markov Model, the analysis shows that travel behavior change is more likely following relocation, changes in the household structure or social role. Based on this data, life stage does not moderate the effect that life events have on travel behavior though it affects travel behavior. For instance, active traveling decreases across life stages – a development even more pronounced for women. In general, the results emphasize state dependence, particularly car users tend to stick to their mode over time. The third research paper concentrates on one specific life event, residential relocation, and investigates the influence of travel attitudes on residential location and mode choices. This article adds to the literature by analyzing intra-household interaction in these processes. Based on a sample of couple households living in the agglomeration area of Vienna (Austria), results from multinomial logit models show that only women's travel attitudes significantly influence residential location choices. They also seem to be more affected by neighborhood characteristics in their mode choice than their male partners. Together the research papers of this thesis contribute to the literature

by clarifying the complex cause-effect relationship between life events, travel behavior and attitudes. As the results highlight, life events may cause change in travel behavior and attitudes while travel-related attitudes may also influence life events when individuals choose residential locations that match their travel attitudes. The analysis also emphasizes the attitudinal influence on travel behavior providing support for the theory of planned behavior. At the same time, the results indicate that the experience of traveling with a transport mode affects the attitude towards this transport mode. This thesis points to the potential benefits of an integrated housing and transportation planning. The results also emphasize that providing better public transport service to women may be beneficial for their labor market integration and higher use of these modes.

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Chapter 1

Introduction

1.1 Background

This thesis contributes to the mobility biography literature that investigates travel behavior over the life course of an individual. Recently, a considerable body of literature has grown up around the theme of mobility biographies including the publication of several books (e.g. Scheiner and Holz-Rau, 2015, Zhang, 2017), special issues (e.g. in Transportation Research Part A, "Life-oriented Travel Behavior Analysis", 2017, 104, Transport Reviews, "Self-Selection", 2009, 29(3)) and literature reviews (e.g. Müggenburg et al., 2015). Taking a life-course perspective, this body of literature links travel behavior to other life domains and acknowledges that travel behavior evolves over an individual's life course as a result of past experiences, social relations and spatial environment. The longitudinal approach allows discussing inertia or state dependence and integrates short- and long-term decisions in a coherent explanatory framework. Previous research ascertains that in everyday life travelers rarely change their behavior and daily travel behavior is often habitual and driven by routines (Müggenburg et al., 2015). From a policy perspective, it is of interest to better understand these moments when persons actually change their travel behavior. Policy initiatives and instruments may be more effective if targeted to persons more susceptible to change.

1.1.1 Life events and the temporal dimension of travel behavior

Based on Salomon (1983), Lanzendorf proposed 2003 a theoretical framework that explains travel behavior over time and establishes three domains: the lifestyle domain considering the social, political and cultural environment (e.g. family foundation), the accessibility domain (e.g. characterizing residential location, workplace) and the mobility domain (e.g. daily travel, car ownership). Key changes, also referred to as "life events", in the first two life

domains (e.g. residential relocation) may trigger changes in the mobility domain. Life events can be defined as "major event[s] in a personal life that will trigger a process of reconsidering current behavior (Van der Waerden et al., 2003). In the literature, researchers also refer to "key event", "life course event", "disruptive event", or "turning point" (Müggenburg et al., 2015). Previous research in this domain has found that individuals tend to change their travel behavior more often in the presence of life events (e.g. Clark et al., 2016, cf. the review of Müggenburg et al., 2015). Numerous life events have been found influential for change in travel behavior and car ownership, for example residential moves, workplace changes, retirement, acquisition of a driver's license, cohabitation, childbirth, children moving out or divorce (Beige and Axhausen, 2017, Dargay and Hanly, 2004, Oakil et al., 2014, 2016). The mobility biography approach provides an interesting framework to study travel behavior because it links long-term decisions (e.g. residential location) to short-term decisions (e.g. commute mode choice) (e.g. Lanzendorf, 2003, Müggenburg et al., 2015). Life trajectories permit following individuals along their life course and consider the influence of past experiences on current behavior (Chatterjee et al., 2013b). It is a coherent framework to discuss path and state dependency, formation of attitudes and time-lagged behavioral responses to life events. For instance, several studies have established that persons often stay loyal to their commute mode, particularly car users show higher state dependence in the presence of life events (De Haas et al., 2018, Kroesen, 2014). In addition, individuals may behave differently at different life stages. Mental and physical capacities, financial constraints, and social responsibilities evolve throughout the life cycle of an individual and may affect travel behavior. Recently, a considerable literature has grown up around the theme of the millennial generation. Researcher have discussed whether observed differences in car ownership, transit use and residential location preferences (e.g. Circella et al., 2017, Delbosc and Nakanishi, 2017, Kuhnimhof et al., 2012) are durable or may be temporary and reflect delays in transitioning to other life stages (Delbosc and Currie, 2013, McDonald, 2015).

1.1.2 The role of attitudes

Over the past decades, research findings have emphasized the role of attitudes for the understanding of travel behavior (e.g. Bamberg et al., 2006). From a psychological perspective, attitudes are considered latent constructs that help to organize and evaluate knowledge (instrumental function), contribute to form a personality and adhere to a social group (social identity function) (Busch-Geertsema, 2018). Sometimes confound in the literature, preferences refer to a comparison between at least two things and imply a ranking or prioritization of these things. While valuation in preferences is based on comparison, valuation in attitudes is based on a positive-negative continuum (Busch-Geertsema, 2018). In contrast, values are more

abstract concepts and refer to the "conception of what is desirable" (Busch-Geertsema, 2018 citing Bordens and Horowith, 2000: 183). Social norms on the other hand provide orientation how to behave in society and may reflect expectation of a social group (Busch-Geertsema, 2018, Hewstone and Martin, 2007). Travel behavior research often uses the theory of planned behavior developed by the psychologist Ajzen (1991) to explain attitudinal influence on travel behavior. According to this theory, attitudes towards a behavior, subjective norm and perceived behavioral control determine the intention to perform a certain behavior (Ajzen, 1991). Behavioral intention (motivation) and perceived behavioral control (ability) determine behavior (Ajzen, 1991). Ajzen (1991) further points out that the level of specificity of attitudes should match the level of behavior and refers to results showing that general attitudes poorly predicted specific behavior. This theory has been applied in various studies that have found evidence for an attitudinal influence on travel behavior (e.g. Bamberg et al., 2006, Busch-Geertsema and Lanzendorf, 2017, Gärling et al., 1998, Molin et al., 2016).

Some researchers, however, discussed a reverse causality that behavior in fact influences attitudes (Kroesen et al., 2017). According to the theory of cognitive dissonance (Festinger, 1957), dissonance between cognition and behavior creates psychological tension that motivates persons to reduce this dissonance. One strategy for reducing dissonance between attitudes and behavior lies in the adaption of attitudes if a person can or is not willing to change behavior. Persons may adapt their mode-related attitudes if they cannot change their commute mode. In fact, Kroesen et al. (2017) found that mode-related attitudes and travel behavior affect each other over time.

More recently, researchers have paid attention to residential relocation as a life event (e.g. the special issue "Travel and residential change" 2019-2020 in Travel Behavior and Society) and have discussed the role of attitudes in this context. In particular, mode-related attitudes have been found to influence residential location choices when persons locate in residential environments that satisfy their travel preferences, a process known as residential self-selection (RSS) (Cao et al., 2009, Handy et al., 2006, Schwanen and Mokhtarian, 2004, 2005). Scheiner (2014b) adds the mobility biography perspective to the RSS discussion and emphasizes that attitudes, personal network and mobility resources formed over a longer period of time may influence residential location choices (Scheiner, 2014b). Other researchers question the ability of households to choose the residential location which satisfies their residential preferences and attitudes (Naess, 2005). Several reasons can be found for residential dissonance that describes individuals who live in neighborhoods that do not match their residential preferences or travel attitudes (De Vos et al., 2012). A constrained housing market and household budget constraints may limit the choice set and alternatives for households, time constraints may limit searching time (De Vos et al., 2012). In general,

these studies confirmed the RSS hypothesis though the impact of travel attitudes and built environment varied across different neighborhoods and countries. An aspect mostly ignored in the RSS literature relates to the assumption of homogeneous preferences and attitudes between household members though residential and travel-related attitudes may vary between household members (Scheiner, 2014b). Although intra-household bargaining processes are discussed in relation to residential location, they are rarely addressed in the context of residential self-selection (Guan and Wang, 2019).

1.2 Theoretical approach

Embedded in the mobility biography literature, this thesis is theoretically based on the conceptual model of Chatterjee et al. (2013a) explaining turning points in travel behavior (cf. Figure 1.1). Chatterjee et al. (2013a) developed it to explain changes in bicycling but it is generalized to all modes for this thesis. This concept assumes that travel behavior is habitual. Change in travel behavior is triggered by contextual change, either by a life event or by change in the external environment (e.g. change in physical transport infrastructure) (Chatterjee et al., 2013a). Life events may change the social role of an individual (e.g. in their family), her values, beliefs, and attitudes. They may trigger a deliberation process driving individuals to scrutinize their travel behavior (Chatterjee et al., 2013a). Mediating or, more accurately, moderating factors include personal history (e.g. travel-related experience and attitudes), intrinsic motivation (e.g. desire for physical health) and existing facilitating conditions (e.g. public transport access) (Chatterjee et al., 2013a). Particularly the first two articles of this thesis are based on this theoretical concept and analyze the effects of life events on travel behavior over time. All three articles are embedded in the life course-perspective and mobility biography literature outlined in this section.

1.3 Research questions

The considerable body of mobility biography literature has clarified the development of travel behavior over time and has paid attention to the influence of life events though contrasting findings, discussions and several research gaps require further investigation.

1.3.1 First article

Previous research that investigates the relationship between life events and travel behavior limits the analysis to brief periods in time or to a specific life stage (e.g. childhood).

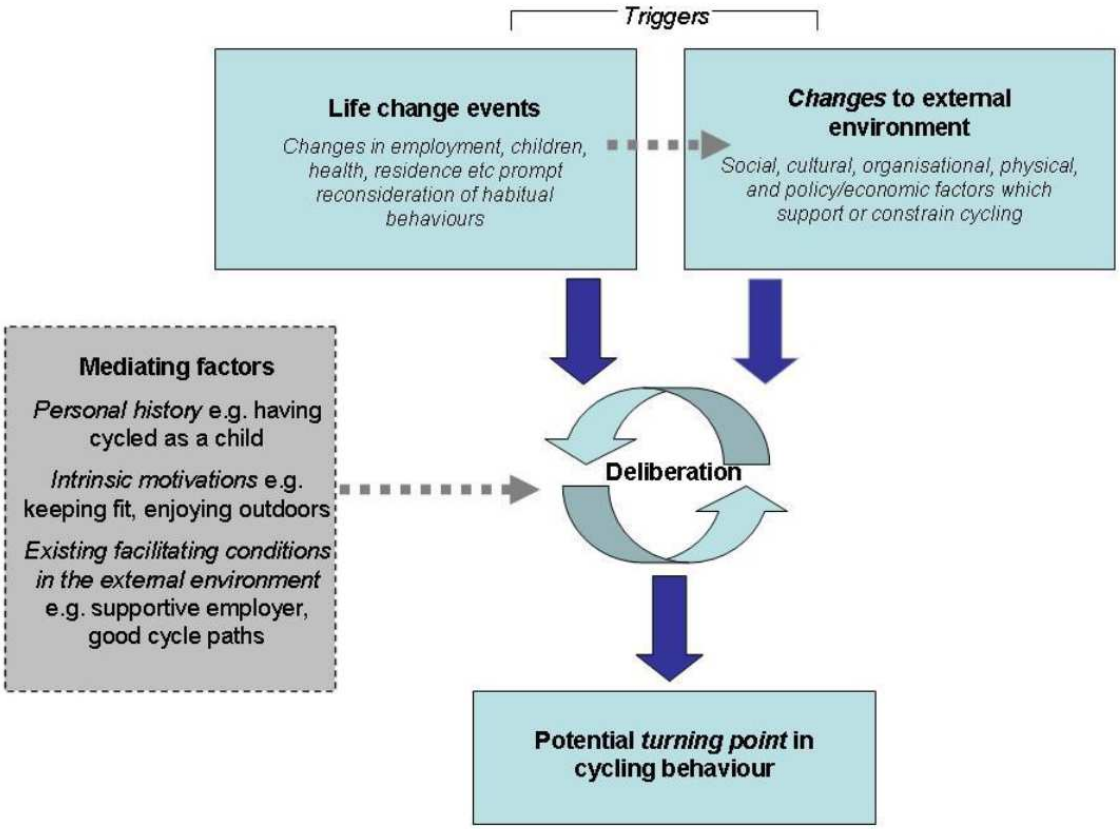

Fig. 1.1 Conceptual model to explain turning points in travel behavior (applied to bicycling) (Chatterjee, 2013a)

This article adds to the literature by providing a long-term perspective on an individual's bicycling history and explores in more detail causal processes by which people start, increase, or stop bicycling. In addition, research to date has not yet determined the direction of influence between travel behavior and attitudes. The theory of planned behavior assumes an attitudinal influence on travel behavior though some empirical evidence points to a potential bi-directional relationship between attitudes and behavior (Kroesen et al., 2017) that may be particularly interesting to explore from a mobility biography perspective. This article aims to answer the following research questions:

- How do life events affect the level of bicycling and attitudes towards bicycling?
- Which causal mechanisms drive change in the level of bicycling and attitudes towards bicycling?

Based on the conceptual approach of Chatterjee et al. (2013a), this article makes use of 54 interviews conducted in Davis, a small college town in California, US, to qualitatively explore these research questions. This article was co-authored by Susan Handy who provided a statement attesting that Julia Janke, the author of this thesis, contributed most of the work for this article, particularly in relation to the study conception and design, analysis and interpretation of results, and draft manuscript preparation) (cf. Appendix A).

1.3.2 Second article

Several studies have provided evidence that life events affect travel behavior change, however, it is unclear whether a person's life stage alters this effect. Financial, professional constraints, social responsibilities, and mental capacities to adapt to new circumstances may change over the life course, more precisely between life stages. Life stages mark different sequences in the life course and introduce new or different constraints and circumstances that may alter decision making. Studying these constraints by life stage may provide additional insights in the sensitivity in the reaction to life events. An analysis differentiated along life stages enables a more detailed exploration of behavioral differences observed for the millennial generation. This article also considers multimodal travel which may be relevant from a policy perspective since for instance several studies have shown that strict car users are more likely to shift to multimodal travel than completely to other modes of transport. This article aims to answer the following research questions:

- To what extent do life events effect change in multimodal travel behavior?
- To what extent do life events affect multimodal travel behavior differently at distinct life stages?

Using a panel data set from a university survey in Davis (California, US), this article explores the effect of life events on travel behavior change for different life stages. This article was co-authored by Susan Handy and Calvin Thigpen who provided a statement attesting that the author of this thesis contributed most of the work of this article, particularly in relation to the study conception and design, analysis and interpretation of results, draft manuscript preparation and editing of final manuscript (cf. Appendix A).

1.3.3 Third article

In the literature on residential self-selection, only a few studies address bargaining processes and heterogeneity in travel preferences and attitudes between household members (e.g. De

Vos et al., 2012; Næss, 2014; Scheiner, 2020, 2010), and explores this issue qualitatively (e.g. Gil Solá, 2016; Oostendorp, 2014). To the best of the author's knowledge, only Guang and Wang (2019) quantitatively investigated the effect of intra-household differences on residential self-selection. Though they did not discuss residential dissonance and the role of heterogeneous attitudes between partners in this context. This article aims to answer the following research questions:

- To what extent does heterogeneity in travel attitudes between partners influence residential location choices and the relevance of travel attitudes for these choices?
- To what extend does heterogeneity in travel attitudes between partners lead to residential dissonance?

Based on 2019 survey data from Vienna's agglomeration area (Austria) and multinomial logit models, this article investigates intra-household heterogeneity in travel attitudes and residential preferences that may influence residential location choices and travel behavior. This article is currently under review in a peer-reviewed scientific journal.

Chapter 2

How life course events trigger changes in bicycling attitudes and behavior: Insights into causality

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Abstract

This paper uses a mobility biography approach to investigate how life course events explain changes in attitudes towards and levels of bicycling. We use 54 interviews conducted with residents of a small US city that include retrospective questions covering six life stages. Three life events emerged from the interviews as influential: parenthood, residential relocation, and meeting a new partner. Most participants with children related their level of bicycling and bicycling attitudes to their children. The impact of children on parental bicycling was non-linear over time, and varied throughout the child's development and between couples or partners. Residential relocation affected attitudes towards and use of bicycles as well. The presence of bike infrastructure, supportive peers, and bicycling culture moderated this process. Meeting new partners prompted participants to discover new types of bicycling and contributed resources that facilitated or impeded bicycling. Our findings provide evidence for a bi-directional relationship between bicycling attitudes and behavior. As life events trigger changes in one of these two variables they are likely to change the other variable as well. The results point to four causal mechanisms that drive changes of bicycling attitudes and behavior in response to life events: Life events trigger a deliberation process, change

social norms, unleash a latent demand for bicycling, and change interest in destinations and activities. These causal mechanisms may be generalizable to other transport modes as well. Life events may present a "windows of opportunity," when persons are more susceptible to change, that planners could make use of to encourage behavior change.

Keywords: Life course events, Travel behavior change, Attitudes, Causality, Bicycling

2.1 Introduction

Bicycling is an important pillar in a sustainable transportation system since it contributes to personal health as an active mode and avoids externalities generated by other transport modes such as ambient air pollution and noise. Though only a small share of the population in the US bicycles regularly (one percent of all the trips, US Department of Transportation, 2018). Understanding why people start, increase, or stop bicycling is crucial for developing effective policies and programs. Previous research has identified several factors that are associated with a higher share of bicycling. Short distances to destinations, good bike infrastructure, and safe bicycling conditions support bicycling. Previous research on this topic, however, often uses cross-sectional data providing evidence about the association of these factors with bicycling but not whether the relationships are in fact causal. Panel studies, which are rare in bicycling research, can provide better evidence for causality. But even so, they do not explain causal mechanisms or reveal the processes that trigger change in the level of bicycling. We aim to address this research gap by exploring what drives people to start or stop bicycling over time. Two bodies of work in the travel behavior field inform our exploration. Recent studies focusing on life course events and using mobility biographies posit that travel behavior is embedded in habits and people do not constantly scrutinize their travel behavior. Life course events (such as changes in employment, residence, or social life) may trigger changes in travel behavior because people deliberatively consider alternatives and break with routines. Other recent studies suggest that changes in behavior, often necessitated by a life event, may lead to a change in attitudes about that behavior that would further reinforce it and contribute to the development of new habits. The reciprocal relationship between attitudes and behavior may be relevant in explaining the impact of life events. We investigate how life course events trigger changes in bicycling and attitudes towards bicycling using 54 in-depth interviews of US residents. Our results confirm the impact of life events and suggest four causal mechanisms. Life course events start a deliberation process, change social norms, unleash a latent demand for bicycling, and change a person's interest in destinations or

activities. In addition, we found evidence that the relationship between bicycling attitudes and level of bicycling is reciprocal.

2.2 Literature review and conceptual approach

2.2.1 Factors that influence bicycling

Research on bicycling has identified several key factors associated with bicycling, including trip distance, bike infrastructure, bike access and equipment, the relative costs of bicycling, and the social environment (Handy et al., 2014). Costs in this context relate to purchase and maintenance costs for the bicycle as well as to avoided costs compared to the use of alternative modes, e.g. parking fees or tolls associated with driving. Socio-demographic variables, particularly gender and age, are also significantly associated with bicycling (Handy et al., 2010).

A growing body of evidence suggests that attitudes also play an important role. Attitudes can be defined as "the expectation of all the outcomes of an activity, and the personal value of these outcomes" (Heinen et al., 2011). A positive attitude towards bicycling has been found to increase the likelihood of bicycle commuting (Dill and Voros, 2007) and bicycling as a mode of transportation in general (Underwood et al., 2014, Xing et al., 2010). The importance of attitudes in explaining behavior is supported by the Theory of Planned Behavior (Ajzen, 1991). Attitudes may affect bicycling indirectly as well as directly. In particular, mode-related attitudes can influence residential location choices when persons locate in residential environments that satisfy their travel preferences, an effect known as residential self-selection (Cao et al., 2009, Handy et al., 2006). Pinjari et al. (2008) found evidence that persons living in bicycling-friendly neighborhoods (a binary variable) also had a higher likelihood of owning a bicycle in San Francisco. They divided neighborhoods in San Francisco into bicycling friendly and less bicycling-friendly ones based on built environment and bicycling-related attributes (length of bike lanes, bike lane density) (Pinjari et al., 2008).

Attitudes may also be the outcome of behavior. Researchers have recently explored the possibility of reverse causality in which the use of a transport mode induces changes in attitudes towards this mode. A possible causal mechanism is suggested by the Theory of Cognitive Dissonance (Festinger, 1957). According to this theory, individuals adjust their attitudes to their actual behavior to reduce the contradictions between them. Using a Dutch panel dataset, Kroesen et al. (2017) investigated the relationship between mode-related attitudes and travel behavior and showed that mode-related attitudes and behavior affect each other over time.

2.2.2 Life course events as a trigger for travel behavior change

In the mobility biography approach, researchers analyze travel behavior over the life course of an individual, focusing on the relationship between different life course stages and patterns of travel behavior (Lanzendorf, 2003). This body of research suggests that changes in travel behavior are frequently induced by life course events such as changes in employment or residential location. Between key life events, mode choice is driven by habits and individuals tend to not scrutinize routines (Holz-Rau and Scheiner, 2015). The travel behavior literature uses a variety of terms to describe key events, such as "life (course) event," "disruptive event," or "life-cycle event." Müggenburg et al. (2015) define key events as triggers for change. Some authors limit key events to context changes in personal life; others also include changes in external conditions, for example in the transportation system.

One possible explanation for the triggering impact of life events on travel behavior is the habit discontinuity hypothesis. According to this hypothesis, individuals are more likely to reconsider their behavior when changes in the "context" occur, whether the physical, spatial or social context (Verplanken et al., 2008). For example, Verplanken et al. (2008) found that environmentally-concerned individuals who recently moved are more likely to switch away from commuting by car than environmentally-concerned individuals who did not move. When they experience life course events, people may change their role in the family. They may be exposed to a new built environment, travel culture, or time constraints that alter their attitudes, preferences, and external conditions in which they make decisions about their travel (Chatterjee et al., 2013b).

Some studies using mobility biographies to analyze individual bicycling over time have found evidence that life events trigger changes in bicycling (e.g. Bonham and Wilson, 2012, Chatterjee et al., 2013b, Jones et al., 2012, Lee et al., 2015, Oakil et al., 2016). Changes in housing, employment, and family status have been found to be important life events. Chatterjee et al. (2013b) conducted 144 in-depth interviews with cyclists and non-cyclists in 13 urban areas in the UK. They identified, in addition to the before-mentioned life events, changes in personal health, relationships, leisure, and fitness interests to also be key triggers for changes in bicycling. Several studies have investigated the effect of life events on commuting behavior including bicycling. Studies in the UK and the Netherlands showed that life events increased the likelihood of changing commute mode (Clark et al., 2016, Oakil et al., 2016). More specifically, switching employers increased the probability of shifting towards bicycle commuting while longer commute distance and childbirth reduced it. Bonham and Wilson (2012) studied changes in women's bicycling behavior in Australia using retrospective questions. Their results suggest that women do not steadily decrease their bicycling but that they often stop and start bicycling again over their lifetimes. In general,

the results of these studies provide quantitative and qualitative support for the relevance of life events for changes in travel behavior.

2.2.3 Conceptual approach

This study adds to the literature by providing a long-term perspective on an individual's bicycling history rather than focusing on brief periods in time or limited to specific life stages (e.g. childhood). By employing qualitative methods, we are able to explore the causal processes by which people start, increase, or stop bicycling. More specifically, we investigate the following research questions:

- How do life course events affect the level of bicycling and attitudes towards bicycling?
- Which causal mechanisms drive change in the level of bicycling and attitudes towards bicycling?

The conceptual approach for our analysis (Figure 2.1) is embedded in the mobility biography literature and mainly based on Clark's et al. (2016) conceptual model which is informed by the work of Lanzendorf (2003) and Salomon (1983). In our conceptual model, life course events can trigger a deliberation process and potentially change bicycling behavior. Moderating factors influence this deliberation process. Previous research suggests that attitudes towards bicycling explain change in the level of bicycling. In addition, personal history encompasses skills and experiences developed in relation to bicycling that moderate the deliberation process as well. For instance, the bicycling culture in childhood may affect perception of and preferences for bicycling as an adult. In the theoretical framework of Busch-Geertsema and Lanzendorf (2017), requirements are understood as subjectively perceived constraints (e.g. time or distance constraints). In addition, physical and financial constraints (or abilities) are thought to impact the decision to start, continue, or stop bicycling as well. At the same time, external factors such as opportunities or facilitating conditions (e.g. bike infrastructure, road safety) and peers also influence the choice process. The dotted line in Figure 2.1 indicates the reverse causal effect that changing bicycling behavior may have on bicycling attitudes.

This conceptual model (Figure 2.1) guided the analysis of the interviews and was updated to illustrate influential moderating factors that emerged from the interviews. In this analysis we concentrate on life course events that occur at the transition phase from one life stage to another or within a particular life stage (cf. section 2.3.2 for the definition of life stages). Although we focus on life course events, our analysis shows that in some cases changes in attitudes and behavior require more time and adaptation to new circumstances and are thus better characterized as a process rather than a one-time alteration.

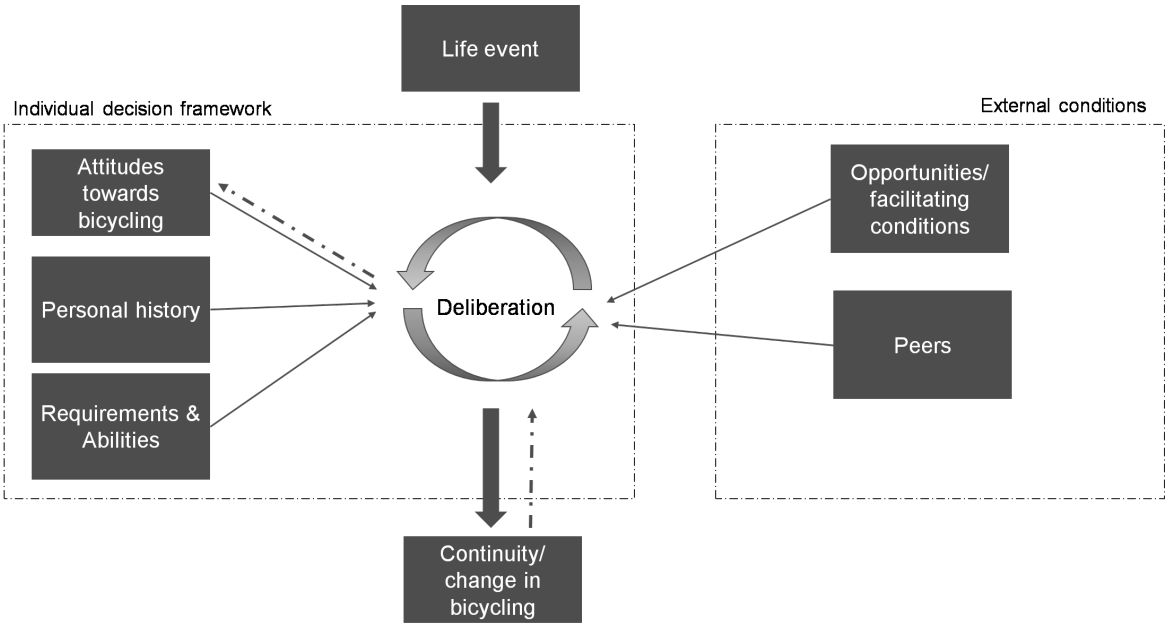

Fig. 2.1 Conceptual model to analyze change in bicycling behavior (adapted from Clark et al., 2016 and the Requirements, Opportunities, Abilities approach from Busch-Geertsema and Lanzendorf, 2017; Harms, 2003)

2.3 Data and methods

2.3.1 Sample

This study uses interviews that were conducted in 2010 with a convenience sample of residents of Davis, California, a small city well known for its high level of bicycling by U.S. standards (Buehler and Handy, 2008). Participants were recruited through flyers and newspaper advertisements describing a study on attitudes towards transportation (rather than bicycling specifically). Participants were required to be English-speaking residents of Davis between the ages of 25 and 65 years old, and they received a $20 gift card for participation. Participants completed a short survey before the interview, answering questions on socio-demographics, travel behavior, mobility resources, and travel-related attitudes. The sample of participants was fairly representative of both Davis and the U.S. population with respect to income and ethnicity (see Underwood et al., 2014 for a comparison), though the average level of educational achievement was higher. Forty percent of the participants were between 25 and 35 years old with the remaining 60% spread between 35 and 65 years old (Table 2.1). Although all participants lived in Davis at the point of the interview, they had previously lived in various locations across the U.S. with an average length of time living in Davis of six to ten years. According to the survey, all but one knew how to bicycle. The final

Table 2.1 Descriptive Statistics

	Counts	Percentage
Gender		
Women	33	61
Men	21	39
Age		
Median	38	
25-30	15	28
31-40	13	24
41-50	10	19
51-60	13	24
>61	2	4
White persons	40	74
Educational attainment		
High school degree	10	19
Bachelor degree	22	41
Graduate degree	22	41
Job position		
Not employed	11	20
Part-time	20	37
Full-time	21	39
Median income	$30,001 to $40,000	

sample was 54 participants, including 34 women and 20 men. More details about the dataset can be found in Underwood et al. (2014) and Lee et al. (2015).

2.3.2 Interviews

Interview guides were developed based on a literature review and input from a multi-disciplinary (urban planning, sociology, cultural studies, and public health) research team. The one-on-one interviews, lasting between an hour and an hour-and-a-half, comprised retrospective questions in a semi-structured format. The questions aimed towards an in-depth exploration of each participant's experiences with bicycling during six stages of life, defined as elementary school, junior high school, high school, college age (19–25 years), young adult (26–40 years), and older adult (40–60 years). At each stage, the interviewer asked questions about a variety of aspects of bicycling, including the nature and extent of bicycling experiences, community norms, and feelings. The interviews were conducted in public spaces, mostly parks, and were audio recorded and professionally transcribed. The interview

guides and recruitment protocols were approved by the Institutional Review Board of the University of California, Davis.

2.3.3 Methods of analysis

The interviewers asked participants about their level of bicycling and how they liked bicycling at each life stage and used open-ended questions to explore the nature of attitudes towards bicycling. For this paper, we coded the transcribed interviews for life course events, bicycling levels, and bicycling attitudes using a coding template. Informed by our conceptual model, the template captured variables of interest at each life stage or residential location. While Underwood et al. (2014) investigated bicycling behavior in childhood and adolescence, in this study we concentrate on changes in bicycling and attitudes after high school. We assessed bicycle availability, the level of bicycling, and bicycling purpose, either recreation, transportation, or both. We coded three dimensions of attitude towards bicycling: one's general liking or disliking of bicycling, comfort with bicycling, and desire to bicycle. We also coded for life events emerging in the personal, professional, or housing sphere. The coding was conducted in the qualitative analysis software program Atlas.ti 8.0. Codes were then grouped to analyze reasons for change in both variables of interest, level of bicycling and bicycling attitudes. We show quotes from the interviews as evidence for our interpretations of participants' experiences and attitudes.

Although participants sometimes explicitly mentioned the cause for a change in bicycling or attitude we often infer causality based on the elucidated context and order of events. Participants sometimes described the occurrence of life course events and changes in their travel behavior at the same time though adaptation may have required time. We linked information from the interviews with the sociodemographic background information provided in the self-administered surveys to understand life stage context and identify life events.

Due to the nature of the open-ended interview guide, some points were not systematically raised with all participants. The statistics shown in this paper are not considered to be representative for the general population but rather to highlight the connection between our variables of interest and related causal mechanisms. The longitudinal and qualitative design of this study is hence well adapted to answer our research questions since it allows for a close examination of the processes that link life course events to our variables of interest.

2.3.4 Limitations and opportunities

At the time of the interviews, all participants lived in a particularly bicycling-friendly environment by U.S. standards (Davis, California). This explains the relatively high number

of participants who bicycled at least occasionally at the time of the interviews. However, at other points in time participants had lived at places in the U.S. that vary considerably in geography, climate, bike infrastructure, and culture.

Data acquired based on retrospective questions allow researchers to analyze travel behavior including habits and ruptures in habits over a long period of life. This is often not possible in more expensive panel studies that generally cover a shorter period of time. However, retrospective questions face the challenge of potentially incomplete or inaccurate memory that may lead to recall errors in the responses. Behrens and Mistro (2010) highlight different errors that may occur: people forget events, a tendency that probably increases with time; people may err in recalling when events occurred, a problem called "telescoping"; people may misrepresent the truth about themselves in reconstructing events, a problem linked to confounding events and "self-disclosure." However, Behrens and Mistro (2010) found that people more accurately recalled changes in travel behavior if they were linked to radical changes and life events. In fact, several studies suggest that information is more reliable if it is related to important events (Beige and Axhausen, 2008; Oakil et al., 2016). In other words, participants may be more likely to accurately recall changes in their bicycling behavior or attitudes if they are linked to life events. As a result, we expect the recall of changes in behavior or attitudes associated with life changes to be relatively accurate.

In addition, recall biases may be less prominent in qualitative interviews compared to self-administered surveys since in the interviews participants had more time to recall and elaborate on changes. The interview guide for this study asked participants at each life stage and each residential location about their bicycling attitudes and behavior. This structure provided a grid to recall and link memories to concrete places and may improve accuracy of the memories.

Given the sample size and non-representative sampling, statistical inference of the qualitative data is not possible, and results may not be generalizable to a larger population. However, the qualitative interviews are well suited to understanding the causal mechanisms of change in bicycling behavior and related attitudes because participants explained reasons for changes and circumstances in detail. Hence the method provides strong internal validity. The results are still susceptible, however, to subjective interpretation by the researchers, which may affect the reliability and internal validity of the analysis. We therefore provide quotes to increase the transparency of our deductions from the interviews. Another concern is social-desirability bias, in which participants provide responses they feel are socially acceptable rather than accurate responses. To limit social desirability bias, we include questions about car driving as well as their perceptions of the attitudes and behavior of peers.

2.4 Results

Two causal pathways emerged in the interviews that explain change in bicycling behavior or attitudes towards bicycling. First, life course events appeared to trigger changes in either bicycling or bicycling attitudes (Figure 2.2). Second, the relation between attitudes towards bicycling and bicycling behavior can be bi-directional and each may trigger change in the other, as illustrated in Figure 2.2. When a life event triggers change in one of the variables of interest it is likely to produce a change in the other variable as well. For instance, several participants relocated to Davis then started bicycling which changed their desire to and comfort with bicycling. The most prominent life events in the interviews related to residential relocation, having children, and acquiring a new partner (Figure 2.3). Other life events such as acquiring a driver's license and change in work situation also came up in the interviews, but this analysis focuses on the three most prominent events. In the following sections, we discuss, for each life event, first, the causal relationship between the life course event and bicycling attitudes and level of bicycling, second, the underlying causal mechanisms, and third, factors moderating this relationship.

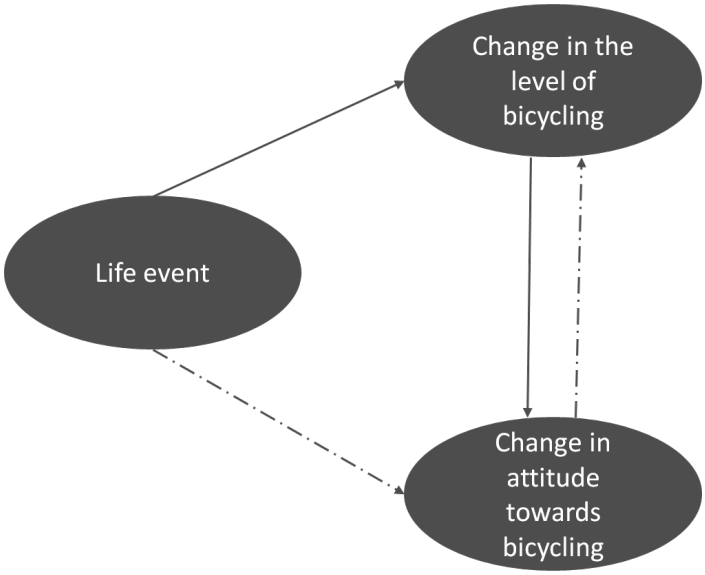

Fig. 2.2 Direction of change between life course events, level of bicycling and attitudes towards bicycling

2.4.1 Children's impact on parental bicycling and attitudes

The life event of becoming a parent and the life stage of parenthood emerged as having an impact on bicycling levels as well as attitudes. Although the birth of a child often has an

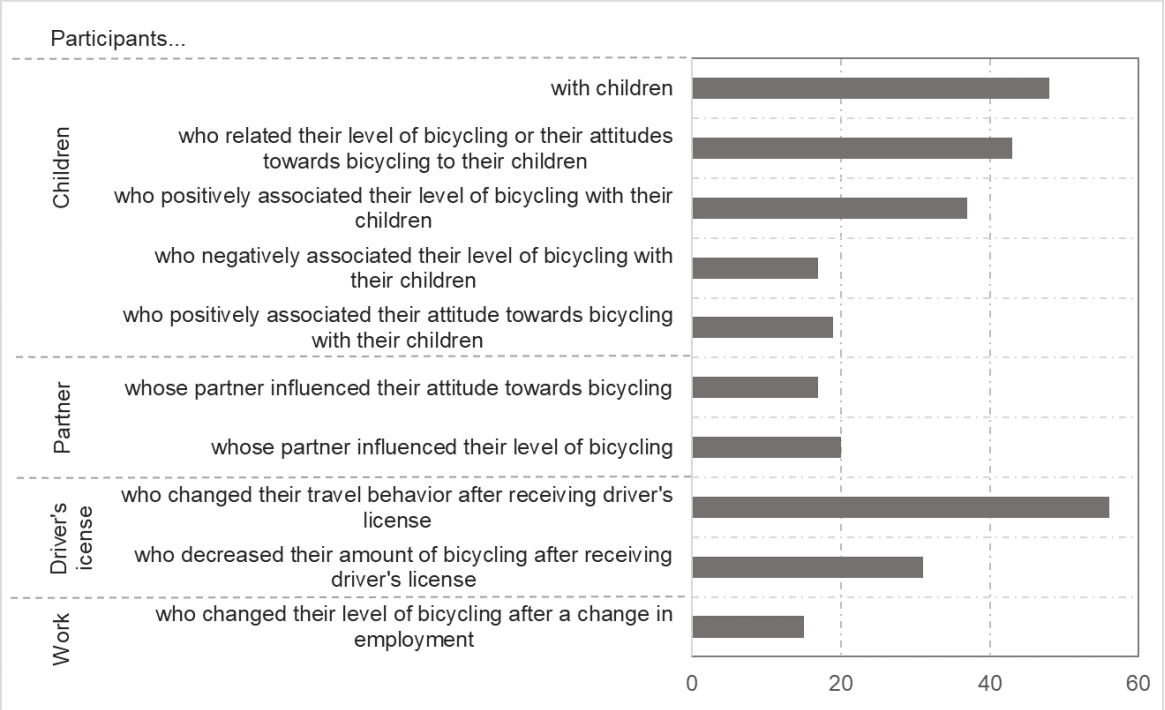

Fig. 2.3 Percentage of participants who related their bicycling attitudes or level of bicycling to life events

immediate effect on travel behavior, i.e. parents become less mobile, they adapt to the new situation over time, sometimes before the child's birth and usually throughout parenthood. Forty-three percent of the participants linked their bicycling behavior or their attitude towards bicycling to their children even though we did not specifically ask about the effect of children. When we asked participants about fond memories of bicycling they often mentioned bicycling with their children. They often started bicycling again (after not bicycling for some years) because of their children. Some started recreational bicycling, while others bicycled for transportation or increased their overall amount of bicycling.

Table 2.2 highlights that women (50%) were more likely than men (30%) to mention their children in explaining their bicycling or their attitude towards bicycling. This may indicate that the way partners share their child-related duties impacts their bicycling behavior (Table 2.4, Quote 1).

Children change the transportation needs of their parents, their comfort in using certain modes, and preferences for specific activities. In the deliberation process of searching for children-friendly activities, parents start to consider and appreciate bicycling as a potential activity. Nearby destinations become more attractive in the presence of children thereby supporting bicycling, a distance-sensitive transport mode. In general, participants put empha-

Table 2.2 Bicycling with children by gender

	Counts		Percentage	
	Female	Male	Female	Male
Total sample	34	20	100	100
Participants with children	18	8	53	40
Participants who related their level of bicycling or their attitudes towards bicycling to their children	17	6	50	30
Participants who positively associated their level of bicycling with their children	14	6	41	30
Participants who negatively associated their level of bicycling with their children	7	2	21	10
Participants who positively associated their attitude towards bicycling with their children	8	2	24	10

sis on the fun and joyful experience of bicycling with their children because they enjoyed the physical exercise, being outdoors, the enjoyment of their children, and the convenience for parent and child alike (Table 2.4, Quotes 2, 3 and 4). Participants pointed out that they enjoyed bicycling more with their children than they had previously enjoyed bicycling, indicating a change in parents' attitudes towards bicycling. Another reason why parents bicycled with their children relates to economic constraints (Table 2.4, Quotes 5 and 6).

Depending on the development stage a child has different impacts on parents' bicycling behavior which appear to be non-linear (Table 2.3). Parents have different opinions about the best moment to start bicycling with a child (Table 2.4, Quotes 7, 8 and 9). Some persons preferred to bicycle with their child at a very young age when the child did not yet bicycle on its own. Others mentioned that they only started bicycling with their children when the children bicycled on their own. Having more children in the household also contributes to the complexity of travel needs.

Appropriate bicycling equipment emerged as a moderating factor influencing whether parents bicycled with their children (Table 2.4, Quote 9). Parents pointed out how convenient bicycling was once they had it. They purchased bike seats and trailers which some also used for grocery shopping. Others explained that they did not bike with their young children because they did not have adequate equipment but started bicycling as soon as their kids had their own bikes. Another moderating factor was the lack of bicycle infrastructure and safety, which impeded some parents from bicycling with their children. For example, one participant drove to another town to safely teach his children how to bicycle. Some participants tried to bicycle with their children but stopped because of safety concerns and drove by car. However, once in Davis, they started bicycling with their children (cf. section 2.4.2). Other parents

Table 2.3 Non-linear effects of children on parental bicycling

Development stage of child	Parents' level of bicycle
Baby	Some parents stop bicycling at the birth of the child. Babies tend to inhibit parental bicycling.
Toddler	Some parents start bicycling with their child.
Child attends elementary	Parents teach child how to bicycle and show the route to school. Some parents regularly bicycle with their children to school.
Child attends junior high	Child bicycles on its own to school. Recreational bicycling with parents. Parents' bicycling often decreases. Child's schedule and activities get more complicated. Parents transporttheir child to various activities.
Child attends high school	Parents' bicycling decreases. Parents transport child by car to high school and activities taking place at larger distance and later during the day. Car is perceived as the more convenient mode of transportation.

stopped bicycling because they worried about their own safety as a parent (Table 2.4, Quote 10).

In sum, the development stage of the child, bicycle equipment, infrastructure, and safety moderated the effect that children have on parental bicycling and attitudes.

2.4.2 Residential relocation to Davis as a trigger for change

When individuals relocate they often experience change in the built and social environments and disrupt their travel habits at the same time. When asked about places that have shaped their bicycling behavior or attitudes, most participants mentioned Davis as a particularly influential place (e.g. Table 2.5, Quote 11). Sixty-three percent of the interviewees stated that Davis positively influenced their attitude towards bicycling. Likewise, the majority of participants (56%) increased their bicycling after moving to Davis.

Twenty percent of the participants moved to Davis because of the bicycling-friendly environment and to bicycle (among other factors), indicating a latent demand for bicycling. Others relocated to Davis so as to bicycle for reasons of convenience (e.g. a bad car parking situation) rather than because they liked bicycling.

Most of the participants, however, did not deliberately factor bicycling into their location choice, but living in Davis has had an effect on attitudes or behavior or both. Most participants did not have a strong inclination to bicycle when arriving in Davis but started bicycling there because it was the most common mode of transportation. Once they started, their attitude

changed and they appreciated bicycling more. Bicycling in Davis is often remembered as a positive experience. Participants who had attended the University of California, Davis liked bicycling because they linked it to fun activities with their friends (Quote 13). Similarly, parents started liking bicycling because they enjoyed that their children could bicycle to school in Davis.

A quarter of interviewees positively changed their attitude towards bicycling because of the bicycling culture in Davis (Quotes 14 and 17). Relocating to a bicycling-friendly environment induced a change in the perception of bicycling as a viable mode of transportation (Quote 12). Some participants mentioned that they felt social pressure to bicycle driven by the high number of bicyclists and environmental awareness in Davis (Quotes 15 and 16). A major factor why people started bicycling when they arrived in Davis relates to the availability of bike infrastructure, the social environment, and the perceived safety of bicycling (Quotes 18 and 19). Accessibility to various destinations, good weather, and geographic conditions made it convenient to bicycle (Quotes 20 and 21). Observing other parents bicycling with children reassured parents that it was a safe place to bicycle. In addition, it seemed easier to purchase equipment to transport children in a bicycling-friendly environment. Some participants chose to live in Davis because their partners had a strong preference for bicycling. A partner's desire to live in a bicycling-friendly environment or bicycle to work can affect the residential location of a household (Quote 22).

The bicycling culture, infrastructure and safety in Davis, peers, and bicycling equipment moderated the effect that residential relocation had on the level of bicycling and the desire and comfort to bicycle.

2.4.3 Partner's influence on bicycling

Nine participants mentioned that their partner affected their own attitude, six in a positive and three in a negative way. Nineteen percent of participants started bicycling or bicycled more because of their partners. These results suggest that the life event of acquiring a partner could have a significant effect on bicycling and attitudes. Meeting a new partner prompted participants to discover new destinations and activities that are more convenient to reach by bicycle or involve bicycling. Partners suggested new types of bicycling such as mountain biking or bicycling as a form of transportation (Table 2.6, Quote 23). Participants appreciated bicycling more after accumulating positive bicycling experiences with their new partners (Quote 24). Partners may unleash a deliberation process while participants scrutinize their attitudes towards bicycling (Quote 25). On the contrary, partners also impeded bicycling because of their dislike of bicycling or different travel needs that could not be satisfied by bicycling (Quote 27). Participants mentioned that they would bicycle more if their partners

Table 2.4 Examples of quotes from the interviews: Parenthood

N°	Person	Quote
1	Female,34	"...if my son's school started earlier than my daughter's school, then I could drop him off on my bike, bike here to school, bike to my job, and then pick everybody up... My husband... bikes back and forth to work every day..."
2	Female, 58	"I bought a bike when my daughter was... four or five years old I think. And that was a recreational thing where I could put her on the back and ride around town."
3	Female, 40	"And I do miss [how] I used to ride the kids to school... that was fun... I don't do that anymore... When I was riding the kids to school every day, maybe it was more habit.... I haven't been riding as much [recently]"
4	Male, 65	"I thought it was an important thing to do. My son doesn't get a whole lot of physical activity. And time on the cycle is among the relatively rare times that he's active. So, it's something that I want to do with and for him."
5	Female, 58	"Because I didn't have any money at all. I was a single parent. I had no money, and it was a form of an activity for us. It was like something we could do that was pretty much free."
6	Female, 52	"We'd ride that way for fun. I'd take them to daycare or to kindergarten. I could have certainly driven them. I don't know why I didn't. It just seemed partly for fun, partly for economics."
7	Female, 44	"...there's a period where it's kind of hard. You can put them in an Alley Cat or something, but when they want to do it on their own, but yet they can't go that far you're kind of limited."
8	Female, 44	"I'm a stay-at-home mom and doing a lot of shuttling to activities... because it's just too far to get them on a bike at their ages for school. Most of the time it's just running kids around to activities and a car is more convenient. If we can bike we bike, but if the practice is on the other side of town, we don't bike."
9	Female, 32	"If there was an easy way to transport an infant in the bike trailer, then yes. ... We didn't bike for a full year... after he was born because... we couldn't. I think in hindsight maybe we would have tried strapping the car seat in the bike trailer"
10	Female, 41	"I stopped road biking in [the city where we were living] since I had children because it was too dangerous. [I didn't want to have them] grow up without a mother"

Table 2.5 Examples of quotes from the interviews: Relocation to Davis

N°	Person	Quote
11	Female, 25	"I don't think... I would have ever really had a bike somewhere [other than Davis], unless [it was] another school that uses bikes a lot"
12	Female, 60	"I think Davis has definitely made me consider bicycling as an attractive, important part of everyday life."
13	Female, 34	"I think my experience as an undergrad [student] in Davis really shaped my liking for biking. Biking was a really fun thing I did... it wasn't just a mode of transportation to campus, but it was something that I would go out with my roommates ... I have some really good memories attached to doing social activities on my bike."
14	Female, 46	"... then I saw people who seemed less athletic than me biking, so... it kind of opened up my belief in who rides a bike around."
15	Male, 26	"I would feel weird if I drove everywhere [in Davis]... Cyclist[s] make it slightly harder to drive because you have to slow down, so it's like you're constantly reminded like you should be biking"
16	Female, 60	"So, you didn't really have a lot of excuses. You kind of needed to ride or you were a jerk."
17	Female, 34	"I don't consider myself a very active bicyclist, unless I'm in Davis clearly... I've lived in a lot of places that are just really set up for cars. And there's not a lot of... big biking culture there."
18	Female, 29	"I like [biking in Davis] more than when I was bicycling in Boston because it's less dangerous I'd say. The roads are wider. There are bike lanes. People stop for you. People don't harass you..."
19	Male, 36	"I biked around, like I said, when I was younger, but... it was mostly pleasure riding, whereas now it's so convenient to get around here in Davis... because of bike paths and clearly marked lanes"
20	Female, 58	"You know, in Davis it's actually easier to get places on a bike than it is in a car a lot of times"
21	Male, 53	"If you're not riding a bike in Davis... I get the impression you're not going to ride a bike anywhere. "
22	Female, 60	"Because of my husband we would have to move someplace where bicycling could be part of our lives or his life... it was important for him to be able to bicycleto work, to use that as his main mode of transportation."

Table 2.6 Examples of quotes from the interviews: Partner's Influence, Attitude

N°	Person	Quote
Partner's Influence		
23	Female, 31	"... he's super into biking... we went on that bike trip together and that to me was like something I never even thought of doing before then. And that really opened my eyes to how you can just go anywhere."
24	Female, 60	"...my boyfriend had a really slick bike. He was into it. So, yeah, then it changed. It was no longer utilitarian, it was exercise, and it was fun."
25	Female, 60	"I think my spouse has shaped a lot of the things I like about [bicycling], because... he's also interested in bicycling as a recreational activity. I think had it not been for him, I wouldn't really consider bicycling as a recreational activity."
26	Male, 61	"...but I did teach my wife, my ex-wife to ride a bicycle during that period. I was extremely surprised and shocked that she did not know how to ride a bicycle. Bought her a bicycle..."
27	Male, 38	"I have a girlfriend who drives a car and she often thinks about taking long trips [by car]... and...that stuff never even occurs to me."
Attitude towards bicycling and bicycling behavior		
28	Female, 27	"I choose [places of residence] based on biking, but that's not the only criteria."
29	Male, 38	"The fact that I've been bicycling for so long... makes me comfortable in most situations"
30	Male, 27	"I think just experience. [...] Having ridden a lot."
31	Female, 60	"And so the bike again became my major source of transportation. And then my attitude changed in terms of it [being] a workout. It was like really good exercise"
32	Male, 26	"It was just something I had forgotten about, and then my attitude radicallychanged, because at the same time as that I started riding my bike again..."
33	Female, 25	"At first, [I liked bicycling] not so much. [I thought] this is what I've got to do to get around everywhere? But like, once I got used to it, I did [like it]. Once I got a basket too that helped..."

joined them. Likewise, partners can discourage their partners from bicycling because they overexert them.

Mobility resources and skills of the partner moderate the impact this life event has on travel behavior and attitudes (Quote 26). We did not necessarily observe the direct change of the life event of acquiring a new partner. But based on the context, we infer the causal effects when both acquiring a new partner and a change in travel behavior or attitude occurred at the same time.

2.4.4 Causal mechanisms

Causal mechanism between attitude and behavior

Although the focus of this paper is on life events, our analysis suggests that bicycling attitudes and the level of bicycling affect each other, thereby raising the question of the causal relationship between the two variables. The usual assumption is that attitudes influence behavior, and indeed the interviews provide many examples of attitudes shaping behavior. For example, some participants voluntarily chose to not own a car but only a bicycle. Other participants chose their residence specifically to bicycle (Quote 28). In these examples the attitude towards a transport mode precedes and influences travel behavior.

But causality also flows in the other direction, with behavior sometimes influencing attitudes. Indeed, the relationship between mode behavior and attitudes towards modes can be circular: the positive experience of bicycling may change the liking of bicycling in general which reinforces its use. When we asked participants what shaped their attitudes towards bicycling, participants often responded that bicycling itself influenced their attitudes (Quote 31). They pointed out that the more they bicycled, the more confident they became on a bicycle and the more comfortable it was to bicycle (Quotes 29 and 30). Hence, bicycling skills and ability shaped attitudes towards bicycling as well. This effect occurs over time, so that the effect of behavior on attitude is better characterized as a process rather than a onetime event. Participants often stated that they had a neutral opinion about bicycling to start with (Quote 32). They started bicycling because it was the most convenient mode of transportation or their peers bicycled, but after a while they started to like it. Some participants disliked bicycling when they started to bicycle for practical reasons or out of necessity but changed their attitudes over time (Quote 33).

Bicycling can also contribute to a negative attitude. For instance, in the case when bicycling is a means of transportation rather than a recreational activity, people sometimes start to dislike it. Likewise, people experienced negative incidents while bicycling which can discourage further bicycling (Lee et al., 2015). In general, the interviews showed that

attitudes towards bicycling and the act of bicycling have a reciprocal relationship and impact each other. These interdependences explain why life events that trigger a change in one of these two variables is likely to influence the other variable as well.

Causal mechanisms for changes triggered by life events

We distinguish four causal mechanisms that explain how these life events effect change in bicycling attitudes and level of bicycling: Life events (i) start a deliberation process, (ii) change the social norm, (iii) enable the expression of a latent demand for this travel mode, and (iv) unleash interest for new destinations and activities. Because attitudes and behavior are linked (as described in the previous section), if these mechanisms affect one outcome (attitudes or behavior), they are likely to affect the other. Table 2.7 provides examples from the interviews that illustrate these causal mechanisms.

First, confronted with changes in other life domains, participants interrupt their habitual behavior and start to scrutinize travel routines. They potentially become more conscious of their bicycling attitude when making new travel choices. In this general deliberation process, perceived barriers to change may be lower because participants acquire additional information while adapting to the new situation. For instance, some participants started recreational bicycling with a new partner. Through these new positive experiences, they came to appreciate bicycling more. This example highlights the interdependences between life course events, bicycling, and related attitudes in general.

Second, life events can put an individual within a new social and physical environment and expose them to new mobility-related social norms prompting participants to adapt their travel behavior and attitudes accordingly. The exposure to new social norms may occur due to residential relocation, changes in the workplace, or a shift to a new life stage. The birth of a child and the life stage of parenthood in general may shift social as well as individual expectations about recreational activities that affect travel behavior. For instance, parents are expected to bicycle to school with their children in some places while in other communities it is perceived unsafe to let children bicycle to school.

Third, life events can unleash a latent demand for bicycling. They change circumstances and conditions prompting individuals who previously faced constraints on bicycling to choose their preferred mode. For instance, individuals can start bicycling to work following a decrease in their commute distance. In some cases, participants chose their residential location, among other factors, to be able to bicycle.

Fourth, life events trigger an interest in (or need for) new destinations and activities that support or discourage bicycling. Life events may change travel time or distance constraints so that nearby destinations become more attractive and individuals become more aware of

them. Life events may trigger changes in taste and preferences for destinations and activities. For example, individuals who retire might also change their valuation of travel time and appreciate traveling with slow modes more. These more profound changes may be more likely to emerge when life events occur at the transition phase from one life stage to another.

Table 2.7 Examples for causal mechanisms explaining the relation between life events and change in bicycling and attitudes

Life events	Causal mechanisms			
	Deliberation process	Social norm	Latent mode demand	New destinations & activities
Starting parenthood	Teaching children how to bicycle and appreciate it more.	New social norms emerge relating to safety rules,the transport of children		Taste and preferences for destinations and activities change.Nearby destinations gain in importance (school,parks)
Meeting a new partner	Person appreciates bicycling more because of positive bicycling experience with new partner			Knowledge about new destinations and activities become available. Persons may start new type of bicycling with partner
Residential relocation	Person acquires information about new location reflects on available modes and comfort to use them, starts to build up new routines	Bicycling is the common mode of transportation at new location. Environmental awareness of community increases social pressure to bicycle	Person moves to bicycle more or because of the bicycling -friendly environment.	New destinations become accessible and new activities feasible. After relocation, park is in bicycling distance.
Change in workplace	New destination requires information to plan and choices for the commute trip.	Dress code at work impedes bicycling. Infrastructure at workplace and colleagues who bicycle to work incentivize commute by bicycle.	New workplace is accessible by bike.	
Retirement	Change in daily routines trigger reflection about new destinations and activities.		Less time constraints lead to more bicycling.	Bicycling as a recreational activity becomes more important.

2.5 Discussion and conclusion

2.5.1 Discussion

This study contributes to the travel behavior literature by providing insights on the non-linear effects of life events on changes in bicycling behavior. These insights could be used to inform retrospective questions in quantitative surveys and improve the quality of the questions to assess behavioral change. In addition, we highlight four causal mechanisms for explaining change in bicycling attitude and behavior that may be generalizable to other transport modes as well. Policy interventions may be more effective if targeted to the causal mechanisms.

In general, we found evidence that life course events trigger changes in the level of bicycling and attitudes towards bicycling. Three prominent life course events emerged from the interviews: having children, meeting a new partner, and residential relocation (to a bicycle-friendly community). The literature on life course events mostly outlines one causal mechanism, namely a deliberation process, through which life events trigger change in travel behavior. Our conceptual model is based on this causal mechanism. This study points out three more causal mechanisms: life events change social norms, unleash a latent demand for bicycling, and alter interest and need in destinations and activities.

The four causal mechanisms that explain changes in bicycling attitudes and behavior in the presence of life events may be generalizable to other modes beyond bicycling. Life events start a deliberation process that also affects other mode choices, as found in previous research (e.g. Clark et al., 2016). Individuals may consider alternative transportation modes after changing their workplace because the planning of their new commute route starts a deliberation process. Changing the workplace may lead to changes in social norms that trigger the use of a particular transport mode. In some enterprises, it may be more common or even expected to use a car to commute to work. Another causal mechanism that emerged from this study is a latent demand for a specific transport mode. As previous studies have pointed out, an increase in income is positively associated with car ownership indicating a latent demand for car driving (Dargay and Hanly, 2004). After retirement, individuals may sell their car because they no longer need to commute to work and nearby destinations become more important. These examples highlight the potential to apply the four causal mechanisms highlighted in this paper to other transport modes.

Our results confirm findings in the literature connecting mode-related attitudes and travel behavior. We found a bi-directional relationship between the level of bicycling and bicycling attitudes implying that a positive attitude leads to more bicycling but also bicycling itself improves comfort with bicycling or desire to bicycle. These findings support the possibility

of a reciprocal relationship between transport mode choice and mode-related attitude, as found in a recent quantitative study (Kroesen et al., 2017).

Another interesting finding indicates that gender plays a role in the effect that children have on parental bicycling. In our sample, more women than men with children related their bicycling to their children. This spread is even more prominent for attitudes towards bicycling. Since we did not directly ask about the influence of children on parental bicycling social desirability response bias is likely to be low, lending greater credence to this result. Other studies support this finding. For instance, Chatterjee et al. (2013b) showed that women are more affected in their bicycling by the development of their children than men.

Another insight from this study is that children's development appears to have a non-linear impact on parental bicycling and related attitudes. Parents with young children tend to bicycle and appreciate bicycling more; when children's travel need become more complicated their bicycling decreases. In a study conducted by Bonham and Wilson (2012), the authors found similar results, namely that parents reacted differently with respect to their bicycling as children got older. These insights may provide a useful contribution for qualitative and quantitative studies that use retrospective questions. Retrospective questions that aim to assess the effect of parenthood on travel behavior may distinguish between development stages of the child, for example as outlined in Table 2.3.

The results of this analysis show that several causal mechanisms explain how life events may trigger change in bicycling in contrast to the one causal mechanism of deliberation presented in our conceptual model. Deliberative decisions may not always precede behavioral or attitudinal change. For example, Goetzke and Rave (2011) describe bicycling culture as "social interaction or spillover phenomenon" that makes people more likely to bicycle in a city with an already high share of bicyclists. They provide three arguments for this phenomenon: first, people like to bicycle with others; second, bicycling culture can be a social norm building up peer pressure; third, a social network spreads internalized information, for instance about the quality of bicycling routes (Goetzke and Rave, 2011). Some participants in this study pointed out that they started bicycling because it was the common mode of transport in the city and bicycling to the university was pervasive.

2.5.2 Policy implications

Individuals who experience life course events seemed to be more susceptible to change in their travel behavior, potentially presenting a "window of opportunity" to influence them more effectively through incentives to bicycle. Policy instruments may be more effective if adapted to the causal mechanisms that drive change in bicycling and related attitudes in the presence of life events.

If a latent demand for bicycling motivates a potential change in bicycling, "hard" factors such as bike infrastructure and travel distance may be more relevant for the decision to start or increase bicycling persons who do not have an explicit desire to bicycle, in contrast, may need additional incentives. In our interviews, participants reported barriers to traveling with children or transporting groceries on their bicycles, reflecting at least in part insufficient knowledge or availability of appropriate equipment. To unleash this latent demand for bicycling, public support, second-hand markets, and advertisements for bicycle equipment may foster the use of bicycles.

Planners might also make use of the deliberation process outlined in this paper. Recent movers make more deliberate choices about their commute to work. They may be more susceptible to trying out alternative modes and to breaking with routines compared to long-time residents. In some cities, development agencies aim to benefit from this "window of opportunity" and provide integrated mobility packages for new residents combining car and bike sharing offers with public transport tickets (Petermann, 2018). Trial packages and temporary offers can provide incentives for recent movers to try out alternative ways of traveling and disincentivize car ownership (Oakil et al., 2016).

Several studies have investigated factors that drive children's choice for active modes to travel to school (e.g. McDonald, 2012). Travel distance has been found to be the most influential factor in determining whether a child bicycles or walk to school with different thresholds observed across countries (Easton and Ferrari, 2015, Sener et al. 2010). Sener et al. (2019) ascertained that parents and their travel-related attitudes also effect a child's mode choice for the trip to school. The results of this study provide some evidence that children in fact can be a pull factor to incentivize parents to bicycle more and to bicycle to school with them, given a supportive environment for bicycling. Parenthood can raise interest in (and need for) new destinations and activities including school. Programs incentivizing children to bicycle to school might encourage parents to bicycle as well. For example, partners of the Safe Routes to School National Partnership, a US organization that advocates for safe routes and active commuting to school, reach out to parents to promote bicycling to school. Participants suggested that more centralized locations for sports and other activities for children could facilitate bicycling for children and parents. In the interviews, some women pointed out that they cannot bicycle to work because of shuttling their children to various activities. Policy programs designed to relieve parents from bringing their children to school or making it more attractive to bicycle to school might foster parental bicycling in general. In addition, bicycle repair service facilities located nearby schools could make it easy for parents to repair their bikes when they bicycle their children to school.

2.5.3 Research implications

Our results allude to the challenges in assessing life events and behavioral responses with quantitative methods given their non-linear impact. In future research, it would be interesting to investigate the time dynamics of deliberation and adaptation processes. A more comprehensive understanding is required about the delay in behavioral or attitudinal change. Little is known about how quickly people adapt and change their travel behavior in response to the occurrence of life events. Future qualitative studies might assess how individuals plan or prepare for life events, producing insights that could inform prospective questions in interviews and surveys.

Another avenue for future research would be to test the causal mechanisms identified in this study in a quantitative framework, particularly relating to social norms, latent demand, and interest for new destinations and activities. Future work might investigate to what extent people experienced a change in bicycling culture and social norms along with a life event. It might also be interesting to explore to what extent a change in bicycling behavior and attitude occurred as a consequence of a deliberate decision process as usually assumed in conceptual models found in this body of literature. Acknowledging that some behavioral and attitudinal changes occur in a non-deliberate process challenges quantitative and qualitative researchers to understand drivers of change.

Future applied research might identify more concretely how to incentivize change in bicycling behavior and attitude for specific population groups. Parents might be more easily accessible over social networks, for example, whereas older adults might be more sensitive to publicity for new destinations and activities. As pointed out earlier, the insights of this study may be generalizable to other transport modes as well. Future studies might test whether the same causal mechanisms are relevant for other modes, too. For example, individuals might move to another location to facilitate public transport use indicating a latent demand for this transport mode. It would be particularly interesting to know under which circumstances changes in social norms work as a causal driver to change the use of transport modes and which transport modes are particularly susceptible.

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Chapter 3

Examining the effect of life course events on modality type and the moderating influence of life stage

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Abstract

Previous research has demonstrated the relevance of life events to explain changes in travel behavior. Less clear is the moderating role played by life stages on the relationship between life events and travel behavior. Our goal in this study is to explore how the influence of life events on travel behavior differs by life stage. We use data from a travel survey of faculty, staff and students at a US university. We define four life stages: millennials living in shared apartments or alone, millennials living with partners, parents (of any generation) living with their children, and non-millennial adults living without children. Four modality types were defined: active travelers, car users, transit users, and multimodal travelers. We use a Manifest Markov Model to estimate probabilities of switching modality types between two waves of the survey. Life stage does not significantly moderate effects of life events on change in travel behavior but does affect modality type: the prevalence of active travel modality types, particularly the share of women who are active travelers, decreases throughout the life stages. Millennials living with their partners and parents living with their children relocate to another town more often than those in other life stages, a life event associated with a higher probability of switching to car use only. Our results identify "windows of opportunity", such as residential relocation, that planners can use to promote sustainable travel behavior.

Keywords: Life course events, Travel behavior change, Multimodality, Manifest Markov model

3.1 Introduction

In everyday life, travelers rarely change their behavior. Studies show that daily travel behavior is often habitual, characterized by routines (Müggenburg et al., 2015). However, in the presence of major changes in other life domains, individuals more deliberatively reflect on their travel behavior and their mode choices become more intentional (Müggenburg et al., 2015). Research in the domain of mobility biographies more explicitly links long-term decisions such as residential location choice to short-term decisions such as transport mode choice. Some researchers have argued that these life events open "windows of opportunities" during which policy interventions and programs may more effectively trigger change towards more sustainable travel behavior.

The impact of these life events might depend on the context of an individual's life stage. The different mental and physical capacities, financial constraints, and social responsibilities that individuals face at different stages of life might enhance or dampen the effect of life events on travel behavior. Recent research suggests that young persons of the millennial generation behave differently, a phenomenon partly explained by a delay in life stage. More specifically, several studies show generational differences between "millennials" and members of "generation X" with respect to car ownership, transit use, and residential location preferences (for California, US: Circella et al., 2017; Thigpen and Handy, 2018; for the UK: Chatterjee et al., 2018; for Australia: Delbosc and Currie, 2014a, b; Delbosc and Nakanishi, 2017; Raimond and Milthorpe, 2010; for Germany: Bohnet and Gertz, 2010; Kuhnimhof et al., 2012; for France: Licaj et al., 2012; for Japan: Zhang et al., 2017). Though these may represent durable differences between generations, they also may be temporary and reflect delays in transitioning to other life stages (Delbosc and Currie, 2013; McDonald, 2015). For example, young couples today often decide to move in together or to build a family at later ages than previous generations, which also affects financial and mobility resources (Chatterjee et al., 2018). It remains unclear if households at different life stages or of different generations react similarly to life events with respect to changes in their travel behavior.

One aspect of travel behavior that is increasingly relevant, given the rise of shared mobility, and could be especially sensitive to life events is multimodality, defined as the use of multiple modes of travel for commute trips or other trips. Many travel behavior studies focus on the primary mode of transportation as an indicator. As ride-hailing and shared-mobility services extend the variety of modes available in the US, understanding multimodal travel is increasingly important. Multimodality may also serve as a transitional pattern of behavior away from exclusive car use. Previous studies, for example, have shown that car users who also use bicycle are more likely to switch to public transport use than strict car users (Kroesen, 2014). Others have pointed out that strict car users tend to stick to their mode, but if they switch mode, they may be more likely to switch to multimodal travel (De Haas et al., 2018).

This paper investigates, first, the impact of life events on travel behavior change, and, second, whether the influence of life events on travel behavior change varies across life stages. We aim to contribute to the discussion about millennials' travel behavior by examining whether this generation

reacts differently to life events depending on their life stage. We focus on changes in multimodal travel over time using panel data from a travel survey at the University of California, Davis (UC Davis) about modes of travel to campus by students, staff, and faculty. The findings show that life events provide explanatory power for changes in travel behavior, but that life stage does not moderate this relationship. Gender and generational differences between millennials and non-millennials, however, play a role in explaining modality type and are linked to life stage. Life events have different effects on the probability of transitioning from one modality type to another depending on the initial modality type. Our results highlight that most people do not change their modality types in response to life events, and that this is particularly true for drivers. They also point to potential synergies for integrative planning, for instance combining planning for housing and transportation to induce behavioral change.

3.2 Literature review and conceptual approach

To improve the sustainability of the current transportation system, it is important to understand how and why travel behavior changes. Recent attention has focused on the mobility biography and life-course approach to explain travel behavior change with numerous publications in journals, for example in the special issue of Zhang and Van Acker (2017), the literature review of Müggenburg et al. (2015) and books (e.g. Scheiner and Holz-Rau, 2015; Zhang, 2017). A life course approach focuses on the relationship between life events, life stage, and travel behavior and links short- and long-term decisions. Key life events can be defined as "major event[s] in a personal life that will trigger a process of reconsidering current behavior" (Van der Waerden et al., 2003, p. 2). Lanzendorf (2003) establishes the concept of mobility biographies proposing a framework that causally links events in the lifestyle (e.g. family foundation) and accessibility domains (e.g. workplace, residence) to the mobility domain (e.g. car ownership). The theoretical background of this approach suggests that daily travel is driven by habits and individuals tend to not scrutinize routines (Holz-Rau and Scheiner, 2015). Key life events may interrupt these habits and unleash a deliberation process during which people reconsider their mode choices and travel behavior in general (Chatterjee et al., 2013b). This deliberation process may be moderated by personal history (e.g. crashes, previous travel experiences), intrinsic motivations (e.g. attitudes) and external conditions (e.g. supportive employer for bicycling) (Chatterjee et al., 2013b; Flamm and Kaufmann, 2006; Lee et al., 2015; Smart and Klein, 2017; Thigpen, 2019).

3.2.1 Life events trigger change in travel behavior

Several studies have found evidence for the influence of life events on travel behavior change (Clark et al., 2016; Beige and Axhausen, 2017; Dargay and Hanly, 2004; Oakil et al., 2016; Scheiner and Holz-Rau, 2015; Verhoeven et al., 2005). For the UK, Clark et al. (2016) using a longitudinal dataset found that a higher share of commuters who experienced changes in the workplace and residential

location switched mode compared to commuters who did not experience life events. These results still hold when the availability of public transport and commute distance are taken into account and point to a separate effect of life events on commute behavior. Besides changes in residential location and employment, the acquisition of a driver's license and children moving out of the household have been shown to affect car ownership and individual travel behavior (Beige and Axhausen, 2017; Dargay and Hanly, 2004; Oakil et al., 2014). An increase in household size such as cohabitation or a childbirth positively influences car ownership while divorce has a negative effect (Oakil et al., 2014). A child leaving home has no significant effect on car ownership, but retirement is connected with a reduction in the number of cars in the household (Oakil et al., 2014). For Dutch travelers, Oakil et al. (2016) showed that households who experience childbirth are more likely to switch from bicycle commuting to other modes, though cohabitation increases the probability of switching to bicycle commuting.

3.2.2 Life events and change in multimodal travel behavior

Only a few studies have examined the impact of life events on the use of multiple modes of travel—multimodal travel—in a quantitative way. Multimodality generally refers to the travel pattern of a person who uses several modes over a defined period of time (e.g. day, week or a longer period) (Scheiner et al., 2016).

Scheiner et al. (2016) found that certain life course events are significantly associated with changes in multimodal behavior: children moving out increased parent's multimodality; individuals who entered the labor market decreased their multimodal travel while the opposite is true for individuals who exited the labor market; an increase in car availability led to a decrease in multimodality and vice versa. In a latent class analysis, Kroesen (2014) found that subsequently residential relocation, strict bicyclists were more likely to become strict car users and strict car users to become public transport users. Change in employment increased the share of public transport users. In another Dutch study, De Haas et al. (2018) found that changes in employment increased the probability of becoming a strict car user except for individuals who also used public transport. Residential relocation affected unimodal users less but led bicycle and car users to shift to strict car use and individuals who walked and used a bicycle to shift to lower mobility classes or public transport. Their results demonstrated that a child's birth affects its parents' multimodality patterns, increasing the probability of becoming a strict car user or a multimodal user of car and walking. In their model, changing or starting an educational program increased the likelihood of becoming a public transport user. All of these studies have established evidence that life events affect multimodal travel though in some cases they observed different directions of change.

3.2.3 Life stage influences travel behavior

Travel behavior also varies between life stages. An individual life course can be divided into sequences—life stages—that mark periods with different living circumstances influencing behavior,

attitudes and preferences (Holz-Rau and Scheiner, 2015; Van Acker, 2017). There is no one standard classification of life stages (Frey et al. 2017), though commonly distinguished stages include childhood, young adulthood, living with a partner, early career, marriage, parenthood, and retirement (Gilly and Enis, 1982). Recent trends towards more complex, non-linear life courses (e.g. divorce and re-marriage) makes it more complicated to approximate a life stage with age only. Travel behavior research usually considers a number of sociodemographic factors that can be related to specific life stages.

Several studies show that travel behavior differs between life stages (Beige and Axhausen, 2008; Clark et al., 2016; Chatterjee et al., 2012, 2013b; Sun et al., 2009). Beige and Axhausen assessed travel behavior over a 20-year period with retrospective questions and revealed that car ownership increases after the age of 18 and is the highest for the age group between 25 and 50 years while the opposite is true for national and regional seasonal public transport tickets (Beige and Axhausen, 2008). With the same data, the authors observed that the main mode of transport to the workplace is relatively stable throughout aging while bicycling tends to decrease in the late 40s and public transport use in the 60s (Beige and Axhausen, 2017). The results of another study indicate that life stage better explained the number of trips made per day than did variation in the built environment (Sun et al., 2009). The number of trips did not increase linearly with age: parents with young children had the highest number of trips while single households (below as well as above 60 years old) the lowest (Sun et al., 2009). Clark et al. (2016) found that individuals in the age group between 16 and 29 are more likely to switch to car commute than other groups are. Chatterjee et al. (2012) point out that the nature of behavioral influence on bicycling changes over the life course. Young adults were prompted to start bicycling with the beginning of their studies or employment, older adults started bicycling because of health benefits (Chatterjee et al., 2013b).

Recently, researchers have addressed the question of whether young persons behave differently in a more fundamental way. Several studies have reported changes in travel behavior for the millennial generation (for US: Circella et al., 2017; McDonald, 2015; Thigpen and Handy, 2018; for the UK: Chatterjee et al., 2018; for Australia: Delbosc and Currie, 2014a, b; Delbosc and Nakanishi 2017; Raimond and Milthorpe 2010; for Germany: Bohnet and Gertz 2010; Kuhnimhof et al., 2012; for France: Licaj et al., 2012; for Japan: Zhang et al., 2017). These studies have observed changes in travel behavior that include postponed acquisition of driver's license, lower car ownership, less car driving and more use of public transport. But no consensus has emerged yet as to whether the observed differences can be attributed to lasting factors such as changes in lifestyle, preferences, and values or by temporal differences such as a delay in life stages (i.e. longer time passed in education, later parenthood). For example, young couples today often decide to move in together or to build a family at later ages than previous generations, which also affects financial and mobility resources (Chatterjee et al., 2018). For the UK, Chatterjee et al. (2018) found that young persons (17–29 years old) tend to drive more when they move into their 30s but still drive less than previous cohorts. Other studies have found life stage (child-rearing, part/ full-time employment) to be an important factor explaining differences in licensing (Delbosc and Currie, 2013, 2014a, b). Comparing millennials to

persons of the previous generation (Generation X) in California, Circella et al. (2017) found that millennials tend to use multiple modes and drive less than the previous generation. Although car ownership was lower for millennials especially for those living in urban cores, older millennials indicated the desire to purchase a car in the future, thereby supporting the hypothesis of a temporary change in behavior. Though millennials may prefer urban centers for living, they may be obliged to locate in suburban areas at later life stages due to high housing prices and then switch to car use (Delbosc and Nakanishi, 2017).

Together, life stage affects ownership of mobility tools, transport mode choice particularly bicycling and the number of trips. Though some changes follow aging others show non-linear effects in relation to age and point to a separate effect of life stage that may not be well approximated by age only.

3.2.4 The moderating role of life stage on the effect of life events for travel behavior change

The relationships between life events, life stage and travel behavior are varied and complex. Some life events mark the transition from one life stage to another, indicating the beginning of a new life stage. For instance, a change in the number of household members may mark the starting of the life stage of parenthood or cohabitation with a partner. At the same time, life events may have different effects on travel behavior depending on the life stage. Research shows that travel needs and mode-related attitudes vary over the course of a person's life as they move through different life stages (Lanzendorf, 2010; Sharmeen et al., 2014), thereby suggesting that the influence of life events on travel may be moderated by life stage. For instance, preferences for residential locations, which affect travel behavior,may change: a British study highlighted that young parents are more likely to move to better neighborhoods than others (Rabe and Taylor, 2010).

Life stage may be linked to financial and organizational resources leading to differences in capacities to adapt. Cohabitation allows partners to pool resources and may increase car use (Scheiner and Holz-Rau, 2013). The wish to purchase property often overlays with the life stage of parenthood or advanced professional career (Thierstein et al., 2016), but constrained housing markets often drive parents to locate in more car-dependent suburban areas to meet their demand for property and living space (Delbosc and Nakanishi, 2017; Gehrke et al., 2019; Thierstein et al., 2016). In a Dutch study, young persons (aged 30 years or less) had a higher likelihood compared to older persons of giving up bicycle commute whereas no significant effects were found for persons older than 50 years (Oakil et al., 2016).

Over the life course, individuals may be less likely to change their travel behavior in the occurrence of life events because they are more likely to own a car and may be reluctant to abandon it. In fact, car ownership is less stable for young households (defined as head of household between 18 and 24 years old) than for older households (Dargay and Hanly, 2004). In the same study, reducing car ownership to zero is also more prevalent for young households or households over 65 years compared

to households in the middle age group (24 to 64 years old). In a Swiss study, retrospective data over a 20-year period showed that stability in the ownership of mobility tools increases with age (Beige and Axhausen, 2008). Increasing stability in mobility resources may explain why persons react differently to life events at distinct life stages. In contrast, Cheng et al. (2019) found for Chinese respondents that elderly persons are more affected by residential relocation than younger persons with respect to their travel frequency and duration. In addition, the frequency of life events may vary throughout the life course. Young persons may be used to adapting to new circumstances. In a Dutch study, young persons frequently changed their residence and workplace making a switch from bicycle to car commute more likely (Oakil et al., 2016).

In general, few studies have empirically investigated mode choice in this context.

3.2.5 Model conceptualization

Our study is embedded in the concept of mobility biographies as a framework for studying travel behavior change. Informed by the literature review, we identify two main research gaps.

Though several studies have established evidence that life events affect travel behavior change, it is unclear whether a person's life stage alters this effect. Studying the moderating effect of life stage may provide additional insights into the conditions under which travel behavior changes. These insights can inform transport policies that aim to incentivize more sustainable travel. Transport management programs, for example, that provide mobility-asa- service packages to recent movers may be more effective if targeted to persons who are more likely to change. Likewise, these packages themselves might be adapted to the preferences of different life stage groups. An analysis differentiated along life stages enables a more detailed exploration of behavioral differences observed for the millennial generation.

In addition, only a few studies have discussed multimodal travel behavior from a mobility biographies perspective. Multimodal travel more accurately describes actual travel patterns than does a simple analysis of mode split. For instance, about 25% of car users in the US make at least seven trips during a typical week by means of transport other than car according to the 2009 US National Household Travel Survey (Buehler and Hamre, 2016). Multimodal travel may also be relevant from a policy perspective. Studies have shown that strict car users are more likely to switch to multimodal than unimodal use (De Haas et al., 2018). Another study reported that young persons may be mode agnostic in choosing whatever mode is best suited best for the given circumstances (Delbosc and Nakanishi, 2017). Young persons may be more likely to travel with multiple modes.

Our conceptual model provides the basis for addressing these gaps and is inspired by Kroesen (2014) and De Haas et al. (2018). With this approach, we attempt to answer two research questions: First, to what extent do life course events effect change in multimodal travel behavior? Second, to what extent do life course events affect multimodal travel behavior differently at distinct life stages?

In the university travel survey that we use, travel behavior is measured as the number of days a person traveled to campus with a specific mode out of five possible weekdays. We define modality

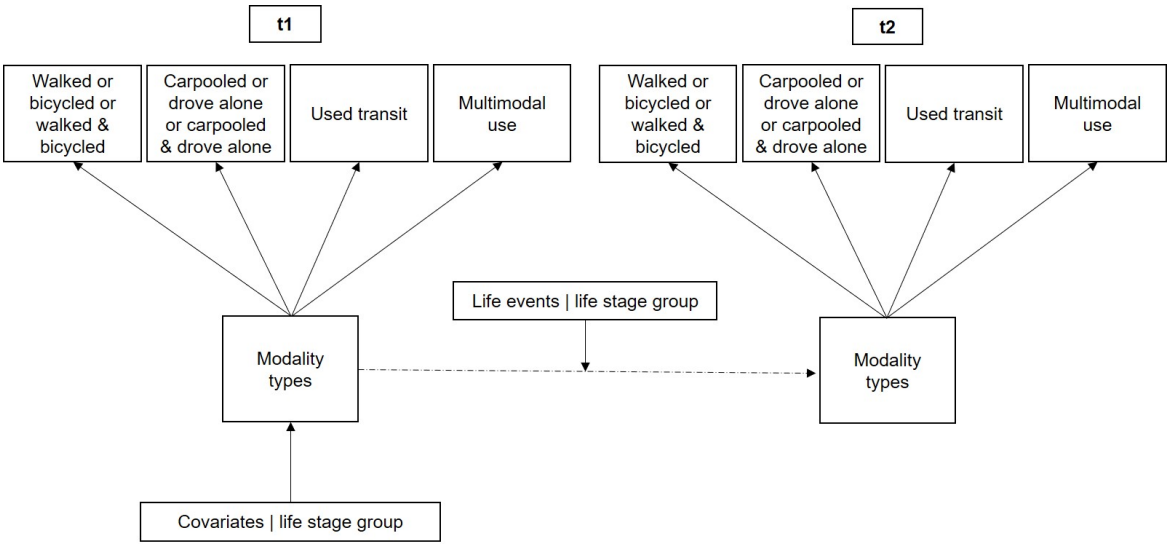

Fig. 3.1 Conceptual model [based on De Haas et al. (2018) and Kroesen (2014)]

types based on multimodal travel behavior as highlighted in Figure 3.1. The dataset captures modality types at two points in time for each person. The model has two parts: one part determines the influence of covariates on modality type membership, the other the transition probability of switching to another modality type between time points. Socio-demographic factors and travel-related attitudes affect the modality type at the first point in time while life events and the previous modality type influence the probability of transitioning to another modality type. We use covariates in the membership model and life events in the transition model that depend on life stage groups to investigate the interaction between life stage groups and multimodal travel patterns as well as transition probabilities.

3.3 Methods and data

3.3.1 Study area

The setting for this study, which focuses on commuters to the UC Davis campus, offers a good opportunity to study multimodality. Most persons in our sample of commuters (79 percent) live in Davis, a small college town with 66,000 inhabitants. Davis is relatively densely populated for a US town of this size and has limited industrial land uses. A university-run bus system connects all residential neighborhoods in Davis to the campus, providing a good alternative to driving or bicycling. Davis has an extensive on-street and off-street bicycle network that far exceeds the bicycle infrastructure found in the typical US city (Buehler and Handy, 2008). Due to the high number of bicycle commuters (compared to the US average), this sample may provide a good opportunity to understand the circumstances under which active travelers switch to strict car use and vice versa. A smaller share of the sample lives outside of Davis. Accessibility to transit for persons living outside of

Davis varies depending on their residential location, and use of non-motorized modes is not feasible for most commuters given the long distances to campus.

3.3.2 Sample description

UC Davis has conducted an annual campus travel survey (CTS) since the 2006–07 school year (e.g. Wei, 2018). Each fall, a UC Davis graduate student administers the CTS to a stratified random sample of students, staff, and faculty. The survey typically achieves a response rate of 10 to 21 percent of the invited sample. The survey asks respondents about commute travel, travel attitudes, and socio-demographic characteristics. In this study, we analyze longitudinal panel data from the most recent eight CTSs (2010–2017) (see Thigpen, 2019 for more information about this panel). In the overall panel sample (3471 persons), 75% of the persons answered the survey twice and 25% three times or more. We chose to construct a two-wave dataset with two points of observation in time per person. For those who answered more than twice, we preferentially selected the pair with the least amount of difference (e.g. 1 year between paired observations) and the most recent pair. Sixty-eight percent of the persons answered 1 year after their first survey, 20% in a 2-year interval and 12% in more than 2-year interval. To account for heterogeneity in the reporting period, we include a time variable as described below.

Since our sample is drawn from a university population, it differs from the average US population in terms of age, educational attainment, and the homogeneous trip destination. Respondents in our sample may have a higher variety of transport modes at their disposal than residents of other small-sized US towns, as the UC Davis campus is easily accessible by bus, bicycle, walking, and driving, though car parking is relatively costly. On the other hand, the variety of transport modes allows the study of multimodal travel more fully than is possible in other US cities of this size. In particular, the remarkable bicycle infrastructure and high level of bicycle commuting in Davis allows us to study switching from and to bicycle commuting.

With respect to our research question, differences between life stages may be less pronounced in a university population since students, staff, and faculty have relatively flexible work schedules and may be less time-constrained compared to non-university workers of the same age group. On the other hand, this study may be more likely to capture the causal effects of life events on change in travel behavior because of the relatively universal public transport and bicycling infrastructure within Davis. Although the university sample may diverge in the beforementioned aspects from the general population, it also provides advantages for the purposes of this study.

3.3.3 Definition of modality types

We classify respondents into modality types to account for a set of travel modes that share similarities or complement each other (Kroesen, 2014). It is assumed that modality styles reflect latent modal preferences that are based on travel-related attitudes, lifestyle choices, and/or emotional constraints

(Vij et al., 2013). In the survey, participants were asked to indicate their primary mode of travel to campus on each day of the preceding week. Participants could choose from among five transport modes for each weekday: walking, biking, driving alone in a car, carpooling, and using transit. We defined four modality types based on the responses to this question. The first modality type encompasses active travelers who either only bicycle or only walk or bicycle and walk to campus over the week (at most 5 days). The second modality type includes car users: persons who only drive alone to campus, persons who only carpool, or persons who only do both. Persons who only use transit to travel to UC Davis are placed in the third modality type, transit users. The fourth type comprises multimodal users who are not in one of the previous types. They mostly bicycle to campus (on average two out of 5 days), also use transit (on average 1.3 days), drive alone in a car (about 1 day on average), but walk and carpool less often to campus. It is important to note that in this study, multimodal travel behavior relates to the different primary modes chosen over a week for traveling to campus and not different modes used on one trip.

3.3.4 Definition of life course events

Five life events are included in the analysis: residential relocation, changes in household size, changes in the role at UC Davis, and changes in the option to drive alone and to carpool. Residential relocation, the first type of life event, includes changes in residence within Davis and relocation from another town to Davis or vice versa. Residential moves are typically included in mobility biography analyses since spatial activity patterns may change and individuals must deliberate their mode choice in planning their travel (Chatterjee et al., 2013b; Holz-Rau and Scheiner, 2015). Changes in the number of persons living in the household are also considered life events. Several studies have found evidence that changes in travel behavior are significantly related to the moving out of children, cohabitation with partners, or moving out of partners (Müggenburg et al., 2015). Life events may mark a transition from one life stage to another as an increase in household members may indicate the beginning of parenthood. Since we cannot distinguish between childbirth or the moving in or out of a partner, child or another family member, we use the more general life event (i.e. change in household size). Changes in the role at UC Davis are considered to be a life event because they may be associated with changes in income, professional responsibility or advances in professional career, which have been found to be influential for travel behavior change (Dargay, 2001; Oakil et al., 2014). Changes in role at UC Davis include any changes between the following groups: undergraduate student, graduate student, faculty, staff, visiting scholar, post doc, recent graduate, and retiree. Changes in the availability of a car to ride as a passenger or to drive alone in a car alter the mobility resources available for travel and are defined as the fifth type of life event. In the mobility biography literature, car ownership is considered to be part of the mobility domain (based on Lanzendorf's (2003) concept). Several studies have analyzed the effect of life events on car ownership (Oakil et al., 2014; Zhang, 2017) whereas we consider changes in the possibility of driving in a car alone or carpooling as a life event. Endogeneity problems may arise since choosing the car-orientated modality type depends on having the option to

carpool or to drive alone, while the latter might also be the outcome of a desire for the former. Still, we include the acquisition of the ability to drive or carpool as a life event because we are interested in how changes in these mobility tools affect the probability of choosing other modality types (active modes, transit, or multimodal travel.

Other life events are also of interest (e.g. children moving out) but could not be included in this analysis because the information was not collected, was not precise enough, or did not make sense in the context of this sample (e.g. employment changes). We consider the direction of change for all life events (except role at UC Davis) since the literature has shown that direction of change matters [e.g. for car ownership (Dargay, 2001), for household size (Oakil et al., 2014)].

3.3.5 Definition of life stages and hypotheses

We define four life stage groups: millennials (currently aged 18–36) living alone or with roommates, millennials living with their partners, parents (of any generation) living with their children, and non-millennial adults (above 36 years old) living without their children. Our analysis is driven by several hypotheses about the effect of life stage groups.

The first two life stage groups include millennials at different life stages to contribute to the discussion on whether millennials behave differently due to delayed life stages. Several studies have reported changes in travel behavior for the millennial generation (as noted in the Literature Review). We distinguish millennials who live alone, in dorms, or in shared apartments (first life stage group) from millennials living with their partners (second life stage group). The first life stage group includes mostly undergraduate and graduate students who may have greater flexibility in their schedules and fewer professional responsibilities that affect their daily travel. Some researchers have found that young persons were somewhat "mode agnostic" individuals who chose the mode best suited in the given circumstances (Delbosc and Nakanishi, 2017) and more likely to change their travel behavior than older individuals (Kroesen, 2014). Our hypothesis related to the first life stage group is as follows:

Millennials living alone or with roommates use more modes in their commutes and are more likely to change their mode in the presence of life events because they are less constrained by the travel needs of others or by professional responsibilities.

The second life stage group comprises millennials who live with their partners. On one hand, members of this group might have more constraints on residential location, which must meet the needs of two people, and on travel, which must be coordinated with the partner, than millennials living on their own (Oostendorp, 2014). On the other, they are likely to share mobility resources and trips with their partners (Scheiner and Holz-Rau, 2013). This categorization may allow us to investigate whether cohabitation makes a difference how millennials react to life events. Our hypotheses related to the second life stage group is as follows:

Millennials who live with their partners are more likely to use a car, particularly to carpool, because they may share mobility resources. They may use different modes including the car over the

week. They are more responsive to life events than millennials living alone or with roommates or parents living with their children because they are generally less constrained and have greater financial and mobility resources.

The third group is distinguished from other life stages by parenthood. Previous studies have shown that parenthood is an important life stage in an individual's life course that affects travel behavior (e.g. De Haas et al., 2018; Lanzendorf, 2010). Parents may be more car-dependent than other life stage groups since they may transport their children to various activities (Lanzendorf, 2010). They face major time and financial constraints that may alter their travel behavior compared to persons of the same age group without children. Our hypotheses related to the third life stage group include:

Parents living with their children are less likely to change their travel behavior following a life event because their travel also depends on the travel needs of other household members.

Finally, the fourth life stage group encompasses non-millennial adults living without children. Persons in this group are older than 36 years and probably more advanced in their professional careers with higher incomes. They have more financial resources to acquire new mobility tools but may be less flexible switching commute modes during the week due to their professional and private responsibilities. Over the life course, persons tend to stay loyal to car driving and are less likely to give away their car (Beige and Axhausen 2008; Dargay, 2001; Fatmi and Habib, 2016). This group also includes some emeriti faculty who tend to be less constrained by their working situation. Hypotheses related to the fourth life stage group are:

Non-millennial adults are less time-constrained and have greater financial resources, for instance to invest in a new car or bicycle, and are more likely to switch modes in the presence of life events.

Persons in other life stages such as retired persons or parents with children at different ages would have been interesting to explore but we are not able to distinguish them in the present dataset. But the life stages defined in this study allow us to investigate whether young persons differ significantly from parents and older adults in their responses to life events. This analysis may contribute to recent discussions about decline or stagnation in car ownership and use. In addition, we compare two millennial groups at different life stages, the results of which may add to discussions about generational differences or delay in life stage.

3.3.6 Other covariates

Previous studies have highlighted factors that are associated with mode choice: sociodemographic characteristics, availability of mobility tools, built environment indicators, attitudinal and trip related factors (e.g. Clark et al., 2016; De Haas et al., 2018). Since the survey did not consistently assess income, we include educational attainment as an indicator for socioeconomic status. Other socio-demographic characteristics are age, gender, household size, and perceived availability of the options to drive and to carpool. The availability of a car may provide a better indicator compared to the number of cars in a household because it reflects the allocation of cars within the household (Scheiner and Holz- Rau, 2013). Numerous studies include mobility tools in transport mode choice models though

some discuss potential endogeneity with respect to related mode choices (Dargay and Hanly, 2004). We decided to include options to drive alone and to carpool because we are interested in the effect of these mobility tools on modality types other than the carorientated modality type. Since travel-related attitudes have been shown in prior studies to significantly explain mode choice (Bamberg, 2006; Busch-Geertsema and Lanzendorf, 2017; Gärling et al., 1998; Molin et al., 2014), we include attitudinal indicators as well. Participants responded to attitudinal statements related to the value of travel time, liking of biking, liking of driving, and the need for a car on a five-point Likert scale, from "strongly disagree" (1) to "Strongly agree" (5).

All commute trips have the same destination, the university campus, with a few exceptions of off-site locations. We include two self-reported transit accessibility variables: access to bus and access to train. While 75% of the sample population has access to bus only, seven percent have access to train services near their residence (cf. Tables 3.1 and 3.2). We did not include any other built environment variables since Davis is relatively homogeneous with respect to its population density and bicycle infrastructure. All residential areas are well served by the university-run public transit system. We account for the different built environment that persons who live outside of Davis experience by including a residential location variable. Also, distance from residence to campus is not included since Davis is a small town with approximately a three-mile radius from the center to the city limits. The homogeneous built environment may increase the likelihood that we captured the causal effects of life events, because changes in travel behavior may be less likely to be linked to changes in unobserved variables, such as mobility culture or accessibility. The residential location variable (living in Davis, living outside of Davis) captures differences in the environment between Davis and other cities, at least in a coarse way.

Table 3.1 Descriptive statistics (N = 3471 pairs of observation)

		Active travel	Car	Transit	Multimodals	Mean(SD)/percentage
Sample Size of modality type	Percentage	41	22	13	23	
Travel indicators (1–5 days)						
Number of days walked to campus	Mean (SD)	0.58	0.00	0.00	0.19	0.31 (1.05)
Number of days bicycled to campus	Mean (SD)	4.16	0.00	0.00	1.99	2.39 (2.21)
Number of days driven alone with car to campus	Mean (SD)	0.00	3.59	0.00	0.87	0.90 (1.69)
Number of days carpooled to campus	Mean (SD)	0.00	0.75	0.00	0.44	0.25 (0.85)
Number of days used transit to travel to campus	Mean (SD)	0.00	0.00	4.66	1.26	0.82 (1.63)
Socio-demographic characteristics						
Age	Mean (SD)	25	37	23	27	28 (13)
Household size	Mean (SD)	1.12	1.60	1.27	1.67	1.40 (1.54)
Educational attainment	Below Bachelor degree	0.47	0.15	0.14	0.24	36%
	Higher than Bachelor degree	0.36	0.36	0.04	0.23	64%
Gender	Male	0.53	0.19	0.08	0.20	30%
	Female	0.43	0.20	0.13	0.24	70%
Residential location	Outside of Davis	0.04	0.69	0.09	0.18	20%
	In Davis	0.57	0.08	0.12	0.23	80%
Option to drive alone	Yes	0.36	0.29	0.08	0.26	61%
	No	0.62	0.04	0.16	0.18	39%
Option to carpool	Yes	0.36	0.29	0.12	0.23	33%
	No	0.52	0.18	0.12	0.18	67%
Access to bus	Yes	0.48	0.14	0.15	0.23	75%
	No	0.43	0.44	0.03	0.10	25%
Access to train	Yes	0.24	0.42	0.17	0.17	7%
	No	0.49	0.20	0.11	0.20	93%
Life stage	Millennials living alone or with roommates	0.55	0.07	0.14	0.23	66%
	Millennials living with partners	0.31	0.37	0.09	0.23	13%
	Parents living with their children (< 18 years)	0.25	0.41	0.04	0.29	5%

Table 3.2 Descriptive statistics (N = 3471 pairs of observation) (continued)

		Active travel	Car	Transit	Multimodals	Mean(SD)/percentage
	Adults (> 36 years old)	0.29	0.47	0.04	0.19	16%
Attitudes (5-point Likert scale)						
"Travel time is generally wasted time"	Mean (SD)	2.88	3.31	3.18	3.06	3.04 (1.13)
"I like riding a bike"	Mean (SD)	4.34	3.61	3.41	4.09	4.04 (1.06)
"I like driving"	Mean (SD)	3.33	3.54	3.25	3.46	3.39 (1.18)
"I need a car to do many of the things I like to do"	Mean (SD)	2.88	4.23	3.13	3.42	3.30 (1.30)
Life events						
Change in household size	Increase	0.26	0.52	0.06	0.16	26%
	No change	0.31	0.43	0.05	0.21	42%
	Decrease	0.27	0.24	0.10	0.38	32%
Residential relocation	No change	0.38	0.26	0.13	0.23	38%
	Relocation within Davis	0.51	0.18	0.11	0.21	57%
	Relocation to another town	0.53	0.18	0.07	0.22	3%
	Relocation to Davis	0.05	0.63	0.14	0.19	1%
Change in the option to drive alone	Increase	0.65	0.05	0.12	0.18	21%
	No change	0.40	0.25	0.11	0.24	71%
	Decrease	0.56	0.06	0.10	0.28	8%
Change in the option to carpool	Increase	0.51	0.19	0.11	0.19	27%
	No change	0.46	0.23	0.11	0.20	63%
	Decrease	0.40	0.19	0.16	0.24	10%
Change in role at UCD	Change	0.53	0.08	0.16	0.23	53%
	No change	0.39	0.32	0.06	0.22	47%

3.3.7 Statistical analysis

We implement a Manifest Markov Model (see Vermunt and Magidson, 2017) in the statistical software program Latent Gold 5.0. A Manifest Markov Model enables the estimation of the probability of belonging to a modality type, the transition probability of switching modality types over time, and the response probability measuring the influence of the latent variable on survey indicators (i.e. number of days traveled with a specific mode). This type of model is well suited for answering our research questions because it assesses membership and transition probabilities in one model. We are particularly interested in the effect of changes in different life domains on changes in travel behavior. Another modeling approach, for instance a multinomial logit model, would require 12 categories of switching between modality types and 4 categories of loyal ones. Manifest Markov Models allow us to directly estimate transition probabilities of switching modality types considering life events and life stage at the same time, an advantage over multinomial logit models. The *Manifest* Markov Model also differs from a *Latent* Markov Model[1] (also known as a latent transition analysis), with which readers may be more familiar. In contrast to a Latent Markov Model, by using a Manifest Markov Model we assume that observed categorical responses (on transport mode choice) are deterministic measures of the true "latent" states (modality types). By using deterministic modality types, we assume that the response probability $P(y_t^d|x_t^d)$ is one for the modality type an individual is classified in and zero for other modality types. The probability of being in a modality type is modelled as a standard logistic regression while the transition model is estimated via a transition logit model (Vermunt and Magidson, 2016)[2]. This Manifest Markov Model is extended so that the membership and transition probabilities include covariates, life stage groups and life events.

[1]The Latent Markov Model calculates the probability that an individual chooses a response from a categorical variable (observed/survey data) based on three probabilities: the initial probability of choosing a modality type at time point 1 (membership probability), the transition probabilities, and the response probability for an individual i at time t. Latent Markov Model: (cf. Vermunt and Magidson, 2016, pp. 92–93):

$$P(y_i) = \sum_{x_0^d=1}^{K_d} \sum_{x_1^d=1}^{K_d} \dots \sum_{x_T^d=1}^{K_d} P(x_0^d) \prod_{t=1}^{T^i} P(x_t^d|x_{t-1}^d) \prod_{t=0}^{T^i} P(y_{it}|x_{t1}^d)$$

The probability of choosing response y for individual i is defined by the probability to choose a latent state (in our case a modality type) at time point 0 $P(x_0^d)$, by the transition probability $P(x_t^d|x_{t-1}^d)$ and the response probability $P(y_t^d|x_t^d)$. A Latent Markov Model assumes that state membership at point t only depends on state membership of the previous period $t-1$ (first order Markov assumption) (Vermunt and Magidson, 2016). The response at point t depends only on the current modality type membership not on previous ones.

[2]Transition Logit Model:

$$\frac{P(x_t^d=s|x_{t-1}^d=r,x,z_{it})}{P(x_t^d=r|x_{t-1}^d=r,x,z_{it})} = \gamma_{xrsp} * z_{itp}$$

The transition logit model calculates the ratio of the probability of switching from one modality type to another and the probability of not switching at all. The transition logit model compares the probabilities of switching to the probability of staying in the same latent state (modality type) with r standing for the original and s for the destination state (modality type) and r unequal s since parameters for no transition are fixed to zero for identification (cf. Vermunt and Magidson, 2016, pp. 92–93).

In specifying the model, we first estimate the influence of covariates (socio-demographic characteristics, travel-related attitudes) on our deterministic modality types. All covariates in the membership equation interact with life stage. Second, the transition probability depends on life events that interact with life stage and the previous modality type. It also includes a time interval variable interacting with the previous modality type (but not with life stage). The time interval variable measures the distance between the reported periods, to account for the fact that 32% of the persons answered their second survey at a later point than 1 year after the first; this is a recommended approach for accounting for heterogeneity in response intervals (cf. Markov Model with time-heterogeneous effects, Vermunt and Magidson, 2015).

Our first research question asks whether life events lead to changes in modality types. Our second research question asks whether life stage moderates the impact of life events on change in modality types. We estimate two models. In the first model, life events interact with life stage and previous modality type in the transition probability model. In the second model, life events only interact with the previous modality type and not with life stage in the transition probability model. We compare both models based on the likelihood ratio test and the p value. However, model comparison based on the likelihood ratio Chi squared statistic and p values do not hold in the case of sparse data (Vermunt and Magidson, 2015, p. 107). Our model includes 732 parameters with the conditional effect of life stage and 336 without the conditional effect of life stage. Although our panel is a considerable size with 6942 points of observations, we may still have sparsity problems due to the three-way interaction of life events, life stage and previous modality types. We use the Bayesian Information Criterium (BIC) as suggested by Vermunt and Magidson (2015, p. 107) in the case of sparse data. Kroesen (2014) also used the BIC due to data sparsity to compare different models in a latent class transition analysis. The model without the interaction effect of life stages in the transition probability provided a lower, better BIC (-12963) than the model with conditional life stage effect (-10217). In addition, almost all interaction effects between life events and life stages in the transition probability were insignificant. Based on these two factors, we chose the model without conditional life stage effect because it performs better in terms of parsimony and expected out-of-sample predictive ability. This may not be a definitive assessment of a potential moderating effect of life stage, however. In the following section, we provide results for the model that includes only life events to explain transitioning from one modality type to another.

Tables 3.1 and 3.2 show descriptive statistics for the variables included in the membership and transition models for the first wave.

3.4 Results

Our findings support the results of other studies that observe a relationship between the occurrence of life events and changes in travel behavior. In this section, we first characterize the modality types and describe the incidence of life events in relation to life stage. Second, we present results from the

membership model that highlight modality type profiles for different life stages. Finally, we explore the effect of life events on modality types.

3.4.1 Descriptive statistics

Modality types

Socio-economic characteristics and attitudes differ in significant and largely predictably ways between the four modality types (active travelers, car users, transit users, and multimodal travelers) (Tables 3.1 and 3.2). Active travelers mostly bicycled to campus and walked only to a small extent. Likewise, car users mostly drove alone by car and only carpooled to a small extent. Multimodal travelers mostly bicycled (on average 2 days) and used transit to travel to campus but also drove alone by car to the university to a small extent.

Modality types and life stage

The share of active travelers decreases over the life stages but is the smallest for parents who live with their children (Figure 3.2). Half of the millennials who lived alone, in a dorm, or in a shared apartment are active travelers. The share of persons who carpooled or drove alone to campus increases sharply when millennials start living with their partners and further increases throughout the life stages. The share of persons in the multimodal modality type is approximately equal across life stage groups; the use of different modes does not seem to depend on life stage. Non-millennial adults living without their children have the highest share of car users. Transit use decreases for older life stage groups. As highlighted in Figure 3.3, the incidence of life events differed between life stage groups. Millennials who lived alone, in a dorm, or in a shared apartment were more likely to change their residence than other groups. More specifically, millennials living with their partners or parents living with children relocated more often than other life stage groups to another town. Only a small fraction in each group relocated to Davis from outside the city. Parents who lived with children were the most likely to change household size, which may relate to the birth of children, marriage, separation, or divorce, or children moving out of the house. Parents living with children and non-millennial adults had more consistent access to driving alone compared to their younger counterparts. Millennials living alone or in a shared apartment switched their position or role at UC Davis more often.

3.4.2 Results from the membership model: differences in modality type profiles between life stages

This section shows the results from the membership model for modality types. The results of the membership model suggest that socio-demographic and attitudinal characteristics determine modality type and have a different impact depending on the life stage. In the model, we specified all constants and covariates for the modality type membership model to be conditional on the life stage. Almost all

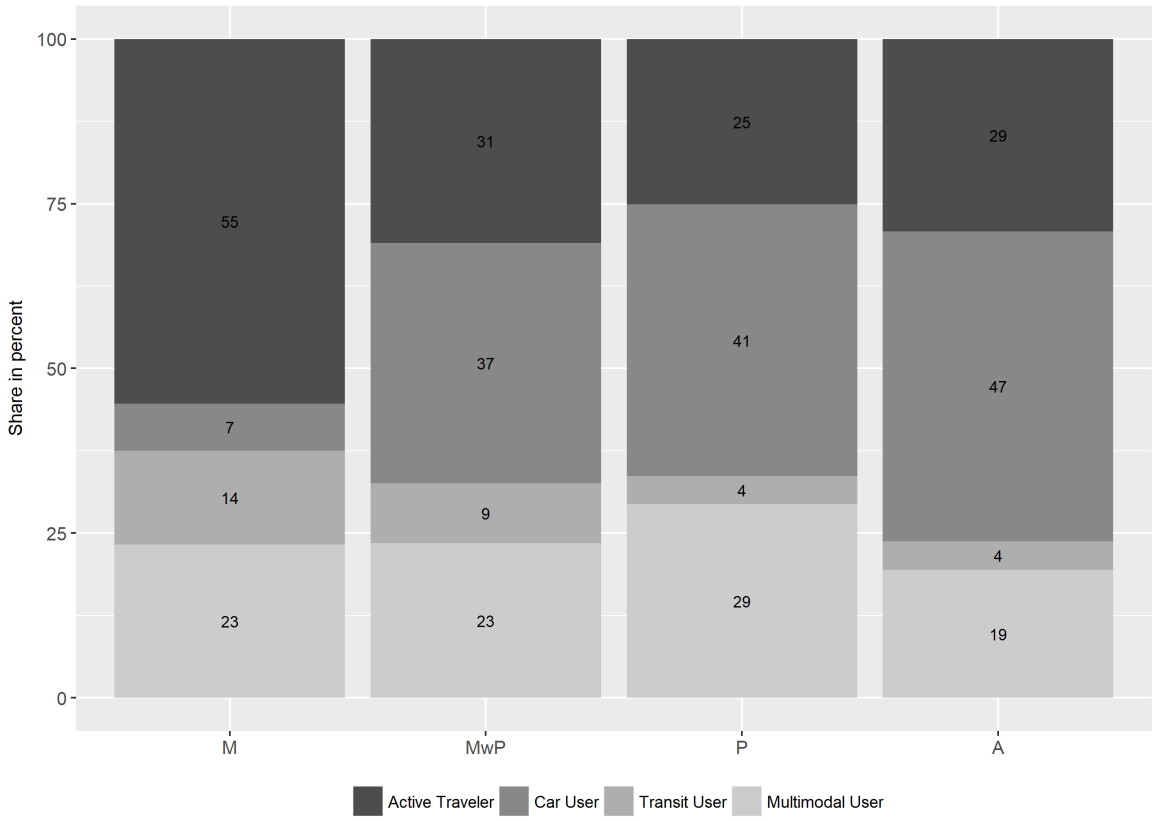

Fig. 3.2 Distribution of modality types across life stage groups. Life stages: M "millennials living alone or shared apartments", MwP "millennials living with their partners", P "parents living with their children"; and A "adults older than 36 years living without their children"

interaction effects between covariates and life stage are significant. Tables 3.3, 3.4 and 3.5 show the results of the membership model, i.e. the estimated probabilities to be in a specific modality type, summarizing the shares and mean values for each covariate-life stage interaction with the corresponding p values in parentheses. Tables 3.7. 3.8 and 3.9 show the parameter estimates for the membership model and indicate whether a response pattern (an interaction between a covariate and life stage) differs significantly between modality types. In this section, we discuss the results of the membership model based on Tables 3.3, 3.4 and 3.5.

Gender differences

Gender differences are the greatest for active travelers in comparison to other modes. More men travel with active modes than women. Gender differences seem to be linked to life stage: the share of female active travelers decreases over the life stages. Women and men are almost equally represented in the active traveler group when they are still millennials who live alone, in a dorm, or in shared apartment. For parents who live with their children or non-millennials, the share of male active travelers is twice

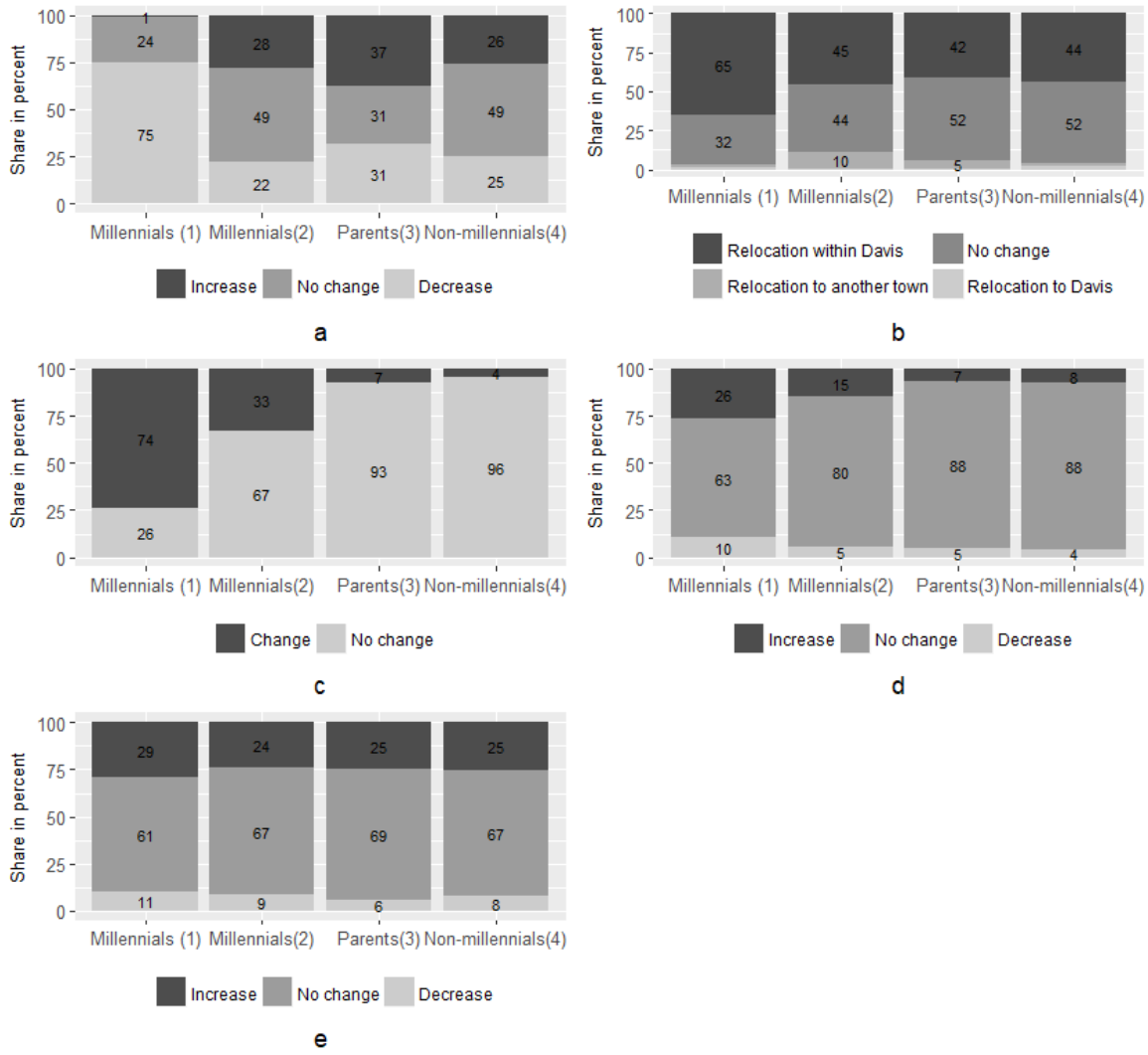

Fig. 3.3 Percentage of persons who experienced a life event out of the total sample per life stage group. Life events: a changes in household size, b changes in residential location, c changes in role at UCD, d changes in the option to drive alone, e changes in the option to carpool, life stages: millennials (1) = “millennials living alone or shared apartments”, millennials (2) = “millennials living with their partners”, parents (3) =“parents living with their children”; and non-millennials (4) = “adults older than 36 years living without their children”

as high as the share of women. Also, women are more likely than men to drive or carpool when they live with their children. In general, gender-differences stand out for parents and non-millennials across all modality types. These results suggest that gender disparities increase over the life cycle but may also indicate that millennials may behave differently than older generations in fundamental ways.

Table 3.3 Modality type profiles and differences between life stages based on the membership model

		Active Travelers	Car users	Transit users	Multimodal travelers
Class size		1432	770	461	808
Indicator variables (mean)					
# of days walked		0.6	0.0	0.0	0.2
# of days bicyclied		4.2	0.0	0.0	2.0
# of days driven alone		0.0	3.6	0.0	0.9
# of days carpooled		0.0	0.8	0.0	0.4
# of days used transit		0.0	0.0	4.7	1.3
Life stage group (p=0.00)					
	M	55%	7%	14%	23%
	MwP	31%	37%	9%	23%
	P	25%	41%	4%	29%
	A	29%	47%	4%	19%
Age (p=0.00)	M	21	24	21	21
	MwP	26	26	25	26
	P	46	42	42	42
	A	53	50	52	51
Gender (p=0.00)					
Male	M	65%	5%	10%	20%
Female	M	52%	8%	16%	24%
Male	MwP	37%	35%	8%	19%
Female	MwP	27%	38%	9%	26%
Male	P	33%	29%	7%	31%
Female	P	17%	53%	2%	28%
Male	A	43%	36%	6%	15%
Female	A	18%	55%	3%	23%
Household size (p<0.03)	M	3.5	3.5	3.8	3.3
	MwP	1.9	2.0	1.9	2.1
	P	2.7	2.2	2.8	2.9
	A	1.7	1.7	1.5	1.7
Residential location (p<0.00)					
Residence in Davis	M	58%	5%	14%	23%
Residence outside of Davis	M	4%	70%	1%	24%
Residence in Davis	MwP	55%	11%	5%	28%
Residence outside of Davis	MwP	4%	66%	14%	16%
Residence in Davis	P	43%	21%	1%	35%
Residence outside of Davis	P	4%	67%	8%	21%
Residence in Davis	A	50%	25%	1%	24%
Residence outside of Davis	A	3%	72%	8%	17%

Table 3.4 Modality type profiles and differences between life stages based on the membership model (continued)

		Active Travelers	Car users	Transit users	Multimodal travelers
Option to drive alone (p<0.00)					
0	M	64%	1%	17%	18%
1	M	46%	14%	11%	29%
0	MwP	52%	13%	16%	19%
1	MwP	26%	42%	8%	24%
0	P	40%	30%	5%	25%
1	P	23%	42%	4%	30%
0	A	42%	40%	8%	10%
1	A	28%	48%	4%	20%
Option to carpool (p<0.00)					
0	M	61%	6%	14%	19%
1	M	45%	13%	15%	27%
0	MwP	33%	39%	9%	19%
1	MwP	29%	45%	9%	17%
0	P	29%	46%	6%	19%
1	P	14%	64%	0%	23%
0	A	37%	43%	4%	16%
1	A	15%	68%	5%	11%
Access to bus (p<0.00)					
0	M	72%	19%	1%	8%
1	M	52%	6%	17%	25%
0	MwP	19%	65%	7%	9%
1	MwP	39%	27%	11%	24%
0	P	19%	67%	3%	11%
1	P	29%	36%	6%	29%
0	A	18%	67%	3%	12%
1	A	37%	42%	5%	16%
Access to train (p<0.00)					
0	M	19%	67%	3%	11%
1	M	29%	36%	6%	29%
0	MwP	18%	67%	3%	12%
1	MwP	37%	42%	5%	16%
0	P	55%	8%	15%	22%
1	P	62%	13%	1%	23%
0	A	37%	39%	5%	19%
1	A	5%	52%	30%	14%

Table 3.5 Modality type profiles and differences between life stages based on the membership model (continued)

		Active Travelers	Car users	Transit users	Multimodal travelers
Disutility of travel time (p=0.00)	M	2.9	3.4	3.3	3.1
	MwP	2.7	3.6	3.0	3.1
	P	3.1	3.4	2.1	2.8
	A	2.8	3.1	2.3	3.0
Liking of bicycling (p=0.00)	M	4.3	3.3	3.3	4.1
	MwP	4.3	3.6	4.0	4.0
	P	4.4	3.9	4.4	4.1
	A	4.7	3.7	3.8	4.3
Liking of car driving (p=0.00)	M	3.4	3.7	3.4	3.6
	MwP	2.9	3.4	3.1	3.3
	P	3.0	3.6	2.6	3.6
	A	2.9	3.5	2.4	3.1
Perceived need of a car (p=0.00)	M	2.8	4.3	3.1	3.3
	MwP	3.0	4.3	3.1	3.6
	P	3.5	4.3	2.9	3.8
	A	2.8	4.1	3.1	3.7

Residential location

The share of persons who only use a car to travel to campus is considerably higher for those living outside of Davis across all life stage groups.[3] This difference is slightly more pronounced for millennials living alone, in dorms, or in shared apartments and for non-millennials. Millennials who live outside of Davis and with their partners have a higher share of transit use than other life stage groups. Millennials who live alone or in shared apartments and outside of Davis have the highest share of multimodal users compared to other life stage groups. Persons of the first life stage group who live outside of Davis like biking and driving slightly less than persons of other life stage groups who live outside of Davis.

Attitudinal statements

Across all life stage groups, car users agree more strongly with the statement "Travel time is generally wasted time." Parents and non-millennials who use transit to travel to campus have the lowest agreement with this statement. Active and multimodal travelers appreciate bicycling the most, with non-millennials scoring highest. Millennials who live without children or a partner and use transit

[3] A small percentage of persons walked or bicycled to campus although they live outside of Davis. These persons provided a different usual mode to travel to campus indicating that in the reporting week they may have stayed in Davis and hence could walk or bicycle to UC Davis.

agree more with the statement “I like driving” while non-millennials are rather neutral. Car users reported the highest agreement with the statement “I need a car to do many of the things I like to do.” Members of the second, third, and fourth life stage groups who are multimodal tend to have a higher agreement, too. Parents in general have a higher agreement with this statement except when they use transit.

3.4.3 Loyalty to modality types and the influence of life events

Transition probabilities in Table 3.6 describe the probability of switching from one modality type to another from one year to the next. The reference level is individuals who do not experience any life event. For instance, it is less likely for active travelers to switch to multimodal use if the household size decreases or increases compared to active travelers who do not experience any change in household size. A decrease in household size makes a switch from strict car use to active travel less likely.

Almost all constants are significant and negative, indicating that travel behavior tends to be stable (Table 3.6). In particular, persons who only drive alone or carpool to campus (car users) tend to stick with their modality type with a probability of 83% (Table 3.6). This suggests that driving may be a stronger habitual behavior than other travel patterns. Multimodal travelers are rather unstable and have the highest probability of switching to active travel but also to car use compared to other modality types. Residential relocation within Davis positively affects the probability of transitioning between modality types: from active travel to transit or multimodal travel, from car to multimodal travel and from transit to active travel. Relocating to another town makes a switch from active travel to car and transit travel more likely because the distance to the campus in most cases becomes too long for active modes. Likewise, switching from car use to multimodal travel and vice versa becomes more likely if persons relocate to another town. Relocating to Davis significantly reduces the probability of switching from multimodal to strict car use but increases the likelihood of switching from transit to active travel.

Persons who no longer have the option to drive alone in a car are also less likely to switch from active travel to strict car use whereas a switch from car or multimodal use to all other modes is more likely. An increase in the option to drive alone makes transitioning from active travel and transit to car use more likely. If carpool becomes unavailable, persons are more likely to switch from strict car use to active travel or from multimodal to transit. Persons who gain access to carpool are more likely to switch from transit to active travel. Transit users seem to be less affected by life events in general than other modality types.

Heterogeneity in the time interval in which respondents answered the survey affects the probability of transitioning to another mode. Table 3.6 shows the probabilities of switching to another modality type with a time interval of two, three and more than 3 years relative to a 1-year time interval. The probability of switching to strict car use significantly increases over time (with duration between two survey responses). With few exceptions, this significant increase appears only for strict car users. Loyalty to a modality type, other than strict car use, decreases over time.

Table 3.6 Comparing transition probabilities between modality types and from wave 1 (rows) to wave 2 (columns) in the presence of life events.

General transition probabilities

	1	2	3	4
1	0.59	0.06	0.12	0.23
2	0.06	0.83	0.03	0.08
3	0.15	0.08	0.52	0.25
4	0.28	0.22	0.13	0.37

Decrease in household size

	1	2	3	4
1	0.67	0.13	0.06	0.14
2	0.06	0.74	0.11	0.10
3	0.15	0.21	0.37	0.27
4	0.24	0.39	0.10	0.27

No change in household size

	1	2	3	4
1	0.59	0.08	0.06	0.27
2	0.10	0.79	0.03	0.08
3	0.04	0.25	0.51	0.19
4	0.24	0.38	0.06	0.33

Increase in household size

	1	2	3	4
1	0.68	0.12	0.07	0.14
2	0.04	0.80	0.04	0.12
3	0.15	0.08	0.54	0.23
4	0.26	0.28	0.08	0.38

No change in residence

	1	2	3	4
1	0.77	0.05	0.03	0.15
2	0.05	0.83	0.07	0.06
3	0.10	0.09	0.54	0.27
4	0.27	0.32	0.09	0.32

Relocating within Davis

	1	2	3	4
1	0.60	0.06	0.10	0.24
2	0.07	0.77	0.04	0.12
3	0.16	0.14	0.46	0.23
4	0.29	0.29	0.12	0.30

Relocating to another city

	1	2	3	4
1	0.05	0.71	0.17	0.07
2	0.01	0.72	0.11	0.17
3	0.00	0.98	0.02	0.00
4	0.03	0.73	0.07	0.18

Relocating to Davis

	1	2	3	4
1	0.85	0.00	0.01	0.14
2	0.39	0.30	0.09	0.22
3	0.34	0.00	0.37	0.29
4	0.33	0.04	0.14	0.49

No change in role at UCD

	1	2	3	4
1	0.68	0.13	0.03	0.16
2	0.05	0.80	0.05	0.10
3	0.10	0.19	0.46	0.25
4	0.21	0.42	0.04	0.33

Change in role at UCD

	1	2	3	4
1	0.52	0.13	0.14	0.21
2	0.11	0.64	0.10	0.15
3	0.17	0.23	0.41	0.19
4	0.29	0.22	0.19	0.30

Decrease in access to DA

	1	2	3	4
1	0.68	0.02	0.10	0.20
2	0.10	0.54	0.13	0.22
3	0.16	0.10	0.44	0.29
4	0.38	0.29	0.12	0.21

No change in access to DA

	1	2	3	4
1	0.61	0.14	0.07	0.18
2	0.08	0.79	0.03	0.10
3	0.12	0.20	0.46	0.23
4	0.21	0.40	0.07	0.32

Increase in access to DA

	1	2	3	4
1	0.54	0.20	0.08	0.18
2	0.06	0.74	0.11	0.10
3	0.13	0.33	0.38	0.16
4	0.23	0.23	0.16	0.39

Decrease in access to carpool

	1	2	3	4
1	0.70	0.08	0.07	0.15
2	0.17	0.64	0.08	0.11
3	0.17	0.09	0.53	0.21
4	0.19	0.40	0.15	0.26

No change in access to carpool

	1	2	3	4
1	0.59	0.15	0.07	0.19
2	0.06	0.75	0.07	0.12
3	0.09	0.25	0.42	0.24
4	0.29	0.27	0.09	0.35

Increase in access to carpool

	1	2	3	4
1	0.57	0.14	0.10	0.19
2	0.06	0.76	0.05	0.13
3	0.15	0.23	0.40	0.21
4	0.23	0.33	0.09	0.35

Time interval of 1 year

	1	2	3	4
1	0.63	0.09	0.09	0.19
2	0.09	0.69	0.09	0.13
3	0.15	0.14	0.48	0.24
4	0.27	0.23	0.12	0.39

Time interval of 2 years

	1	2	3	4
1	0.60	0.14	0.09	0.18
2	0.12	0.67	0.12	0.09
3	0.12	0.15	0.46	0.28
4	0.29	0.28	0.15	0.27

Time interval of 3 years

	1	2	3	4
1	0.62	0.13	0.08	0.17
2	0.02	0.86	0.00	0.12
3	0.23	0.26	0.19	0.32
4	0.17	0.41	0.10	0.32

Time interval >3 years

	1	2	3	4
1	0.56	0.21	0.03	0.20
2	0.05	0.81	0.00	0.14
3	0.00	0.43	0.57	0.00
4	0.21	0.58	0.00	0.21

Modality types: 1 active travelers, 2 car users, 3 transit users, 4 multimodal travelers. Grey cells indicate a significant increase in the probability to switch from one to another modality type and dark cells a decrease.

3.5 Discussion and conclusions

Our first research question was the extent to which life events effect change in travel behavior. The results of this study highlight the importance of life events in explaining travel behavior change, specifically shifts in modality type. Residential relocation, changes in household size, changes in the option to drive alone or to carpool, and changes in role at UC Davis significantly affect the probability of switching between modality types. A move from Davis to another town, which necessarily means an increase in commute distance, is associated with a switch towards car, transit, or multimodal travel. Conversely, moving to Davis, which necessarily decreases commute distance, increases the chance of switching to active and multimodal travel. Transition may be explained in part by the fact that Davis has extensive bicycle infrastructure and a strong bicycling culture. However, only one percent of the sample actually relocated to Davis. Active travelers seem to be more affected by changes in household size, which is consistent with findings that the share of active travelers decreases throughout the life stages. For instance, previous research revealed that persons are likely to stop bicycling when they become a parent (Oakil et al., 2016).

Almost all modality types showed state dependence, meaning that modality type is more likely to not change than it is to change, though car users showed the highest behavior probability of staying loyal to their modality type. These results suggest a rigidity in travel once participants have adopted the modality type of car travel. Our results are consistent with Kroesen (2014) and De Haas et al. (2018), who found that unimodal users were more likely to stick to their modes than multimodal users. Interestingly, in our study, an increase in carpool access does not affect the probability of transitioning to another modality type (except for transit users switching to active travel) whereas an increase in the possibility of driving alone increased the probability for all respondents (except for multimodal travelers) of switching to strict car use. This result suggests that policies that incentivize carpool over driving alone may discourage strict car use and allow persons to reach destinations only accessible by car. In general, transit users seem to be less affected by life events than other modality types, which may indicate that transit users are captive riders and cannot freely switch between modes. Kroesen (2014) found that persons were more likely to switch to public transport when they also switched employment, a life event that we did not include in our analysis.

With our second research question, we investigated whether life events affect travel behavior differently at distinct life stages. Life stage did not moderate the effect of life events on travel behavior, as we had hypothesized. We propose several explanations for this result. This analysis considered the life stage situation of the first wave for the membership model although individuals may switch life stage groups by the second wave. In fact, life events may trigger a transition from one life stage to another, marking the beginning of a new life stage such as the birth of a child marking the beginning of parenthood. Previous studies highlight the interdependence of life events, life stage and travel behavior (e.g. Beige and Axhausen, 2008; Zhang, 2017). Life events and life stage may be correlated and not as distinguishable as our research questions suggests. This may explain some of the insignificant moderating effects of life stages in our study. Another explanation may relate to the

fact that we mix generation and life stage since millennials can also be in the third life stage group. In addition, the three-way interaction of life stage, life event, and previous modality type may lead to insufficient variation in the data. For these reasons, this study is not a definitive test of the moderating effect of life stage on the impact of life events.

However, life stage did significantly influence membership in one of four modality types. Millennials living with partners or parents more often relocate to another town, possibly reflecting specific preferences for more space and comfort at this life stage as well as high housing prices in Davis. Pressures in the housing market may drive young couples or parents to locate in more car-dependent areas (Delbosc and Nakanishi, 2017; Gehrke et al., 2019; Thierstein et al., 2016). Millennials who live alone or in shared apartments are more dynamic: they change their residence within Davis, their role at UC Davis and car availability more often than other life stage groups. This could reflect the fact that they are at the beginning of their career and experience more change with respect to their socioeconomic status and mobility resources, as supported by previous studies (Beige and Axhausen, 2008; Dargay and Hanly, 2004; Oakil et al., 2016). Life stage significantly affects active traveling and car use. The share of active travelers decreases over the life stages and is particularly low for parents. A possible explanation for this might be that it gets more difficult to combine the travel needs of other persons and professional responsibilities with active travel at this life stage (Oakil et al., 2016). Contrary to our hypothesis, all life stage groups have an approximately similar share of multimodal travelers; life stage seems to not affect multimodal travel. We acknowledge, however, that our sample is drawn from a university population and a university town that offers a greater variety in available transport modes and modal split compared to other small-sized US towns.

Another important finding is that gender differences play a role in explaining modality type membership and may also be linked to life events and life stage. The share of women who are active travelers decreases throughout the life stages, as also found in other studies (e.g. Scheiner, 2014a). Since we group respondents into life stages that also correspond to different generations it is not clear whether gender disparities increase over the life cycle or generational differences play a role in explaining gender disparities. If we split our sample into millennials with children and without children, female and male millennials without children are equally represented in the active travelers group while only a quarter of millennial active travelers with children are women. However, female non-millennials have the same share in the active traveler group regardless of their status of parenthood. This observation suggests that millennials may fall back into gender disparities of travel behavior of former generations when they become parents. These results support the argument of other studies that behavioral differences of millennials may be temporal and partly due to delayed life stage (Delbosc and Currie, 2013). Since the numbers of observations in our dataset are relatively small in each category these results should be treated with caution and tested with a larger sample. Nevertheless, these results raise several questions for future research: Do millennials change their travel behavior to become more similar to non-millennials as they pass through the life cycle? More specifically, are gender disparities between millennials more or less pronounced compared to non-millennials as they move through the life cycle?

As pointed out in the literature, life events represent a potential "window of opportunity" for triggering changes in travel behavior. According to our results, it seems that this momentum for change is not moderated by the life stage of a person. Interventions might target recent movers or persons who change their household composition, regardless of life stage. Our results highlight that individuals tend to change their travel behavior after relocation. In particular, moving to locations at larger distance from the workplace was often associated with an increase in car use. These results put emphasis on the fact that residential and travel choices are interlinked and suggest that some transportation policies may be more effective if planned in accordance with housing policies. Also, policies that incentivize better use of mobility resources within and between households through sharing and pooling and discourage the purchase of an additional car may be more effective if targeted towards recent movers who may need a car for their commute. For example, providing this group with the possibility of borrowing a second car occasionally when needed may promote lower car ownership. Our results show that a considerable number of persons switched from strict car use to multimodal travel in the presence of life events, suggesting that multimodal travel might be a more promising strategy for reducing car use than attempts to shift commuters from driving entirely to another mode. Car users might be open to reducing car travel on some days and thus could be good targets for interventions that provide positive experiences with active modes. Several countries provide local programs fostering bicycling to work during the month of May and may provide starting points to encourage multimodal use and hence active travel (for the UK: European Cyclists' Federation, 2019; for the US: Nordback, 2014; League of American Bicyclists, 2019). Policy programs that encourage multimodal travel may address a diverse population since multimodal travel seems to not depend on life stage, according to our results.

Further research on these questions is required since many travel surveys only capture the primary mode of transport and provide limited understanding about multimodal and intermodal behavior. This is also a limitation of this study since we asked for the primary mode to travel to campus on a given day and assessed multimodality based on the variety of selected modes over the week. Future studies could explore methods for more precisely measuring intermodal travel. Research on the motivation for multi- and intermodal travel, using qualitative as well as quantitative methods, could provide needed evidence to improve the effectiveness of travel demand management programs as well as transportation planning in general.

In this study we measure the effect of life events on travel behavior in most cases for a 1-year interval, although behavioral responses may require more or less time, and travel behavior may change several times between 2 years or even lead to changes in anticipation of future travel needs (e.g. car acquisition before a childbirth). Time-lagged effects in behavioral responses make it difficult to causally link life events to changes in travel behavior. Several studies raise the issue of the temporal dimension of life events, life stage, and behavioral response (e.g. Lanzendorf, 2003, 2010; Holz-Rau and Scheiner, 2015; Oakil et al., 2014) though only a few studies empirically consider time-lagged effects (Müggenburg et al. 2015). Most of the quantitative studies consider time-lagged effects of life events on car ownership (Dargay, 2001; Oakil et al., 2014; Wang et al., 2018). The literature mentions

several reasons to explain delayed effects of life events: learning and experience induce continuous change in a transition process (Holz-Rau and Scheiner, 2015), financial or mental restrictions (Oakil et al., 2014; Wang et al., 2018), time constraints, persuasiveness of habits, inertia, high searching costs, uncertainty, and imperfect information (Dargay, 2001). Others put emphasis on the idea that individuals constantly adapt their travel behavior (Scheiner et al., 2016). Capturing time-lagged effects with quantitative data is methodologically challenging. Further research based on qualitative data may provide more precise information on temporal intervals that could help to inform survey design (e.g. retrospective and prospective questions) and improve quantitative data collection that would provide deeper insights into individuals' planning, adaptation, and delay in behavioral responses to life events and choices such as inertia, periods of change, and transitioning. In general, the mobility biography approach is useful in linking short-, medium-, and long-term decisions and in understanding the temporal dimension of travel-related choices.

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Author's contribution JJ: study conception and design, analysis, interpretation of the results, draft manuscript, editing of final manuscript; CGT: study conception and design, data collection, analysis, interpretation of the results, editing of final manuscript. SH: study conception and design, data collection, interpretation of the results, editing of final manuscript.

3.6 Appendix

The parameter estimates in Tables 3.7, 3.8 and 3.9 indicate the probability to be in one of the three modality types (car, transit users, or multimodal travelers) instead of being in the active traveler modality type conditional on the specific life stage-covariate interaction. For instance, female millennials who lived alone, in a dorm, or in shared apartments have a higher probability than male millennials to be strict car users instead of being in the active traveler group. Millennials who were strict car users and lived with their partner were more likely to agree with the statement "Travel time is generally wasted time" (Disutility of travel time) compared to active traveling millennials living with their partner (see Tables 3.10, 3.11 and 3.12).

Table 3.7 Parameter estimates for membership model (reference: active travelers)

	Car users			Transit users			Multimodal travelers		
	Coef	SE	*p* value	Coef	SE	*p* value	Coef	SE	*p* value
Age									
M	0.16	0.03	**0.00**	0.02	0.03	0.59	0.03	0.02	0.11
MwP	0.03	0.05	0.57	−0.03	0.06	0.60	0.03	0.04	0.47
P	−0.03	0.02	0.23	−0.09	0.07	0.17	−0.04	0.02	0.09
A	−0.03	0.02	0.08	0.01	0.03	0.68	−0.02	0.02	0.27
Women (basis: men)									
M	0.98	0.29	**0.00**	0.51	0.18	**0.00**	0.37	0.13	**0.01**
MwP	0.36	0.40	0.37	−0.14	0.48	0.77	0.61	0.34	0.07
P	1.31	0.54	*0.01*	−2.30	1.99	0.25	0.67	0.48	0.16
A	1.23	0.31	**0.00**	−0.32	0.60	0.59	1.37	0.31	**0.00**
Household size									
M	−0.15	0.17	0.38	0.16	0.09	0.06	0.10	0.06	0.10
MwP	−0.13	0.18	0.47	−0.15	0.21	0.48	0.16	0.15	0.29
P	−0.62	0.26	*0.02*	−0.30	0.60	0.62	−0.03	0.21	0.89
A	0.18	0.23	0.42	−0.21	0.46	0.65	−0.10	0.23	0.65
Residential location outside of Davis (basis: Residence in Davis)									
M	3.21	0.40	**0.00**	0.60	0.39	0.13	1.05	0.28	**0.00**
MwP	4.96	0.55	**0.00**	3.13	0.61	**0.00**	1.91	0.47	**0.00**
P	3.62	0.74	**0.00**	7.09	2.39	**0.00**	1.70	0.71	*0.02*
A	3.81	0.47	**0.00**	5.22	1.11	**0.00**	1.79	0.47	**0.00**
Educational attainment: Bachelor degree or higher (basis: below Bachelor degree)									
M	−0.43	0.44	0.33	−0.88	0.30	**0.00**	−0.25	0.22	0.26
MwP	1.32	0.70	0.06	−0.50	0.83	0.54	0.48	0.60	0.42
P	0.36	0.96	0.71	1.70	2.43	0.48	0.47	0.90	0.60
A	0.38	0.64	0.55	−0.38	0.91	0.68	0.00	0.65	1.00

Table 3.8 Parameter estimates for membership model (reference: active travelers) (continued)

	Car users			Transit users			Multimodal travelers		
	Coef	SE	*p* value	Coef	SE	*p* value	Coef	SE	*p* value
Option to drive alone (basis: no option to drive alone)									
M	1.90	0.34	**0.00**	−0.12	0.16	0.44	0.50	0.12	**0.00**
MwP	1.40	0.56	*0.01*	−0.68	0.52	0.19	0.47	0.38	0.22
P	1.37	0.86	0.11	−0.52	2.09	0.80	0.50	0.72	0.48
A	0.98	0.54	0.07	−0.57	0.82	0.49	1.04	0.58	0.07
Option to carpool (basis: no option to carpool)									
M	1.13	0.24	**0.00**	0.50	0.16	**0.00**	0.59	0.13	**0.00**
MwP	0.41	0.41	0.31	−0.10	0.50	0.85	0.05	0.35	0.89
P	−0.26	0.69	0.71	−5.27	2.98	0.08	0.36	0.62	0.56
A	0.37	0.36	0.30	−0.82	0.68	0.23	0.02	0.37	0.95
Access to bus (basis: no bus access)									
M	−3.05	0.64	**0.00**	−0.48	0.40	0.23	0.44	0.25	0.07
MwP	−0.24	0.66	0.72	2.56	0.72	**0.00**	1.20	0.62	0.05
P	−1.34	1.18	0.25	1.82	2.14	0.40	0.88	1.08	0.41
A	−0.84	0.67	0.21	2.19	0.90	*0.01*	1.11	0.66	0.09
Access to train (basis: no train access)									
M	−0.62	0.27	*0.02*	2.44	0.36	**0.00**	1.02	0.18	**0.00**
MwP	0.16	0.46	0.72	1.12	0.57	0.05	0.80	0.43	0.06
P	−0.24	0.62	0.70	3.57	2.31	0.12	0.72	0.62	0.24
A	−0.17	0.35	0.63	1.87	0.73	**0.01**	−0.09	0.35	0.80
Disutility of travel time									
M	0.19	0.10	0.05	0.28	0.07	**0.00**	0.12	0.05	*0.02*
MwP	0.42	0.16	**0.01**	0.22	0.20	0.26	0.21	0.14	0.14
P	0.14	0.23	0.54	−0.39	0.54	0.47	−0.17	0.20	0.39

Table 3.9 Parameter estimates for membership model (reference: active travelers) (continued)

	Car users			Transit users			Multimodal travelers		
	Coef	SE	*p* value	Coef	SE	*p* value	Coef	SE	*p* value
A	0.25	0.13	0.05	−0.40	0.24	0.10	0.09	0.12	0.45
Liking of bicycling									
M	−0.80	0.10	**0.00**	−0.91	0.07	**0.00**	−0.28	0.06	**0.00**
MwP	−0.30	0.18	0.09	−0.27	0.21	0.19	−0.24	0.16	0.12
P	−0.24	0.24	0.33	−0.36	0.70	0.61	−0.24	0.23	0.29
A	−1.14	0.19	**0.00**	−0.91	0.30	**0.00**	−0.51	0.20	**0.01**
Liking of car driving									
M	0.12	0.10	0.26	−0.03	0.07	0.63	0.04	0.05	0.50
MwP	0.60	0.16	**0.00**	0.25	0.20	0.21	0.35	0.13	**0.01**
P	0.43	0.25	0.09	−0.72	0.69	0.29	0.47	0.24	*0.05*
A	0.03	0.13	0.82	−0.65	0.25	**0.01**	−0.09	0.12	0.47
Perceived need of a car									
M	0.93	0.12	**0.00**	0.02	0.06	0.71	0.21	0.05	**0.00**
MwP	0.80	0.17	**0.00**	0.16	0.19	0.40	0.29	0.13	*0.03*
P	0.60	0.27	*0.03*	−0.67	0.59	0.25	0.22	0.23	0.35
A	1.00	0.14	**0.00**	0.39	0.24	0.10	0.67	0.13	**0.00**

Bolded cells indicate a significance level of below 0.01 and italic cells indicate a significance level at 0.05

Table 3.10 Parameter estimates for transition between modality types

	Wave 2											
	Active travelers			Car users			Transit users			Multimodals		
	Coef	SE	*p* value	Coef	SE	*p* value	Coef	SE	*p* value	Coef	SE	*p* value
Wave 1												
Active travelers												
Constant		0		−3.59	0.56	**0.00**	−4.22	0.53	**0.00**	−1.27	0.25	**0.00**
Decrease in household size		0		1.02	0.75	0.17	−0.22	0.71	0.76	−0.74	0.43	*0.08*
Increase in household size		0		0.38	0.87	0.67	0.05	0.81	0.95	−0.85	0.45	*0.06*
Relocation within Davis		0		0.35	0.30	0.24	1.55	0.29	**0.00**	0.72	0.16	**0.00**
Relocation to another town		0		5.72	0.69	**0.00**	4.58	0.77	**0.00**	1.99	0.78	**0.01**
Relocation to Davis		0		−4.69	1.52	**0.00**	−1.66	1.22	0.17	−0.21	0.94	0.83
Decrease in option to drive alone		0		−2.18	0.86	**0.01**	0.10	0.27	0.71	−0.14	0.22	0.53
Increase in option to drive alone		0		0.46	0.27	*0.09*	0.03	0.20	0.89	0.03	0.15	0.86
Decrease in option to carpool		0		−1.20	0.59	**0.04**	−0.31	0.33	0.34	−0.46	0.25	*0.07*
Increase in option to carpool		0		−0.25	0.29	0.40	0.31	0.20	0.12	0.03	0.16	0.86
Change in role at UCD		0		0.15	0.26	0.57	1.90	0.26	**0.00**	0.66	0.14	**0.00**
Car users												
Constant	−3.14	0.48	**0.00**		0		−3.99	0.70	**0.00**	−3.62	0.49	**0.00**
Decrease in household size	−1.31	0.77	*0.09*		0		0.80	0.90	0.38	0.04	0.68	0.96
Increase in household size	−0.82	0.68	0.23		0		−0.15	1.06	0.89	0.57	0.54	0.29
Residential location within Davis	0.44	0.43	0.31		0		−0.55	0.58	0.35	0.75	0.38	**0.05**
Relocation to another town	−1.64	2.23	0.46		0		1.05	1.09	0.34	1.41	0.79	*0.07*
Relocation to Davis	3.63	0.61	**0.00**		0		1.96	0.90	**0.03**	2.75	0.62	**0.00**
Decrease in option to drive alone	0.97	0.87	0.27		0		1.92	0.80	**0.02**	1.41	0.65	**0.03**
Increase in option to drive alone	−0.09	0.83	0.91		0		1.44	0.70	**0.04**	0.00	0.67	1.00
Decrease in option to carpool	1.34	0.50	**0.01**		0		0.23	0.80	0.77	0.41	0.53	0.44
Increase in option to carpool	0.01	0.46	0.98		0		−0.38	0.67	0.57	0.24	0.36	0.51

Table 3.11 Parameter estimates for transition between modality types (continued)

	Wave 2											
	Active travelers			Car users			Transit users			Multimodals		
	Coef	SE	*p* value	Coef	SE	*p* value	Coef	SE	*p* value	Coef	SE	*p* value
Change in role at UCD	1.00	0.38	**0.01**		0		0.99	0.49	**0.04**	0.66	0.35	*0.06*
Transit users												
Constant	−3.43	0.98	**0.00**	−2.39	0.95	**0.01**		0		−0.85	0.59	0.15
Decrease in household size	1.41	1.30	0.28	0.41	1.33	0.76		0		0.59	0.86	0.49
Increase in household size	1.18	1.56	0.45	−3.86	2.10	*0.07*		0		0.12	1.02	0.91
Relocation within Davis	0.74	0.37	**0.04**	0.32	0.54	0.56		0		0.10	0.27	0.71
Relocation to another town	−1.45	2.09	0.49	8.82	6.28	0.16		0		−0.67	1.75	0.70
Relocation to Davis	1.98	1.10	*0.07*	−9.53	7.11	0.18		0		0.71	1.03	0.49
Decrease in option to drive alone	0.43	0.62	0.49	0.25	1.24	0.84		0		0.21	0.50	0.68
Increase in option to drive alone	0.30	0.38	0.44	1.56	0.55	**0.00**		0		−0.17	0.34	0.62
Decrease in option to carpool	0.38	0.47	0.41	−3.07	2.07	0.14		0		−0.40	0.40	0.32
Increase in option to carpool	0.65	0.39	*0.09*	−0.29	0.60	0.63		0		−0.02	0.32	0.95
Change in role at UCD	0.55	0.41	0.18	0.46	0.66	0.49		0		−0.23	0.28	0.41
Multimodals												
Constant	−0.54	0.33	0.10	−0.73	0.35	**0.03**	−3.06	0.62	**0.00**		0	
Decrease in household size	0.04	0.47	0.93	0.37	0.44	0.41	0.36	0.78	0.65		0	
Increase in household size	−0.01	0.56	0.99	−0.31	0.57	0.59	0.25	1.02	0.80		0	
Relocation within Davis	0.07	0.21	0.74	−0.15	0.24	0.53	0.46	0.31	0.14		0	
Relocation to another town	−1.49	0.95	0.11	2.01	0.63	**0.00**	0.28	0.87	0.75		0	
Relocation to Davis	−0.18	0.79	0.82	−2.77	1.02	**0.01**	0.18	0.88	0.83		0	
Decrease in option to drive alone	1.01	0.32	**0.00**	0.50	0.38	0.19	0.80	0.41	*0.05*		0	
Increase in option to drive alone	−0.08	0.26	0.75	−0.94	0.37	**0.01**	0.57	0.29	*0.05*		0	
Decrease in option to carpool	−0.10	0.34	0.77	1.12	0.36	**0.00**	0.65	0.39	*0.09*		0	

Table 3.12 Parameter estimates for transition between modality types (continued)

	Wave 2											
	Active travelers			Car users			Transit users			Multimodals		
	Coef	SE	*p* value	Coef	SE	*p* value	Coef	SE	*p* value	Coef	SE	*p* value
Increase in option to carpool	−0.17	0.25	0.48	0.37	0.29	0.19	0.00	0.33	1.00		0	
Change in role at UCD	0.37	0.19	*0.05*	−0.93	0.23	**0.00**	1.59	0.33	**0.00**		0	

Bolded cells indicate a significance level of below 0.05 and italic cells indicate a significance level at 0.1

Chapter 4

Re-visiting residential self-selection and dissonance: Does intra-household decision-making change the results?

Abstract

A considerable amount of literature has discussed the relevance of travel attitudes for location choices and travel behavior. Numerous studies have reported evidence that individuals choose neighborhoods that allow them to travel with their preferred transport mode, a process referred to as residential self-selection. Most studies, however, assume homogeneous attitudes and preferences among household members and ignore negotiation processes between partners that influence travel and location choices. The goal of this study is to investigate the extent to which heterogeneity in attitudes between partners affect residential self-selection and residential dissonance. This study uses data from a travel survey conducted in the agglomeration area of Vienna (Austria), factor analyses and multinomial logit models to explore residential location and mode choices.

Descriptive analysis reveals that depending on the neighborhood type travel attitudes have different effects on mode choice. Heterogeneity in travel attitudes between partners partly explains limited evidence of residential self-selection and dissonance. In general, effects of residential dissonance on location choice are most relevant if both partners are dissonant. Surprisingly, only women's travel attitudes substantially influence neighborhood selection which may be explained by the fact that female partners are also more affected by neighborhood characteristics in their travel behavior than their male partners. One third of respondents does not live in neighborhoods that match their travel attitudes. More dissonant households live in suburban areas than in the urban core indicating potential pressures on the housing market. Policy implications of these results emphasize the relevance of gender and highlight the challenge of providing affordable housing with good mobility services.

Keywords: Residential self-selection; Residential dissonance; Intra-household interaction; Mode choice

4.1 Introduction

Travel behavior research has emphasized the impact of built environment[1] on travel behavior as summarized in several meta-studies (Ewing and Cervero, 2001, 2010). Recently, researchers have shown increased interest in residential self-selection (RSS) defined as the process of persons choosing residential locations that match their travel attitudes and satisfy their travel preferences (Cao et al., 2009). Accordingly, the effect of built environment on travel behavior is in part attributed to travel attitudes leading to a selection of specific residential locations (Mokhtarian and van Herick, 2016). For instance, persons who like car-driving may favor neighborhoods with good parking and comfortable driving conditions. A large body of literature has reported evidence supporting the RSS hypothesis (e.g. Cao et al., 2009; van Wee, 2009) though some researchers have only found moderate or no effects (e.g. Ettema and Nieuwenhuis, 2017). Others discussed the magnitude of RSS (Mokhtarian and van Herick, 2016) or argued that travel-related residential location criteria may have minor relevance for residential location choices (Ettema and Nieuwenhuis, 2017). Other researchers addressed the phenomenon of residential dissonance which refers to residents who live in neighborhoods which do not match their travel attitudes and preferences (Schwanen and Mokhtarian, 2005). Different factors can explain such residential dissonance, such as a constrained housing market, high real-estate prices in preferred locations, financial constraints, or priority of other location criteria (e.g. distance to workplace) (De Vos et al., 2012). Some studies found that residential dissonance partially explains the limited relevance of RSS (De Vos et al. 2012; Schwanen and Mokhtarian, 2005).

The RSS literature, however, mostly neglects that location choices are the outcome of negotiation processes between household members who value location criteria differently (Guan and Wang, 2019; Oostendorp, 2014; Zhang and Fujiwara, 2009). For instance, work locations may affect residential location choices of partners differently as Oostendorp (2014) pointed out in her qualitative study on couple households. Only few studies in the RSS literature acknowledge the relevance of negotiation processes and intra-household heterogeneity in travel attitudes and preferences (De Vos et al., 2012; Guan and Wang, 2019; Næss, 2014; Scheiner, 2010).

Addressing this research gap, this study examines the extent to which heterogeneity in travel attitudes between partners affects RSS and explains residential dissonance. To the author's knowledge, only Guan and Wang (2019) investigated this problem quantitatively though they did not discuss the relevance of heterogeneous travel attitudes between partners for residential dissonance. This article contributes to the literature by providing an analysis at the household level that improves the

[1] In this study, built environment is used as a general term to describe spatial structures in urban environments, land-use, street design and accessibility.

understanding of RSS processes and illustrates the influence of male and female partners on residential location and travel choices.

Using 2019 survey data from the larger agglomeration of Vienna (Austria), this paper jointly investigates location and transport mode choices of couples living in the same household. The results reveal that heterogeneity in travel attitudes between partners influence residential location choices, in turn leading to residential dissonance. The findings show the additional gain of separately examining mode choices of women and men of a common household that would not have been revealed by including a gender variable only. Women seem to be more influential on location choices and more affected by the built environment in their transport mode choice than their male partners. More concretely, this study addresses the interconnectedness of location choices and daily travel behavior by including not only residents of Vienna, who, in general, have access to high-level public transport services, but also residents of Vienna's larger agglomeration where most of the persons live who commute to Vienna by car. The results indicate that more mismatched couples lived in suburban areas and may reflect pressures in the housing market driving households to the urban fringe or out of town. Policy implications of the findings in this study clarify challenges in providing adequate housing and good public transport provision particularly in the prospect of population growth in Vienna's agglomeration.

4.2 Literature review

4.2.1 The concept and relevance of residential self-selection

A great body of literature has examined the relationship between the built environment and travel behavior. In two meta-studies, Ewing and Cervero (2010, 2001) provided an overview over the effect of built environment characteristics on travel variables. They found a rather inelastic relationship (for example with a largest absolute elasticity of 0.39 for the weighted average elasticity of walking with respect to street density), though the cumulative effect of several variables on travel variables (distance, mode choice) was significant in size (Ewing and Cervero, 2010). The influence that built environment exerts on travel may vary between countries and mobility cultures. As Buehler (2011) shows, population density and public transport access have larger effects on the likelihood of choosing public transport in Germany compared to the US. Many recent studies have discussed whether the influence of built environment on travel behavior is in part indirect since "a household with a predisposition towards a certain type of travel 'self-selects' a residential location enabling the pursuit of that preferred type of travel" (Schwanen and Mokhtarian, 2005: 84). The research interest in this process, labelled as residential self-selection (RSS), led to a number of special issues in Transport Reviews ("Self-Selection", 2009, 29(3)), in the Journal of Transport and Land Use ("Viewpoints on self-selection", 2014, 7(3)) as well as in Travel Behavior and Society ("Travel and residential change", 2019-2020). Most studies have found evidence for RSS and reported an autonomous significant effect of the built environment using different modeling approaches (see Cao et al., 2009 reviewing different

approaches; Khattak and Rodriguez, 2005 for sample selection modeling; Bhat and Guo, 2007 for joint discrete modeling; Scheiner, 2010 for structural equation modeling). The magnitude of this effect is still discussed. Mokhtarian and van Herick (2016) compared the quantified proportion of the built environment effect that is due to the built environment itself (after controlling for residential self-selection) for seven studies with an effect varying largely between 34 and 98 percent.

4.2.2 Considering residential dissonance

A number of studies raised concerns about the limitation of RSS because some residents do not live in their preferred neighborhood (Chatman, 2009; De Vos et al., 2012; Guan and Wang, 2019). Several factors might explain such residential dissonance between attitudes and built environment characteristics at the residence such as constrained housing markets, prioritizing of other location criteria (e.g. distance to family) or fundamental changes in living circumstances (such as the life event of childbirth) that change household needs and attitudes (De Vos et al., 2012; Ettema and Nieuwenhuis, 2017). Real estate prices and rents may limit the set of alternatives for residential location (Thierstein et al., 2016). For instance, public transport access can be positively correlated to real estate prices as several studies point out for German cities (Cologne, Karlsruhe, Munich, Stuttgart) (BPD Immobilienentwicklung GmbH, 2019; Thierstein et al., 2016). Explicitly considering residential dissonance, Schwanen and Mokhtarian (2005) sorted their respondents based on their residential and travel attitudes into four groups (consonant urbanites, dissonant urbanites, consonant suburbanites, dissonant suburbanites), and examined their transport mode choice. Their results confirmed the RSS hypothesis and highlighted that built environment had a stronger influence on transport mode choice than travel attitudes. Though the effect of both factors (built environment, travel attitudes) was more balanced for urban residents than for suburban residents. Their results suggest a continuum with an increasing share of private vehicle use from matched urban residents, over mismatched urban residents to mismatched suburban residents, and matched suburban residents. Following this approach, De Vos et al. (2012) classified residents into urban and rural neighborhoods and found that half of students and staff members of the University of Antwerp were mismatched. Dissonant rural residents were more capable of realizing their transport mode preferences compared to urban dissonant residents. The authors explained this result by the strong urbanization in Flanders, good public transport access and a widespread wish for quiet and green neighborhoods. In their data, attitudes and land use preferences influenced walking, bicycling and transit use more than the built environment in contrast to car use. Interestingly, US suburban residents were less able to realize their travel preferences compared to urban residents while the opposite was true for urban compared to rural residents in Belgium. These studies confirmed the RSS hypothesis though the impact of travel attitudes and built environment varied across different neighborhoods and countries.

4.2.3 Household members influence each other's travel behavior

There is a considerable body of literature examining activity patterns and time sharing between household members (cf. the comprehensive review of Ho and Mulley, 2015). A lot of research concentrates on car travel and ownership (Ibid.). Household members coordinate household tasks and travel decisions. Partners share mobility resources whose use has to be negotiated if they do not travel jointly (Scheiner, 2020). Extensive research has examined household interaction by exploring activities such as household keeping tasks or chauffeuring of other persons (e.g. Schwanen et al., 2007). For example, parents rarely jointly escort their children to school (Scheiner, 2016). Couple households have been given particular attention in the literature. Using the German Mobility Panel, Kroesen (2015) found that partners of couple households influenced each other's travel behavior over time. The analysis showed for instance that men were more likely to switch to a specific travel pattern if women showed this travel pattern in the first period (Kroesen, 2015). In a qualitative study, Gil Solá (2016) interviewed 20 high-skilled persons (10 men, 10 women) living in couple households with children in Gothenburg (Sweden). In the interviews, women and men valued women's work equally or less than men's work. Women let her male partner commute by car which restrained their access to the labor market. The interdependence between constrained car access and access to labor markets has also been found in other studies (e.g. Chidambaram and Scheiner, 2020). Gil Solá (2016) suggested that respondents used economic reasons to explain unequally shared tasks. Interestingly, car access provided women better access to labor markets but sometimes supported unbalanced sharing of tasks. More generally, theories in sociology and the economics of gender literature provide various insights and explication for unequally shared household tasks, labor time and childcare between genders (e.g. Auspurg et al., 2017; Bettio and Verashchagina, 2008; Jacobsen, 2007). To sum up, household members, particularly couples, affect each other's travel behavior via their distance and access to workplaces, shared mobility tools, household tasks and childcare.

4.2.4 Intra-household interaction of travel behavior and location choices

Discussing intra-household interaction with respect to residential location choices, Ho and Mulley (2015) point to the open question of whether households should be understood as one decision-making unit or as separate decision makers. Some studies compared individual to joint valuation of location criteria between household members (Borgers and Timmermans, 1993; Timmermans et al., 1992; Zhang and Fujiwara, 2009). Dutch studies found that travel time to workplace was less important than characteristics of the dwelling and environment at an individual decision level but household members jointly weighted the travel time to workplace higher (Borgers and Timmermans, 1993; Timmermans et al., 1992). Similarly, Zhang and Fukijwara (2009) reported that individuals chose different options when deciding individually, or jointly in a stated preference experiment on residential location.

Relating to intra-household interaction of location and travel choices, studies have mainly discussed commute time and distance between partners as an outcome of negotiation for residential

location choices. Thus far, most data have suggested that women have shorter commute trips than men (Sicks, 2011; VCÖ, 2010), though diverging evidence has been found on whether residential locations are adapted to women's (Chapple and Weinberger, 2000; Manaugh et al., 2010) or men's workplace (Oostendorp, 2014). Some researchers found support for a "substitutability" between commute distances of two working household members (Davis, 1993). Others point out that commute distance is rather complementary between couples (Plaut, 2006, Guan and Wang, 2019). For the US, Plaut (2006) analyzed dual-worker households based on the 2001 American Housing survey and found that commute distance and time were complementary between household spouses, meaning that commute trips are jointly chosen to be longer. Among homeowners, an increase in the size of the household decreases women's commute distance and time while it has no effect on men's travel. In contrast, female and male renters have both longer trips if household size increases. In general, women and men commute longer (in distance) for higher salaries. Abraham and Hunt (1997) modeled home location as joint choice, workplace location and commute mode as individual choices using a nested logit model for households in Calgary, Canada. Travel attributes of women had larger positive effects on household utility than those of men. Thus, travel conditions of female partners were relatively more important than those of men. For Germany, Chidambaram and Scheiner (2020) found that men commuted longer, earned more and spent less time on unpaid work than their female partners. The presence of children in the household increased commute distance and gender gaps. The commute gap, the difference between male and female commute distance to workplace, increases with female "household obligations" and family duties (Chidambaram and Scheiner, 2020). Similar to other studies (e.g. Scheiner and Holz-Rau, 2012), they found that car access and use reduces the commute gap between women and men. They found evidence to support the economic power hypothesis suggesting that social status is positively associated with commute distance. Hence these studies point out that negotiation processes between partners play a significant role for residential location and commute distance though other factors, such as car access and social status, moderate commute distance.

Few studies qualitatively explored intra-household negotiation processes for residential location choice and travel behavior (e.g. Gil Solá, 2016; Oostendorp, 2014). Oostendorp (2014) surveyed 1884 households and conducted 18 interviews with two-worker households in the greater agglomeration area of Cologne and Bonn (Germany). Distance to the workplace was more relevant for residential location choice if both partners worked full-time. The workplace of the male partner was more often reason for relocation than those of the female partner and this phenomenon occurred more often if men worked full-time and women part-time. In households with children, women worked more often in the "home-office" than men and the opposite was true if the couple did not live with children. In general, full-time working women tend to make less compromises with respect to the professional life of their male partner.

Quantitative research on household interactions is rather limited with respect to discussing RSS. Susilo and Liu (2016) examined RSS and parents' influence on children's travel in the UK though they only captured residential preferences for the household in total and do not distinguish between

household members. They reported that residential location motives were differently associated to mode choice between household members. Women reduced their car use more than men after relocating closer to work or school. Looking for a better neighborhood or larger flat/house were associated with a higher car use by men and children but with decreased car use by women. They found a significant effect of RSS on mode choice only for women and not for men. Built environment was more relevant for mode choice than attitudes. To the best of the author's knowledge, Guan and Wang (2019) is the only study which quantitatively assessed intra-household interaction with respect to RSS. Based on a survey with 557 dual-earner couples living in Beijing, Guan and Wang (2019) found that husbands' travel attitudes were more important for RSS though women's travel attitudes had a greater influence on commute distance of both partners. Women's preference for car driving significantly increases commute distance of both partners and reduced husbands travel time by car on weekdays. In general, partners influenced each other in their travel behavior through their travel attitudes. Built environment had an autonomous effect after controlling for RSS. Residential dissonance also prevailed since some residences preferred proximity to non-work destination but lived in low-accessible areas for non-work destinations. Guan and Wang (2019) point to cultural differences in intra-household negotiation processes that potentially explain different results in the literature. According to the aforementioned Canadian study, the travel demand of female decision-makers in the household had a more important effect on location choice of residence and workplace (Abraham and Hunt, 1997). On the contrary, a Japanese study found that husbands were more influential on residential location choices than their female spouses (Zhang and Fujiwara, 2009).

4.2.5 Research questions

Household members may have diverging travel attitudes and preferences that require negotiations and compromises to find a residential location. Although many studies acknowledge the potential explanatory power of intra-household heterogeneity in the context of residential self-selection (De Vos et al., 2012; Næss, 2014; Scheiner, 2010), to the best of the author's knowledge, only Guan and Wang (2019) examined the effect of intra-household differences on residential self-selection quantitatively (Scheiner, 2020). Though they did not discuss residential dissonance and the role of heterogeneous attitudes between partners in this context. This paper aims to address this concern with the following research questions:

- To what extent does heterogeneity in travel attitudes between partners influence residential location choices and the relevance of travel attitudes for residential location choices?
- To what extend does heterogeneity in travel attitudes between partners lead to residential dissonance?

Several hypotheses motivated these research questions. Residential dissonance of one person may be explained by partners whose diverging travel attitudes match with the neighborhood type. Residential self-selection may be more important if both partners are matched. Additionally, built environment

may affect partners differently. Informed by previous evidence, employment may increase the influence of women on residential location choices.

4.3 Methodological approach

4.3.1 Data

Study area

This paper draws data from Vienna (Austria) and its agglomeration area (Figure 4.1). Vienna is characterized by a well-serviced public transport system and a high share of public transport in the modal split with 38% of all weekday trips that are done by public transport (Bundesministerium für Verkehr, Innovation und Technologie, 2016). Notwithstanding, some areas in the suburban districts do not have access to high-level public transport (metro, suburban train) or secondary public transport (tramway, rapid bus lines) (Fersterer et al., 2019). In addition, Vienna attracts a considerable number of daily inbound commuters (193,973 employees from other Austrian federal states or foreign countries) who mostly travel by motorized individual transport (MIT) (Seisser, 2016; Stadt Wien, 2014b). Based on a cordon survey in 2014, 74% of persons traveling by motorized modes (i.e. public transport, car, motorcycle) commuted by car and 26% by public transport into Vienna (Technisches Büro für Verkehrswesen und Verkehrswirtschaft, 2014). Most of the inbound commuters (55%) live in the agglomeration area of Vienna with a varying level of public transport service (Niederösterreichische Landesregierung, 2015; Riesenfelder, 2011; Stadt Wien, 2014b). To address this issue of different public transport service levels and housing market pressures, this study does not only include residents of Vienna but also of its agglomeration area. More specifically, the sampling frame included six Lower Austrian districts (Mödling, Gänserndorf, Baden, Korneuburg, Tulln, Mistelbach and municipalities of the former district Wien-Umgebung). These districts cover 72% of all Lower Austrians commuting to Vienna and 52% of all Austrians commuting to Vienna in 2016 (Statistik Austria, 2019b). Commuters who live in these sampling districts hence encompass a large part of total inbound commuters traveling to Vienna. Including them into the analysis is important to assess and understand the interdependence between residential location and daily mobility.

Focus group and survey

A web-based survey was conducted in June 2019 in the Vienna agglomeration (Figure 4.1) and assessed daily travel behavior, residential location preferences, and travel attitudes of respondents. The questionnaire has been first tested in a focus group with five recently moved residents of a new developed residential area (Aspern) at the urban fringe in Vienna. Four women and one man discussed their residential location choices, the influence of partners and their daily mobility. The feedback improved the comprehensiveness of the questionnaire and added important group-specific aspects (e.g.

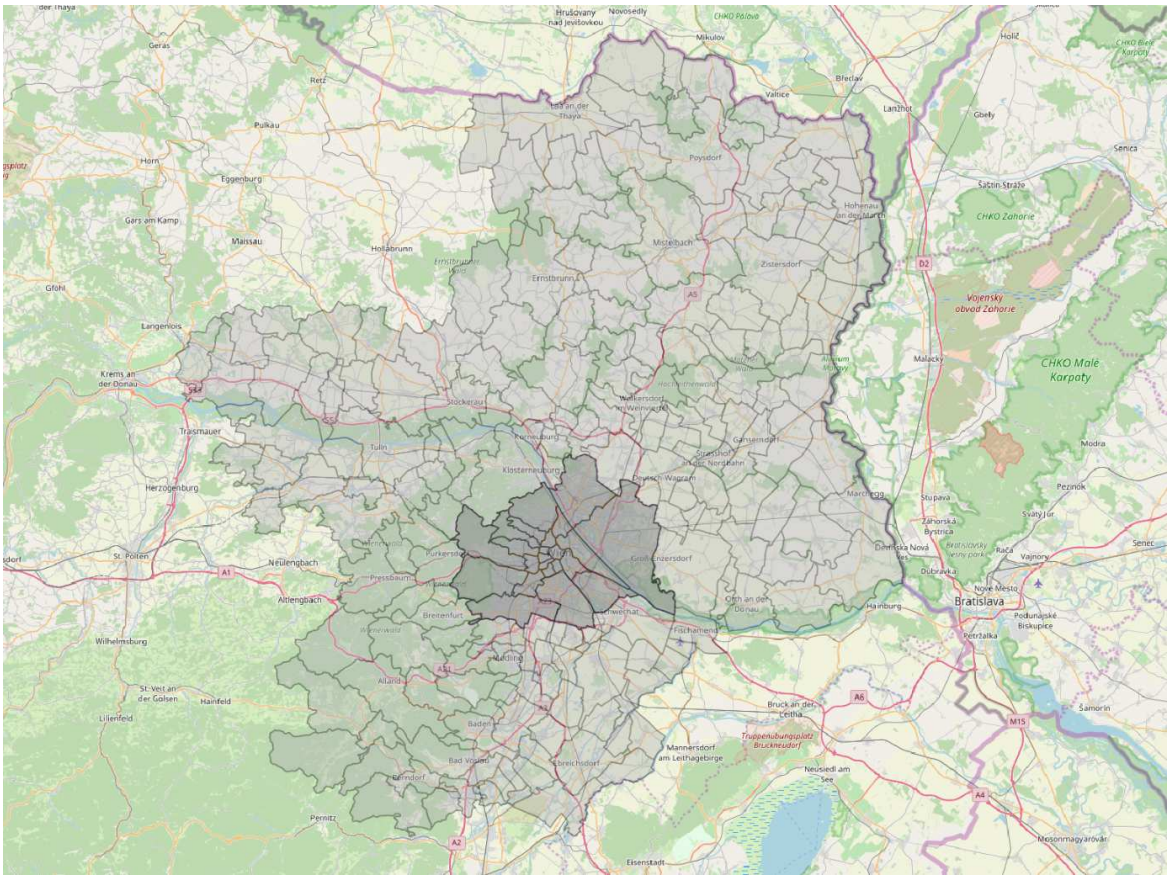

Fig. 4.1 Sampling region: Vienna's agglomeration area (grey shaded municipalities, darker shaded municipalities for the city of Vienna) (ESRI, Transportation 2020; Statistik Austria, 2020)

access for persons with disabilities). The web-based survey was conducted by an Austrian market research institute (market Marktforschungs GmbH & CoKG).

320 households from Vienna and 180 households from the six Lower Austrian districts have been selected out of the sampling frame. The survey was sent to one person in the household who was invited to send an additional survey link to his or her partner or another adult family member in the household. The aim was to sample household members who participate in residential location choices (e.g. partner, spouses or older family members). 2,800 households have been contacted by the market research institute and 518 households completed the survey leading to a response rate of 19%. The sample is representative for Vienna and Lower Austria (on a district level) with respect to household head's age, gender, highest educational degree in the household and household size. Table 4.9 in the Appendix compares sample statistics for these indicators with the actual population for Vienna and Lower Austria. Though the sample only includes some districts of Lower Austria this comparison is based on the assumption that the sample approximates the population distribution of Lower Austria. In general, the sample matches the distribution of household size, age and gender, however, has a

higher share of households with higher educational degree than in the actual population. This bias is considered when interpreting the results. In the following, this study only considers heterosexual couple households whose partners responded to the survey (798 out of 1,036 persons, and 399 out of 518 households). Both partners negotiate their residential preferences and finally decide on a location. They split household chores and childcare tasks and influence each other's travel behavior. Couple households may provide more insights into travel outcomes of these negotiating processes than interaction between other household members. In addition, heterosexual couples allow analyzing the role of gender in these processes since the literature points to relevant differences between genders (see literature section and literature on economics of gender, e.g. Bettio and Verashchagina, 2008; Jacobsen, 2007).

4.3.2 Variables of interest

This study investigates residential self-selection (RSS) and interaction between partners in couple households. Hence, data from a survey and other sources provide information on travel attitudes, residential location criteria and built environment and have been aggregated using factor analyses. The resulting residential, travel attitude and neighborhood types provide a convenient way to test the hypotheses on RSS and household interaction in regression models.

Attitudes

Previous research has confirmed the relevance of travel-related attitudes for transport mode choice (Bamberg et al., 2006; Busch-Geertsema and Lanzendorf, 2017; Gärling et al., 1998; Molin et al., 2014). Particularly, attitudes relating to bicycling seem to be an important determinant to predict the level of bicycling (Handy et al., 2014). Analyses of attitudinal influence on travel behavior have often been embedded in the Theory of Planned Behavior (Ajzen, 1991) and extended versions (Bamberg, 2006; Busch-Geertsema and Lanzendorf, 2017). The Theory of Planned Behavior emphasizes the sociological and psychological perspective of travel behavior explaining that attitudes towards transport modes, perceived behavioral control and subjective norm influence the intention to perform a specific behavior which at last influences the actual behavior (Ajzen, 1991; Busch-Geertsema and Lanzendorf, 2017). Travel attitudes, more specifically attitudes toward transport modes, may be discussed along three dimensions: instrumental, affective and symbolic (Busch-Geertsema, 2018). The instrumental dimension addresses flexibility provided by using a transport mode, its costs, user friendliness, time or weather when using a transport mode. The affective dimension refers to feelings such as autonomy or relaxation while using the transport mode, while the symbolic dimension conveys, for instance, status seeking behavior (Busch-Geertsema, 2018). In this study, travel attitudes are considered to be latent constructs that are not directly observable but approximated by attitudinal statements. Respondents were asked to agree or disagree on a five-point Likert scale to travel-related attitudinal statements (Tables 4.1 and 4.2). These statements aimed to address all three mentioned

dimensions of attitudes towards car driving, bicycling, public transport and walking. Another part of the survey assessed the importance of residential location criteria (Tables 4.1 and 4.2). These opinion statements cover different residential attributes, neighborhood and accessibility characteristics and have been informed by inputs provided by the focus group and literature (e.g. Thierstein et al., 2016). Since respondents weighted the importance of these criteria these valuations are further referred to as residential preferences.

Built environment

Built environment is of special interest in this study that investigates RSS and hence the relationship between built environment, attitudes and travel behavior. This study uses two types of data to assess built environment, one relates to statistical data provided by Austrian municipalities, the second type relates to accessibility characteristics self-evaluated by the respondents. Respondents provided the postcode or municipality of their residence since it is legally challenging to directly ask survey participants for their residential addresses (Bundesministerium für Verkehr, Innovation und Technologie, 2011). The survey did not include questions to geo-localize the residence of the respondents in a map since it tends to significantly increase the dropout rate. However, respondents self-evaluated their access to public transport and shopping facilities and characterized their settlement type providing information on the neighborhood level. Built environment variables were selected based on the literature, the geographical context and available data. Population density is one of the most often included built environment variable in transport mode choice models (Ewing and Cervero, 2010). Several studies showed that population density is negatively correlated to vehicle miles traveled, and positively associated with walkability, land-use mix and accessibility of shops and other facilities (Ewing and Cervero, 2010; Pfaffenbichler et al., 2016). This analysis also includes a land-use variable since it indicates the diversity in built environment and is often correlated to a higher share of walking and public transport use (Ewing and Cervero, 2010). The land-use mix (LUM) indicator in this analysis is based on the entropy formula developed by Shannon and Weaver (1949) and used by Frank et al. (2005) (Mavoa et al., 2018: 686) and is defined as follows

$$LUM = -1 * \frac{(sum_{i=1}^{n} * ln(p_i))}{ln(n)}.$$

The land-use mix score is a measure of land-use concentration considering the proportion (p) of each land-use category (i). n indicates the number of land-use categories that are three in this case and include residential, office and commercial buildings at a municipality level. A LUM score of one indicates the maximum of building mix between the three categories and zero the concentration in one of the three land-use categories. To address local accessibility, this study includes the settlement area type at the residence since for instance dispersed settlement necessitates more car driving than densely populated areas (Tables 4.1 and 4.2). Walkability is approximated by access to shopping facilities since it has been shown to be associated with higher elasticities for walking (Ewing and Cervero, 2010). Another feature of the built environment relates to public transport access. Respondents self-evaluated their access to public transport (PT) and reported walking distance in minutes to the next

bus, tramway, metro and train station (Tables 4.1 and 4.2). The variable commuters per inhabitant on a municipality level may correlate with the traffic volume and a higher use of motorized individual transport (MIT). The indicator parking area per inhabitant highlights the automobile friendliness of the neighborhood since parking at residential location has been shown to be associated with increased car use (Knoflacher, 2006). Acknowledging the positive effect of green areas on walking and bicycling that has been found in previous studies (Pfaffenbichler et al., 2016; Sugiyama et al., 2013), I calculated the share of green area (bushes, gardens and woods) relative to the total area of the municipality.

Residential, travel and built environment types

Three factor analyses allowed aggregating information on travel attitudes, residential preferences and built environment to create discrete types for each topic which are then included in the econometric models. Attitudes are considered to be latent constructs. Factor analysis helps identifying the latent constructs associated with different attitudinal statements by explaining variation in these variables. Statements related to residential location criteria are as well aggregated to find the underlying construct related to a residential type. Built environment variables are aggregated to form neighborhood types that characterize residential locations of respondents. Several built environment variables, items related to travel attitudes and residential location criteria are measured on an ordinal scale. Therefore, all three factor analyses used a polychoric correlation matrix assuming variables to be bivariate normally distributed and an ordinal measurement of an underlying continuum (Kolenikov and Angeles, 2004). The polychoric correlation matrix takes into account the ordinal nature of the Likert variables and provides a better correlation estimation for the underlying data than the Pearson-correlation matrix that assumes continuous data (Kolenikov and Angeles, 2004). Screen plots, eigenvalues (>1) and meaningful interpretation of the factors informed the number of types selected for each factor analysis. Respondents were assigned to the factor type yielding the highest factor score using the OLS regression method.

The residential dissonance indicator is defined in the results section since it is based on the results of the factor analyses of travel attitudes and built environment variables.

4.3.3 Modeling approach

This study uses a statistical control approach suggested by several studies to address the research questions (e.g. Ettema and Nieuwenhuis, 2017; Moktharian and Cao, 2008). Although more complex approaches do exist to model RSS and intra-household interaction, several reasons favor the use of statistical control and multinomial logit models. Cao et al. (2009) reviewed different approaches to estimate RSS effects and concluded that longitudinal data and structural equation models are the most suited to respond to these questions. Due to the cross-sectional nature of the data, the longitudinal approach is not possible in this study, a limitation further discussed in the following section. Structural equation models provide the advantage to consider endogenous variables and indirect effects though

Table 4.1 Descriptive statistics of 798 persons living in 399 households

Variable	Definition	Percentage/mean (s.d.)
Sociodemographics		
Age	20 to 24	1%
	25 to 29	7%
	30 to 34	12%
	35 to 39	11%
	40 to 44	11%
	45 to 49	11%
	50 to 54	10%
	55 to 59	11%
	60 to 64	11%
	65 to 69	7%
	70 and older	9%
Gender	Women	50%
Employment status	Employed or attending an educational institution or training	70%
	Unemployed or without own income	30%
Household size	Two persons	62%
	More than two persons	38%
Children (below 15 years)	No	74%
	Yes	26%
Income	Less than 850 Euro	1%
	851-1000 Euro	1%
	1001-1250 Euro	1%
	1251-1650 Euro	3%
	1651-2000 Euro	5%
	2001-2500 Euro	9%
	2501-3200 Euro	16%
	3201-4000 Euro	20%
	4001-4650 Euro	12%
	More than 4650 Euro	16%
	No information	17%
Trip information		
Trip purpose	Trip to work or educational facility	56%
	Other purposes (e.g.shopping, leisure activities,chauffering persons)	44%
Trip distance	In kilometers	13.35(17.29)

Table 4.2 Descriptive statistics of 798 persons living in 399 households (continued)

Variable	Definition	Percentage/mean (s.d.)
Attitudinal statments		
Residential preferences: How important are the following residential location criteria in general for you (4-point Likert scale: very important, important, less important, not important at all)	Size of apartment/house	3.44(0.59)
	Equipment of apartment/ house (balcony, garden)	3.55(0.61)
	Home ownership (appartment/house)	2.91(1.04)
	Distance to family and friends	3.14(0.78)
	Living costs	3.6(0.55)
	Mobility costs	3.15(0.75)
	Access to public transport	3.39(0.78)
	Walkable and bicycling-friendly environment	3.04(0.89)
	Access to transport modes for persons with disabilities	2.5(0.96)
	Good car parking	2.94(0.93)
	Secured and sheltered bicycling parking	2.53(1.02)
	Calm neighborhood (e.g. noise, security)	3.61(0.55)
	Access to shopping and service facilities	3.41(0.63)
	Proximity to leisure and cultural activities (sport, cinema, restaurants)	2.8(0.79)
	Child-friendly environment	2.65(1.04)
	Proximity to parks and green areas	3.15(0.81)
Travel attitudes (5-point Likert scale: I strongly agree, I agree, undecided, I disagree, I strongly disagree)	I travel quickly by car.	3.85(1.23)
	There is not enough car parking.	3.69(1.24)
	I like car driving.	3.66(1.26)
	Car driving means freedom.	3.47(1.3)
	I can relax while driving (as a driver or passenger).	2.99(1.27)
	I travel quickly by public transport.	3.51(1.2)
	I can relax in public transport.	3.19(1.21)
	My privacy is uncomfortably limited in public transport.	3.42(1.09)
	I reliably plan my way with public transport modes.	3.59(1.1)
	I like bicycling.	3.19(1.53)
	Bicycling means freedom.	3(1.47)
	I bicycle because I enjoy the exercise.	3.15(1.5)
	I like walking.	4.11(0.99)
	I feel responsable to use environmentally friendly transport modes in daily life because of environmental and climate change reasons.	3.4(1.24)

Table 4.3 Descriptive statistics of 798 persons living in 399 households (continued)

Variable	Definition	Percentage/mean (s.d.)
Built environment		
Dwelling type	Apartment house (> 3 apartments)	62%
	Single family (detached) and duplex (semi-detached) house	38%
Settlement area type	Densely developed area - urban core	47%
	Less densely developed and populated area - suburban area or the city fringe	40%
	Sparely developed and populated area - dispersed, isolated settlement or rural area	14%
Access to bus services	Less than 5 minutes	63%
	5 to 10 minutes	31%
	11 to 15 minutes	0%
	more than 15 minutes	2%
	not available / do not know	4%
Access to tram services	Less than 5 minutes	32%
	5 to 10 minutes	21%
	11 to 15 minutes	0%
	more than 15 minutes	8%
	not available / do not know	40%
Access to metro services	Less than 5 minutes	14%
	5 to 10 minutes	26%
	11 to 15 minutes	0%
	more than 15 minutes	19%
	not available / do not know	40%
Access to train services	Less than 5 minutes	7%
	5 to 10 minutes	29%
	11 to 15 minutes	0%
	more than 15 minutes	46%
	not available / do not know	18%
Land-use mix (a)	0 concentrated (1 land use only), 1 maximally mixed	0.07(0.04)
Access to shopping facilities	Less than 5 minutes	44%
	5 to 10 minutes	39%
	11 to 15 minutes	0%
	more than 15 minutes	14%
	not available / do not know	4%
Share of green area (b)	Area dedicated to bushes, gardens, forests out of total municipality area	0.34(0.21)
Commuters per inhabitant (c)	Ratio of commuters (employees, students) per inhabitant in municipality	0.45(0.03)
Parking area (b)	Parking area per inhabitant in m² in municipality	3.06(3.57)
Population density (d)	Inhabitants per km² in municipality	5152(6059)

s.d. standard deviation, sources: survey statistics, a Statistik Austria (2019e), b and d Bundesamt für Eich- u. Vermessungswesen (2012), c Statistik Austria (2019a), d Statistik Austria (2019c), e Statistik Austria (2019c)

they require variables to be multivariate normally distributed. They are also more restrictive towards categorical variables since this modeling approach requires linear equations. Generalized structural equation models allow categorical dependent variables but when tested with the data used in this study the generalized structural equation model led to the same results as the multinomial logit models. Hence the simpler multinomial logit approach was preferred in this analysis. Another aspect relates to the approach of modeling intra-household interaction. Ho and Mulley (2015) provide a comprehensive overview over modeling approaches for household interaction. Several studies modeled household interaction based on group utility functions (cf. review of Ho and Mulley, 2015; Zhang et al., 2009). However, these studies concentrate on activity pattern, time sharing or car ownership. They do not seem adequate to model transport mode choices because partners may have different commute trips and destinations. Thus, multinomial logit models seem to be an adequate approach to directly answer the proposed research questions.

The modeling approach foresees three separate multinomial logit models: one for neighborhood selection, one for women's mode, one for man's mode choice (cf. Figure 4.2). Dotted lines in Figure 4.2 show the relationships of interest in this study. The process of residential self-selection is operationalized by examining first the influence of female and male travel attitudes on location choice (neighborhood type selection). This approach compares model results without and including a residential dissonance indicator. Second, I assess the impact of built environment (neighborhood type) on mode choice and test the effect of including travel attitudes. Intra-household interaction is captured by distinguishing the effect of female and male travel attitudes and residential preferences on location and mode choices.

The neighborhood selection model includes residential and travel attitude types and tests the relevance of residential dissonance by comparing coefficients between two models (with and without including residential dissonance). Mode choice models distinguish three modes: non-motorized transport (NMT), public transport (PT) and motorized individual transport (MIT). NMT includes walking, bicycling and kick scooters (non-electric and electric). PT includes the use of bus, tram, metro and train and MIT the use of car, motorcycle, and scooter (electric or combustion engine). Mode choice models of both partners show two effects. First, this model approach allows examining the moderating role of travel attitude type on the effect of neighborhood type on mode choice to test the RSS hypothesis. According to this statistical control approach, travel behavior is determined by built environment and other control variables (Ettema and Nieuwenhuis, 2017; Moktharian and Cao, 2008). Following the RSS hypothesis, persons with specific travel attitudes select themselves in neighborhood types allowing them to travel with their preferred modes. Built environment is hence correlated to the error terms via omitted attitudinal variables[2] (Ettema and Nieuwenhuis, 2017; Moktharian and Cao, 2008). The model partially corrects this bias by explicitly including travel

[2] $TB = f_1(BE(AT), X) + \varepsilon(AT)$ with travel behavior (TB), built environment (BE), attitudes (AT), other control variables (X) and errors (ε)

attitudes[3] . The second purpose of the mode choice models is to reveal potential interaction between partners by including travel attitudes of the partner.

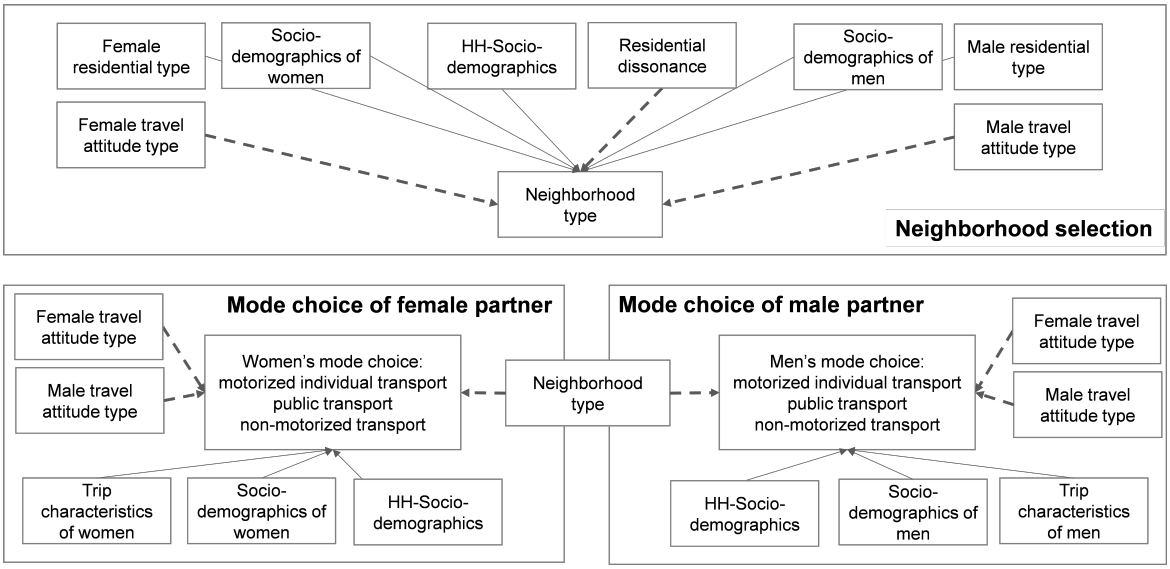

Fig. 4.2 Model structure (dotted lines highlight the impact of residential self-selection and dissonance)

4.3.4 Model specification

Next to travel attitude, residential and neighborhood types, socio-demographic and trip-specific variables are included in the models. Several studies demonstrated the relevance of trip purpose for trip distance and mode choice (Ho and Mulley, 2015). The models also include trip distance since particularly, non-motorized modes (NMT) are distance sensitive. Socio-demographic information covers age, household size, income, educational attainment, employment status, and age group of children in the household (below 15 years old and above 15 years old). Children's impact on parental traveling may vary with their age (Janke and Handy, 2019). Another variable included in the analysis refers to the dwelling type. Neighborhoods with single family or semi-detached houses tend to be less densely populated and more concentrated in residential land-use. Their residents are often more car-dependent and likely to own a car compared to residents of buildings with multiple apartments (VCÖ, 2010). Car ownership is not considered since all households in the sample own at least one car. 36% of Viennese households do not own any car and 15% of Lower Austrian households (Bundesministerium für Verkehr, Innovation und Technologie, 2016). Though the share of households without car ownership decreases for households with two or more persons (19% for Vienna, 4% for Lower Austria). The overrepresentation of car owners in the sample is potentially linked to fact that

[3]The new function controlls for this bias by expliciting considering attitudes with ξ as standard errors $TB = f_2(BE, AT, X) + \xi(AT)$

we oversampled households of higher educational degree and income classes. Respondents may be more likely to choose car over other modes compared to the average population. Attention is paid to this potential bias while discussing the results. Although income and educational attainment are correlated in this sample both variables are included in the models. All persons with college degree do not have a high income and the influence of both variables on neighborhood selection is relevant for this analysis.

4.3.5 Limitations

Cao et al. (2009) enumerated several conditions necessary to establish the causal relationship between attitudes and built environment suggested by the RSS hypothesis. One of these conditions relates to time precedence and the authors suggest the use of longitudinal data. However, as numerous studies before (De Vos et al., 2012; Ettema and Nieuwenhuis, 2017; Schwanen and Mokhtarian, 2005), this study tries to contribute to the RSS literature by using cross-sectional data. The causal relationship between travel attitudes and built environment is questioned by several studies that have found reverse effects (e.g. Kroesen, 2019; Naess, 2009; Van Acker et al. 2014). Naess (2009) suggested that the fact of spending time in a specific neighborhood may influence travel attitudes and car ownership indicating a reverse causality between built environment and attitudes. More recently, Kroesen (2019) confirmed this relationship and reported that built environment and travel behavior influenced travel-related residential preferences over time. This paper still tests the RSS in its classical understanding of the relationship between built environment and travel attitudes though discussing possible reverse effects in the conclusion section. Another limitation relates to the fact that the survey does not provide any information about how long respondents have lived at their current residential location. Hence, it is not possible to account for the time passed since relocating. Travel attitudes may change over time and do not reflect attitudes at the point of relocation. Unfortunately, it is not possible to control for this potential bias. One shortcoming of this study is that the survey does not provide information whether partners had joint trips and potentially misses synergy effects (e.g. partners sharing a car). The share of joint trips may be lower for weekday compared to weekend and lower for mandatory compared to discretionary trips (Ho and Mulley, 2013; Scheiner, 2010). For instance, couples living with children often divide childcare tasks and rarely bring their children together to school (Scheiner, 2016). In our data, 56% of all trips headed to work, school or other educational institutions. Therefore, the share of joint trips may be small in this data.

4.4 Results

First, this study explores heterogeneity in attitudes and mode choices between partners. Second, residential self-selection and dissonance are tested in several multinomial logit models.

4.4.1 Differences in travel attitudes and residential preferences between partners

Respondents were classified into three travel attitude types using factor analysis. Table 4.4 highlights factor loadings and statistically significant differences in the evaluation of attitudinal statements between partners. Cronbach's alpha of 0.81 indicates a good internal reliability implying that the covariance between the items significantly explains their variance and items are related to an underlying latent construct. The first type "Anti-car-pro-PT-bike type" (factor1) includes respondents who like public transport (PT) and bicycling, dislike car driving and consider themselves environmentally conscious (258 respondents). The second type "Anti-PT-pro-bike-car type" (factor2) includes persons who like driving and bicycling but dislike traveling by public transport (275 respondents). The third type "Anti-bike-pro-PT-car type" (factor3) appreciates using PT, likes car driving, but dislike bicycling and wishes for more car parking (264 respondents). The last column of Table 4.4 shows the mean difference in the evaluation between partners for each travel attitude item and the significance level based on the t-test. Partners seem to differently evaluate car- and bicycling-related attitudinal statements and have rather similar opinions on public transport. This may be linked to the fact that partners face the same quality level of public transport service at their residence that may affect their overall evaluation of using public transport services. This interpretation would support the argument for a reverse causality between built environment and attitudes as pointed out in the previous section (cf. Kroesen, 2019). Based on another factor analysis, respondents were classified into four residential types: the neighborhood-orientated type who gives equal weight to several criteria with a moderate focus on neighborhood characteristics (factor1), the car- and property-orientated type (factor2), the cost-minimizing type (factor3), and the pro-walking-bicycling type (factor4) (Table 4.5). The last column of Table 4.5 shows the mean difference in the evaluation of residential criteria between partners and significance level based on the t-test. It seems that partners attributed significantly different importance to residential location criteria though with modest mean differences. Particularly, partners attached different levels of importance to distance to family members and friends when choosing their residence. It stands out that partners tend to differ more in their evaluation of travel-related attitudinal statements compared to residential location criteria (with respect to the size of mean difference). This result seems intuitive since mode choices are individual decisions that indirectly depend on other household member's choices (e.g. availability of car) while residential location choices are more often jointly made by partners.

4.4.2 Residential dissonance and the relative importance of neighborhood types

To analyze travel behavior in different built environments, residences of respondents are classified into neighborhood types based on factor analysis. Three factors are retained (cf. Table 4.6). The first neighborhood type is characterized by a densely populated environment, very good public transport

Table 4.4 Factor loadings for travel-related attitudinal statements and significant mean differences between partners

Items	factor1	factor2	factor3	uniqueness	mean
I travel quickly by car.	-0.61	0.28	0.06	0.55	-0.05
There is not enough car parking.	-0.25	0.12	0.32	0.82	0.03
I like car driving.	-0.68	0.39	0.37	0.24	-0.29 ***
Car driving means freedom.	-0.72	0.46	0.32	0.17	-0.2 ***
I can relax while driving (as a driver or passenger).	-0.58	0.40	0.33	0.39	-0.24 ***
I travel quickly by public transport.	0.57	-0.14	0.59	0.32	0.07
I can relax in public transport.	0.53	-0.08	0.40	0.55	0
My privacy is uncomfortably limited in public transport.	-0.44	0.15	0.09	0.78	-0.01
I reliably plan my way with public transport modes.	0.62	-0.11	0.52	0.33	0.05
I like bicycling.	0.49	0.80	-0.19	0.08	-0.28 ***
Bicycling means freedom.	0.47	0.84	-0.08	0.07	-0.22 ***
I bicycle because I enjoy the exercise.	0.47	0.83	-0.16	0.06	-0.22 ***
I like walking.	0.47	0.17	0.16	0.73	0.19 ***
I feel responsible to use environmentally friendly transport modes in daily life because of environmental and climate change reasons.	0.61	0.04	0.16	0.60	0.22 ***
Persons+	258	276	264		

+ Number of respondents classified into this type based on the highest factor score, Cronbach's alpha: 0.81, *** pvalue <0.01, ** pvalue <0.05 based on t-test, Bartlett test of sphericity (chi-square statistic= 6,135, p-value=0) indicates that the variables in the matrix are correlated. Uniqueness shows the percentage of variance for the variable that is not explained by the common factors.

Table 4.5 Factor loadings for residential location criteria and significant mean differences between partners

Items	factor1	factor2	factor3	factor4	unique-ness	mean
Size of apartment/house	0.35	0.26	0.13	0.21	0.66	-0.03
Equipment of apartment/ house(balcony, garden)	0.42	0.38	0.13	0.19	0.57	0.13 ***
Home ownership (apartment/house)	0.29	0.48	-0.06	0.09	0.60	-0.07
Distance to family and friends	0.45	0.17	0.05	-0.18	0.67	0.22 ***
Living costs	0.40	-0.12	0.26	0.10	0.65	0.1 ***
Mobility costs	0.55	-0.31	0.29	0.16	0.44	0.1 **
Access to public transport	0.51	-0.58	0.15	0.06	0.35	0.13 ***
Walkable and bicycling-friendly environment	0.61	-0.31	-0.28	0.20	0.37	0.13 ***
Access to transport modes for persons with disabilities	0.59	-0.13	-0.04	-0.24	0.51	0.1 **
Good car parking	0.28	0.49	0.13	-0.17	0.57	-0.02
Secured and sheltered bicycling parking	0.47	-0.06	-0.26	0.25	0.59	0.04
Calm neighborhood (e.g. noise, security)	0.50	0.38	0.17	0.18	0.51	0.05
Access to shopping and service facilities	0.56	-0.12	0.22	-0.24	0.49	0.16 ***
Proximity to leisure and cultural activities (sport, cinema,restaurants)	0.66	-0.01	-0.01	-0.31	0.44	0.12 ***
Child-friendly environment	0.49	0.17	-0.38	-0.08	0.50	0.09 **
Proximity to parks and green areas	0.62	0.00	-0.29	-0.03	0.47	0.14 ***
Persons+	229	209	184	176		

+ Number of respondents classified into this type based on the highest factor score, Cronbach's alpha: 0.77, ***pvalue <0.01, ** pvalue <0.05 based on t-test, Bartlett test of sphericity (chi-square statistic= 2,467, pvalue=0) indicates that the variables in the matrix are correlated. Uniqueness shows the percentage of variance for the variable that is not explained by the common factors.

Table 4.6 Factor loadings for built environment variables

	factor1	factor2	factor3	uniqueness
Settlement area type	-0.81	0.01	-0.14	0.21
Access to bus	0.37	-0.13	0.19	0.73
Access to tram	0.81	-0.25	-0.19	0.23
Access to metro	0.85	-0.12	-0.01	0.24
Access to train	0.41	-0.07	0.09	0.76
Land-use mix	0.63	0.41	0.08	0.40
Access to shopping facilities	0.68	-0.07	0.15	0.48
Share of green area	-0.31	-0.49	-0.14	0.60
Commuters per inhabitant	-0.43	0.50	-0.10	0.53
Parking area per inhabitant	-0.28	-0.02	0.56	0.61
Population density	0.76	0.30	-0.18	0.28
Persons+	336	225	237	

+ + Number of respondents classified into this type based on the highest factor score, Cronbach's alpha(of standardized items): 0.81, Bartlett test of sphericity (chi-square statistic= 2,824, pvalue=0) indicates that the variables in the matrix are correlated. Uniqueness shows the percentage of variance for the variable that is not explained by the common factors.

access, mixed land-use, less green areas, less commuters and parking area. It is named urban core environment and mainly includes Viennese postcodes. The second neighborhood type is moderately populated, rather concentrated in land-use, has poor public transport access (relative to other service quality levels in the sample area), less green area and parking per inhabitant but a high number of commuters. It is further referred to as suburban environment. The third neighborhood type includes dispersed settlement among others, is less densely populated, has modest public transport access though with access to bus and train services. It is characterized by significant parking area and further referred to as urban-rural environment. One of the research questions of this paper asks about the influence of residential dissonance. To set up a residential dissonance indicator, mode-specific attitude types have been manually matched with neighborhood types based on the interpretation of the factors (cf. Table 4.7). Neighborhood types differ in their built environment characteristics that incentivize or privilege the travel with specific transport modes. Residential dissonance is thus not based on residential preferences but on a matching between travel attitude and neighborhood types since this paper aims to test the residential self-selection (RSS) hypothesis. This manual matching seemed to be more appropriate than setting an arbitrary threshold for each built environment variable to be matched or mismatched and to define rules to aggregate matches or mismatches for different variables into one residential dissonance indicator. The anti-car-pro-PT-bike type is matched in the urban core because it provides less comfort for car drivers, has excellent PT access and is densely populated, often correlated with shorter trip distances and hence more attractive for NMT. Poor PT access in suburban areas and auto-orientated urban-rural areas (e.g. with respect to the parking situation) suggest that

Table 4.7 Matching between travel attitude and neighborhood types

		Neighborhood type		
		Urban core	Suburban	Urban-rural
Travel attitude type	Anti-car-pro-PT-bike type	matched	mismatched	mismatched
	Anti-PT-pro-bike-car type	mismatched	matched	matched
	Anti-bike-pro-PT-car type	matched	mismatched	matched

anti-car-pro-PT-bike types may be mismatched in these areas. Anti-PT-pro-bike-car type is matched in suburban neighborhoods since this type tends to dislike using PT and PT access is relatively poor in suburban neighborhoods. Suburban and urban-rural areas may provide favorable conditions for car use and bicycling. Anti-bike-pro-PT-car types are mismatched in suburban neighborhoods because of the relatively poor PT access but are matched in the other neighborhood types either because of good PT access or the comfort of car driving. Based on this manual matching, 283 out of the 798 respondents are considered to be mismatched or dissonant and the majority matched or consonant. Following the approach of Schwanen and Mokhtarian (2005) and De Vos et al. (2012), Figure 4.3 lines up the modal split of consonant and dissonant residents by neighborhood type. Figure 4.3 lists the neighborhood types with respect to their public transport service level: Neighborhoods in the urban core provide most public transport service, followed by urban-rural and suburban neighborhoods. Consonant and dissonant residents are listed with respect to a hypothesized decreasing share of public transport (PT) in the modal split based on their travel attitude types. Figure 4.3 shows a continuum of increasing of motorized individual transport (MIT) and decreasing PT share from urban core to suburban neighborhoods and travel attitudes as indicated by other studies (e.g. Schwanen and Mokhtarian, 2005) though residents in urban-rural neighborhoods fall apart. A comparison of residents in the urban core with those living in suburban neighborhoods indicates that the influence of the neighborhood type dominates the influence of travel attitude type on mode choice. For instance, the share of MIT for suburban residents is higher than for urban core residents regardless of their travel attitudes (i.e. their matching). Though the difference between consonant and dissonant residents in the modal split illustrates the relevance of travel attitudes for mode choice. For instance, consonant residents use less MIT and more non-motorized transport (NMT) and PT than dissonant residents in the urban core, emphasizing the attitudinal influence on mode choice. Contrary to Schwanen and Mokhtarian (2005) who reported that travel attitudes were more important for the modal split of urban than of suburban residents, Figure 4.3 shows that differences in PT and MIT shares between consonant and dissonant residents are more substantial in urban-rural areas. Hence, depending on the neighborhood type, residential dissonance has a different effect on mode choice. To operationalize interaction between partners in the multinomial logit models, the residential dissonance indicator was aggregated on household level and distinguishes four levels: 1) both partners are matched, 2) the woman is mismatched but the man is matched, 3) both partners are mismatched, 4) the woman is matched and the man mismatched.

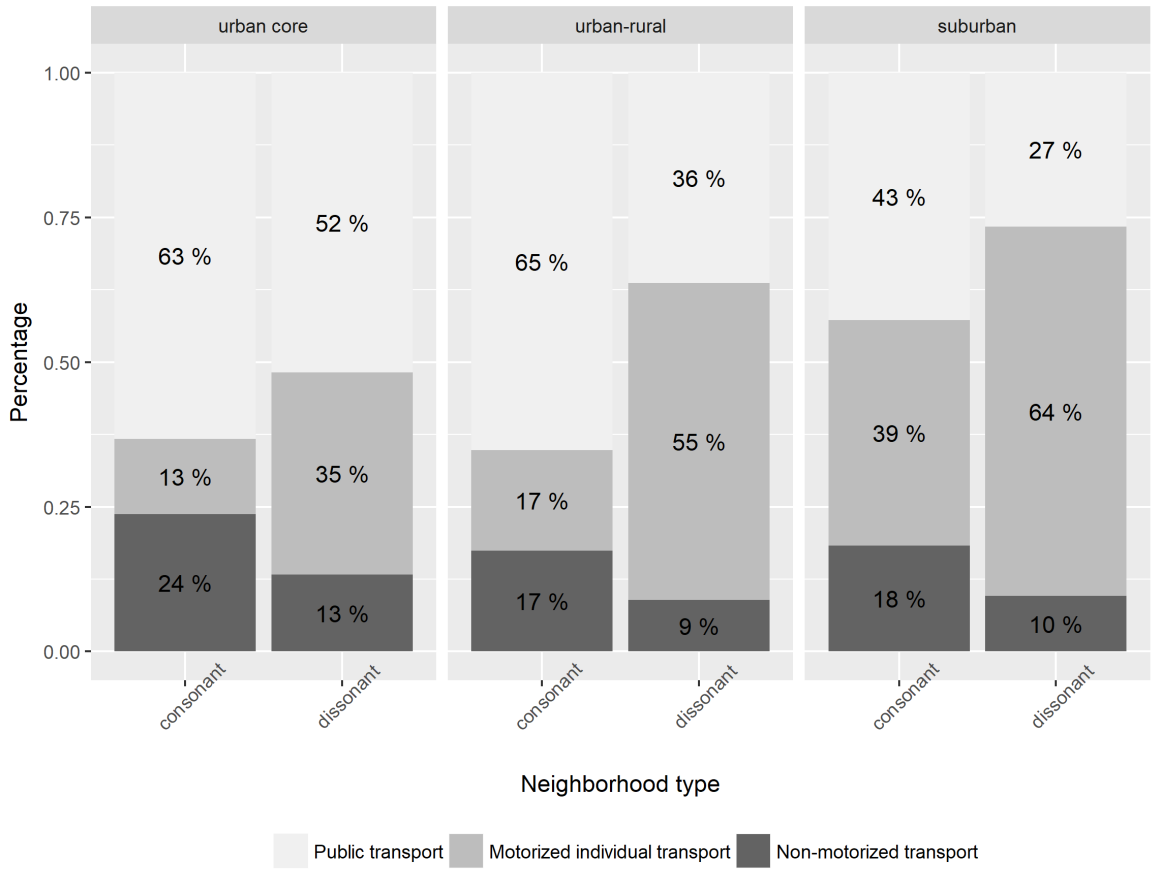

Fig. 4.3 Modal split by residential dissonance and neighborhood type

4.4.3 Model results

Model performance

An important assumption for multinomial logit models states that the ratio of the probabilities for two alternatives should not depend on another alternative – also known as the independence of irrelative alternatives (IIA) assumption (Louviere et al., 2010). Hausman and McFadden (1984) proposed a test to evaluate the IIA assumption. However, the typical Hausman test does not allow for clustered observations since the variance matrix of the coefficients of the two models is not well defined in this case. The observations of this study are clustered on the household level with two observations per household. The seemingly unrelated estimation test provides a good alternative to test for the IIA assumption as it estimates simultaneously variance and covariance matrices of the coefficients between different models.[4] I test the IIA assumptions for the three models (neighborhood selection including residential dissonance, mode choice of women and men including travel attitudes). The chi-squared statistic and p-values of this test indicate that the H0-hypothesis of equal coefficients between models with different alternatives cannot be rejected[5] and hence the IIA assumption seems not to be violated. Multinomial logit models were solved using STATA and the maximum likelihood method. McFadden's pseudo R-squared, chi-square test and BIC have been used to assess model performance (cf. Table 4.8). The likelihood ratio (LR) chi-square test indicates that all models perform better than the model including only constants. The pseudo R-squared is lower for mode choice models of women compared to those of men. This study compares the effect of residential dissonance on neighborhood selection by including the residential dissonance indicator and tests for the RSS hypothesis by including travel attitudes in the mode choice models. The BIC, penalizing for additional loss of degrees of freedom, takes the lowest (and best) value for the model that includes residential dissonance though is slightly higher for models including travel attitudes in mode choice.

[4]The seemingly unrelated estimation test calculates the differences between the coefficients of different models V(b-B) by V(b)-cov(b,B)-cov(B,b)+V(B) and allows to include clustered observations (Stata 2020).

[5]For the neighborhood selection model without urban core (chi2= 32, pvalue= 0.08), without suburban (chi2= 18, pvalue= 0.72), without urban-rural (chi2= 25, pvalue= 0.32), for the mode choice model for women without MIV (chi2= 12, pvalue= 0.78), for women without NMT (chi2= 13, pvalue= 0.75), for women without PT (chi2= 14, pvalue= 0.67), for the mode choice model for men without MIV (chi2= 16, pvalue= 0.49), for men without NMT (chi2= 13, pvalue= 0.72), for men without PT (chi2= 20, pvalue= 0.28).

Table 4.8 Results of neighborhood selection and mode choice of female and male partners

	Without residential dissonance				With residential dissonance				Without travel attitudes Women				With travel attitudes Women				Without travel attitudes Men				With travel attitudes Men			
	Suburban		Urban-rural		Suburban		Urban-rural		MIT vs. PT		NMT vs. PT		MIT vs. PT		NMT vs. PT		MIT vs. PT		NMT vs. PT		MIT vs. PT		NMT vs. PT	
	coef	std	coef	std	coef	std	coef	std	coef	std	coef	std	coef	std	coef	std	coef	std	coef	std	coef	std	coef	std
Age (f)									0.97	(0.07)	0.90	(0.06)	1.00	(0.07)	**0.87***	**(0.07)**								
Age (m)																	0.98	(0.06)	1.07	(0.09)	1.00	(0.06)	1.10	(0.09)
Unemployed/without own income (f) (basis: employed/in education)	0.83	(0.31)	0.91	(0.36)	0.87	(0.41)	0.86	(0.35)	2.19	(1.09)	**0.28****	**(0.15)**	**2.44***	**(1.24)**	**0.25****	**(0.14)**	1.83	(0.71)	1.32	(0.55)	1.81	(0.72)	1.54	(0.73)
Unemployed /without own income (m) (basis: employed or in education)	0.61	(0.24)	0.57	(0.24)	0.49	(0.26)	0.59	(0.26)	**0.40***	**(0.19)**	0.81	(0.37)	**0.44***	**(0.21)**	0.78	(0.39)	**0.39***	**(0.19)**	0.86	(0.58)	**0.34****	**(0.17)**	1.11	(0.76)
College degree(f) (basis: no college degree)	**0.47****	**(0.17)**	0.63	(0.23)	**0.44****	**(0.18)**	0.66	(0.24)																
College degree(m) (basis: no college degree)	0.64	(0.21)	**0.34*****	**(0.12)**	0.75	(0.30)	**0.34*****	**(0.12)**																
Household size: more than 2 persons (basis: 2 persons)	3.15	(3.17)	**5.67***	**(5.53)**	5.72	(6.49)	**5.89****	**(5.05)**	0.39	(0.27)	1.59	(1.35)	**0.25***	**(0.18)**	1.51	(1.32)	0.78	(0.50)	0.26	(0.33)	0.67	(0.48)	0.27	(0.32)
Children below 15 years (basis no children or 15 years and older)	0.79	(0.74)	0.47	(0.42)	0.75	(0.80)	0.51	(0.41)	2.70	(1.73)	0.96	(0.76)	**3.03***	**(2.03)**	1.09	(0.89)	1.07	(0.65)	3.11	(3.42)	1.09	(0.73)	2.89	(3.02)
Children 15 years or above (basis no children or below 15 years)	0.94	(0.85)	0.43	(0.36)	0.76	(0.79)	0.44	(0.35)	**3.48****	**(2.13)**	1.00	(0.78)	**4.40****	**(2.81)**	1.12	(0.88)	1.70	(1.02)	1.50	(1.38)	2.15	(1.42)	1.94	(1.68)
Income	1.08	(0.08)	**1.23****	**(0.10)**	0.98	(0.08)	**1.18***	**(0.10)**	1.11	(0.09)	1.08	(0.09)	1.09	(0.10)	1.09	(0.09)	1.08	(0.08)	0.94	(0.08)	1.07	(0.08)	0.96	(0.09)
Family and semi-detached housing (basis: apartment housing)									**2.48*****	**(0.76)**	1.03	(0.45)	**2.82*****	**(0.86)**	0.98	(0.46)	**1.97****	**(0.57)**	1.56	(0.79)	**2.14****	**(0.63)**	1.32	(0.70)
BE-type: suburban (basis urban core)									**4.14*****	**(1.60)**	**2.27****	**(0.92)**	**3.68*****	**(1.44)**	**2.44****	**(0.99)**	**2.00****	**(0.65)**	1.05	(0.53)	**1.81***	**(0.61)**	1.35	(0.69)
BE-type: urban-rural (basis urban core)									**2.32****	**(0.83)**	0.90	(0.34)	**1.96***	**(0.71)**	0.94	(0.36)	1.51	(0.47)	0.61	(0.29)	1.34	(0.42)	0.63	(0.33)
TA (f): Anti-PT-car-bike type (basis: Anti-car-PT-bike type)	**1.92***	**(0.67)**	1.65	(0.60)	**4.06*****	**(2.04)**	2.00	(0.85)					**5.08*****	**(1.91)**	0.69	(0.31)					1.20	(0.39)	**0.33***	**(0.19)**
TA (f): Anti-bike-PT-car type (basis: Anti-car-PT-bike type)	1.11	(0.38)	0.87	(0.31)	**2.33****	**(0.94)**	1.18	(0.42)					**1.97***	**(0.79)**	0.61	(0.21)					1.28	(0.43)	0.69	(0.36)
TA (m): Anti-PT-car-bike type (basis: Anti-car-PT-bike type)	1.05	(0.36)	1.17	(0.41)	1.26	(0.58)	1.03	(0.43)					1.33	(0.47)	0.67	(0.26)					**3.91*****	**(1.31)**	0.82	(0.40)
TA (m): Anti-bike-PT-car type (basis: Anti-car-PT-bike type)	0.60	(0.22)	0.70	(0.27)	0.61	(0.27)	0.58	(0.23)					1.17	(0.49)	1.30	(0.49)					1.74	(0.64)	**0.39***	**(0.20)**
RES (f): car-property-orientated (basis: neighborhood-orientated)	**3.20*****	**(1.26)**	**2.53****	**(0.99)**	**3.47*****	**(1.55)**	**2.55****	**(1.03)**																
RES (f): cost-minimizing (basis: neighborhood-orientated)	1.34	(0.55)	1.08	(0.43)	1.15	(0.55)	0.97	(0.39)																
RES (f): walking-bicycling-orientated (basis: neighborhood-orientated)	1.86	(0.71)	1.32	(0.52)	1.78	(0.77)	1.28	(0.51)																
RES (m): car-property-orientated (basis: neighborhood-orientated)	**2.62****	**(1.05)**	1.05	(0.43)	**3.85*****	**(1.99)**	1.15	(0.50)																
RES (m): cost-minimizing (basis: neighborhood-orientated)	1.46	(0.61)	0.79	(0.34)	2.01	(0.93)	0.85	(0.37)																
RES (m): walking-bicycling-orientated (basis: neighborhood-orientated)	1.66	(0.69)	1.08	(0.42)	**2.68****	**(1.26)**	1.25	(0.48)																
Res.dissonance: women consonant, men dissonant (basis: both consonant)					1.19	(0.45)	**0.46***	**(0.19)**																
Res.dissonance: women dissonant, men consonant (basis: both consonant)					**9.96*****	**(5.30)**	**2.84****	**(1.36)**																
Res.dissonance: both dissonant (basis: both consonant)					**20.44*****	**(11.69)**	**2.25***	**(1.03)**																
Trip to work or educational facility (basis: other trip purpose)									**0.36*****	**(0.14)**	0.69	(0.33)	**0.34*****	**(0.13)**	0.64	(0.30)	0.63	(0.22)	0.95	(0.52)	0.80	(0.29)	0.75	(0.42)
Trip distance in km									1.00	(0.01)	0.92	(0.06)	1.00	(0.01)	0.93	(0.06)	**1.02****	**(0.01)**	**0.73*****	**(0.06)**	**1.02****	**(0.01)**	**0.73*****	**(0.06)**
Constant	**0.22****	**(0.14)**	**0.20****	**(0.14)**	**0.06*****	**(0.05)**	**0.21****	**(0.14)**	**0.19****	**(0.16)**	2.07	(1.63)	**0.07*****	**(0.06)**	3.35	(2.84)	0.37	(0.29)	1.76	(1.86)	**0.14****	**(0.11)**	1.88	(2.19)
LR chi-square statistic	82***				127***				104***				73***				112***				112***			
McFadden's pseudo R2	0.107				0.200				0.162				0.173				0.210				0.223			
BIC	998				953				843				851				808				816			

*** p-value < 0.01, ** p-value < 0.05, * p-value < 0.1, std robust clustered standard errors, f female, m male, TA travel attitude type, RES residential type, BE-type neighborhood type

Neighborhood selection

The first model shows the selection of one of the three neighborhood types (urban core, suburban, urban-rural) on household level (column 1). Including residential dissonance improves the model fit (based on BIC) and increases the level of significance of travel attitudes (column 2). This result highlights that residential self-selection gains in importance (coefficients of travel attitudes increase) considering residential dissonance. In the model that does not account for residential dissonance (column 1), travel attitudes only weakly influence neighborhood type selection with a low significance level for one female travel attitude type. Including residential dissonance increases the significance level of women's travel attitudes (column 2). Disapproving car driving is relevant for neighborhood selection. Female anti-PT-pro-car-bike and anti-bike-pro-PT-car types are more likely to live in suburban and urban-rural neighborhoods than female anti-car-pro-PT-bike types. Particularly disliking public transport increases the probability of choosing suburban over an urban core neighborhood. Travel attitudes of both, women and men, seem to not influence the choice of urban-rural over urban core neighborhoods. The coefficients of the residential dissonance indicator highlight that couples of dissonant partners are more likely to live in suburban rather than in urban core areas. Residential dissonance seems to be more prevalent in suburban and to a lesser degree in urban-rural environments. Dissonant women living with a consonant partner are more likely to live in suburban areas. Residential preferences of both, women and men, significantly influence neighborhood type selection. Persons seeking a car-friendly residential location are more likely to locate in suburban and urban-rural than in urban core neighborhoods. Men are also more likely to live in suburban areas if they care for a walkable and bicycling-friendly environment. Relating to sociodemographic variables, women with a college degree are less likely to choose suburban and men less likely to choose urban-rural over urban core neighborhoods. Households with more than two persons have a higher chance to live in urban-rural areas. The significance level of income decreases if residential dissonance is considered.

Transport mode choice

Testing the residential self-selection (RSS) hypothesis, Table 4.8 compares mode choice models without and with travel attitudes (columns 5 to 12). The results support the RSS hypothesis since travel attitude type affects mode choice and alters the effect of neighborhood type on mode choice though only to a limited extent for the male partner. Including travel attitudes in mode choice decreases the coefficients of the neighborhood types. Notwithstanding, the results demonstrate an autonomous significant effect of neighborhood type on transport mode choices. For the male partner, neighborhood type and travel attitudes only have limited influence on his mode choice (columns 9 to 12). Neighborhood type seems to have a larger and more significant effect on women's mode choice (column 5 compared to 7 and 6 compared to 8). Living in a suburban and for woman also in an urban-rural rather than in an urban core area makes it more likely to choose car over public transport (PT) (columns 5 and 7). For women, suburban neighborhoods have a positive effect on the likelihood of choosing non-motorized modes (NMT) over PT (columns 6 and 8). In general, travel

attitudes seem to influence car mode choices more than NMT for daily traveling. Women and men who appreciate car driving and bicycling, but dislike PT are more likely to choose MIT over PT (columns 7 and 11). While women have a higher chance of choosing MIT (column 7), men have a lower chance of choosing NMT if they dislike bicycling (column 12). The results do not provide strong evidence for interaction between partners' travel attitudes and their mode choices (columns 7, 8, 11, and 12). Only women affect men's mode choice but at a weak significant level (p-value < 0.1) (column 12). Women have a negative influence on men's likelihood to choose NMT over PT if they do not like using PT (column 12). Women seem to use more PT than car for commute trips (columns 5 and 7). In general, trip purpose seems to be more influential on women's mode choice (columns 5 to 8) while for men trip distance reduces the chance of choosing NMT over PT (columns 10 and 12). Interestingly, variables related to household size or structure only affect women's mode choice although at a weak significance level (columns 5 and 7). Women who live in households with more than two persons are less likely to choose car over PT for their daily trips except if they live with their children (columns 5 and 7). Living in a family or semi-detached house increases the likelihood to choose car over PT for men and women (columns 5, 7, 9, 11). In contrast to men, women are more likely to choose MIT over PT if they are unemployed (column 7). However, unemployed men have a negative impact on women's likelihood of choosing car over PT, while women's employment status does not affect men's mode choice.

4.5 Discussion and conclusion

4.5.1 Discussion

An initial objective of this study was to identify whether heterogeneity in travel attitudes between partners of a common household alters residential self-selection (RSS). The results indicate that heterogeneity in travel attitudes and influence among partners affect the process of RSS. Travel attitudes of women were more influential on neighborhood type selection than those of men. This result may be explained by the fact that women were more affected by neighborhood type in their transport mode choice than men. Additionally, women in our sample used more non-motorized transport (NMT) and public transport (PT) whose use is generally more dependent on built environment than car driving (Ewing and Cervero, 2010). In contrast to my results, Guan and Wang (2019) reported that travel attitudes of both partners influenced land use characteristics of the residential location with a larger effect of male attitudes. Corroborating the results of this study, several studies have found that built environment affects women's travel behavior more than men's. For the UK, Susilo and Liu (2016) observed that mothers whose reasons for residential relocation related to a better neighborhood and living closer to work or school increased their walking and cycling and decreased their car use after relocation though no significant effect was found for fathers. Supporting this result, Spence et al. (2006) found in a Canadian study that women's physical activity was more strongly correlated to perceived environment. Results from previous studies have highlighted that

negotiating power of partners and the role of gender in location choices depend on the social and cultural context. For studies in Japan and China, researchers found that men's attitudes were more influential for location choices than those of women (Guan and Wang, 2019; Zhang and Fujiwara, 2009) while a Canadian study found the contrary (Abraham and Hunt, 1997). The findings of this study on intra-household interaction suggest that women and men exert a different influence on location choices and show distinct sensitivity to built environment. These results may be difficult to capture by including a gender variable only. To the contrary of travel attitudes, also men's residential preferences influenced neighborhood selection. Property seeking and car-orientated persons tend to locate more often in suburban and urban-rural areas but also persons who favor walkable and bicycling-friendly environments. Residential preferences are more relevant for choosing a residence in suburban than in urban-rural neighborhoods. As other studies suggested before (e.g. Kroesen, 2019), living in a certain neighborhood may change travel attitudes over time, pointing to a reverse causality between built environment and travel attitudes. For instance, persons who live in a car-friendly neighborhood may increasingly appreciate and enjoy car driving over time inducing a change in their attitudes towards car use. Although the author acknowledges potential reverse effects this relationship was not tested in this study due to the cross-sectional data.

The second research question thought to determine the role of residential dissonance for RSS. As the model results suggest residential dissonance may explain limited evidence for RSS. Some respondents seem not to live in the neighborhood type matching their travel attitudes. Including residential dissonance into the location choice model improved the model fit but also the significance of travel attitudes. Considering dissonance, the influence of travel attitudes on neighborhood type and hence RSS gained in importance. Moreover, heterogeneity in travel attitudes between partners contributes to the understanding of the relationship between RSS and residential dissonance. Dissonant women and consonant men were more likely to locate in suburban areas while dissonant men only had a weakly significant effect on neighborhood selection. Hence male travel attitudes may indirectly affect location choices. Heterogeneity in travel attitudes between partners may explain mismatches and hence limited evidence for RSS. In general, residential dissonance had the highest effect on location choice if both partners were mismatched. It is important to bear in mind that residential dissonance, as defined in this article, only relates to travel attitudes and is based on manual matching. Residents may in general be satisfied with their current location with respect to other non-travel related criteria. More generally, the results of this analysis provide evidence for RSS since travel attitudes significantly influenced mode choice while controlling for neighborhood characteristics. The results highlight an autonomous effect of neighborhood type next to travel attitudes on mode choice though only at a weak significance level for men's mode choice. Including travel attitudes in mode choice decreased the size of the coefficients and partly the significance level of neighborhood type. The literature has been discussing the direction of RSS on built environment and has found positive (Chatman 2009; Ewing and Cervero, 2010) as well as negative effects (Cao et al., 2009; Mokhtarian and van Herick, 2016).

In this study, travel attitudes mainly affected the use of MIT modes and not NMT use. These results contrast findings in the literature emphasizing the predictive power of travel attitudes for the level of bicycling (Handy et al., 2014). One explanation may relate to the fact that a low share of respondents bicycled, and most respondents walked. This result may indicate that persons do not travel with their preferred modes on daily trips. Surprisingly and contrary to findings in other studies (e.g. Guan and Wang, 2019), partners influenced each other's mode choice via their travel attitudes only to a limited extent. Women only weakly influenced NMT choice of men. The descriptive analysis showed that partners seem to differently evaluate car- and bicycling-related attitudinal statements and have rather similar opinions on public transport. Returning to mode choice, the influence of travel attitudes between partners may be more prevalent for discretionary trips compared to mixed (commute, other mandatory, and discretionary) trips used in this paper. The descriptive analysis revealed that the relevance of travel attitudes for mode choice varies among neighborhood types. The neighborhood effect on mode choice seems to dominate that of travel attitudes though this relationship is less pronounced for urban-rural environments. Contrary to the population, households in this sample detained on average a higher educational degree which correlates with higher income in Austria (Vogtenhuber et al., 2012). Respondents may be less likely to be captive riders than persons with lower educational degree. This effect may be strengthened by the fact that all households in this sample own a car. These households may be less sensitive to determinants influencing mode choice (e.g. expensive parking in the urban core) because they can afford to travel by car. Hence travel attitudes may have a higher impact on mode choice in this study compared to a population with a higher share of lower income classes and car ownership.

4.5.2 Policy implications

Interestingly, households with dissonant women and consonant men were more likely to choose suburban over urban core areas. Although women preferred the urban core they may be bound by other constraints (e.g. housing prices) or compromises with their partners to choose suburban areas. In general, women differ in their travel pattern and use of public space from men: their trips are shorter, they use more public transport (PT) and do more trips chauffeuring persons (VCÖ, 2010). Transport planning agencies and transport service providers may emphasize their strategies providing women with a good experience using PT and facilitating trip chaining. This may be beneficial in two ways. According to the results of this study, women's travel attitudes seem to be more influential for location choices than those of men and more affected by built environment in their mode choices. First, improving female user experience of PT may increase PT use and in the long-run may decrease the attractiveness of residential locations with poor PT service levels. Second, in this study women used more PT than MIT for commuting. Providing better PT service levels may improve women's access to labor markets. This is particularly pertinent since previous studies demonstrated that car access helped women to overcome spatial limitations to the job market (Chidambaram and Scheiner,

202; Gil Solá, 2016). Providing affordable residence with good PT access may also favor gender equality in the labor market.

This paper explains some of the potential interconnections between residential location and travel decisions. The results indicate that dissonant couples more often live in suburban areas characterized by a relatively poorer public transport access and higher car dependency. Although persons may prefer taking more environmentally friendly modes, they locate in more car-dependent areas. Households with a college degree and potentially higher income are less likely to locate in suburban areas. Both results may point to pressures in the residential housing market in the urban core of Vienna. With an anticipated population growth of 10% in Vienna between 2013 and 2025 (Stadt Wien, 2014a), housing demand will increase and further constrain the housing market. Population growth within Vienna is mostly expected in the suburban districts that are characterized by a "poorer" public transport access (out of the catchment area of high level or secondary public transport modes) and a higher use of MIT (Fersterer et al., 2019). Another challenge lies in the cooperation between transport and planning agencies of Vienna and its greater agglomeration area. The current tariff system and lack of tangential public transport routes hampers PT use between Vienna and its agglomeration (Stadt Wien, 2014b). These trends augment the challenges in providing attractive residential location and environmentally sustainable mobility services in Vienna and its agglomeration area.

Future studies may qualitatively explore in more detail negotiating processes for location choices and interaction in travel behavior between partners. Schwanen et al. (2007) found that men perform more out-of-home duties in more densely and mixed neighborhoods than men living in lower density and less diverse neighborhoods. Do more gender-equal households locate in densely urban neighborhoods, or do built environment characteristics favor more gender-equal behavior? Moreover, partners may adapt and converge their attitudes over time to avoid negotiating processes. As demonstrated in several studies, neighborhoods may shape attitudes, pointing to a reverse causality. It would be interesting to test the results of this paper in other geographical areas and with a larger sample. As previous studies indicated (e.g. for Germany Kuhnimhof et al., 2012), couples belonging to different generations may differ in their travel behavior, location choices and negotiating processes. It would be worth comparing these processes and choices between generations. It would be interesting to test results related to gender with a larger sample, more specifically if such effects change between renters and homeowners as Plaut (2006) suggested for the US. A larger sample also would allow for testing for differences between mandatory (commute) and discretionary trips since RSS may be more relevant for discretionary trips.

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4.6 Appendix

Table 4.9 Comparison of sample and population statistics

		Vienna		Lower Austria	
		population*	sample	population*	sample
Household size	2 persons	52%	64%	48%	53%
	3 persons	23%	17%	24%	22%
	4 persons	16%	15%	19%	20%
	5 and more persons	9%	4%	10%	5%
Gender	Men	48%	50%	49%	49%
Age	15 to 19	6%	2%	7%	2%
	20 to 24	8%	3%	7%	5%
	25 to 29	9%	7%	7%	9%
	30 to 34	9%	13%	7%	7%
	35 to 39	8%	10%	8%	9%
	40 to 44	9%	11%	10%	9%
	45 to 49	9%	12%	10%	9%
	50 to 54	8%	10%	9%	11%
	55 to 59	7%	10%	7%	12%
	60 to 64	6%	8%	7%	11%
	65 to 69	6%	6%	6%	7%
	70 and older	14%	8%	16%	9%
Educational degree	Primary education	26%	4%	24%	5%
	Secondary education	53%	60%	64%	72%
	Tertiary education	21%	36%	11%	22%

* Statistik Austria (2019a, 2019d, 2013)

Chapter 5

Conclusion

5.1 Summary

This doctoral thesis is embedded in the mobility biography literature and based on the understanding that daily travel behavior is to a large extent habitual as individuals rarely question their daily travel choices. Life events may trigger a deliberation process and cause individuals to scrutinize their travel behavior. This doctoral thesis concentrates on these moments of fundamental change when travel behavior is more likely to change. Three articles investigate causes of change and cause-effect relationships between life events, travel behavior and attitudes.

The first article uses 54 interviews conducted with residents of a small college town (Davis, California, US) following their bicycling behavior and attitudes towards bicycling over their life course. Three life events emerged to influence the level of bicycling or bicycling attitudes: parenthood, residential relocation and meeting a new partner. Most respondents related their bicycling experience and attitudes towards bicycling to their children. The impact of children on parental bicycling was non-linear over time, and varied throughout the child's development and between couples or partners. More women related their level of bicycling to their children, and this result was even more pronounced in relation to bicycling attitudes. Since the questionnaire did not include any child-related question social desirability response bias is likely to be low, lending greater credence to this result. New partners prompted participants to try out new types of bicycling and provided resources that facilitated or improved bicycling. The results provide evidence for a bi-directional relationship between bicycling attitudes and the level of bicycling. As life events trigger changes in one of these two variables they are likely to change the other variable as well. Four causal mechanisms emerged from the interviews explaining how life events induce change in bicycling attitudes or behavior. First, life events trigger a deliberation process that lead individuals to scrutinize their travel routines. Second, life events change social norms that favor or disincentivize bicycling and attitudes towards bicycling. Third, life events may unleash a latent demand as for instance bicycling infrastructure changes after relocation. Fourth, life events can change interest in destination and activities.

The second article uses data from a travel survey of faculty, staff and students at a US university that was conducted in the same college town as the previous study (Davis, California, US) over several years. One goal of this article was to assess the role of life stages potentially moderating the impact that life events have on travel behavior. Different mental and physical capacities, financial constraints, and social responsibilities that individuals face at different stages of life might enhance or dampen the effect of life events on travel behavior. In this study, four life stage groups were defined: millennials (currently aged 18–36) living alone or with roommates, millennials living with their partners, parents (of any generation) living with their children, and non-millennial adults (above 36 years old) living without their children. To analyze travel behavior over time, four modality types were defined including active travelers, car users, transit users, and multimodal travelers. This study used a Manifest Markov Model to estimate probabilities of switching modality types between two waves of the survey. The results indicate that life stage seems to not significantly moderate the effect life events have on travel behavior change. Life stage, however, affects travel behavior. The share of active travelers decreases across life stages, a result even more pronounced for women. Residential relocation is prominent as a life event since millennials living with their partners and parents living with their children relocated to another town more often than those in other life stages. In general, persons tend to stick to their transport mode supporting the argument that daily travel is to a large extent habitual. Particularly car users show a high state dependence.

As the first two studies pointed out, residential relocation may be a "window of opportunity" to change travel behavior. The third study concentrates on this life event and investigates in more detail the relationship between travel behavior and attitudes. Several studies have found evidence that individuals choose neighborhoods that allow them to travel with their preferred transport mode, a process defined as residential self-selection (RSS). Other researchers have discussed whether residential dissonance, individuals who do not live in neighborhoods matching their travel attitudes, contradicts RSS. Although several authors acknowledge that residential location may be an outcome of bargaining processes between household members only one study quantitively investigated RSS while considering this aspect. The goal of this article is to assess the effect of heterogeneity in travel attitudes between partners on RSS and residential dissonance. Using a dataset from the agglomeration area of Vienna (Austria), this study demonstrates that heterogeneity in travel attitudes partly explains residential dissonance. While only women's travel attitudes substantially influence neighborhood selection, they are also more affected in their travel behavior by neighborhood characteristics at their residence than their male partners. Depending on the neighborhood type of the residential area, travel attitudes have different effects on mode choice. A comparison of residents in the urban core with those living in suburban neighborhoods indicates that the influence of neighborhood type dominates the influence of travel attitudes on mode choice.

5.2 Discussion

This thesis contributes to the travel behavior literature by clarifying the complex cause-effect-relationships between life events, travel behavior and attitudes. The articles provide evidence for the influence of life events on travel behavior and attitudes that changed more often in the presence of life events and corroborate results found in other studies (Beige and Axhausen,, 2017, Chatterjee, 2013b, Clark et al., 2016). Next to evidence for travel behavior change, the results of the second article also provide support for state dependence and habitual daily travel consistent with findings of other recent studies (e.g. Chatterjee 2013a, 2013b, De Haas et al., 2018, Kroesen, 2014, Müggenburg et al., 2015). Particularly car users seem to be loyal and tend to stick to their mode, a finding that was also reported by De Haas et al. (2018) and Kroesen (2014).

All three articles address the role of life stage for travel behavior change. While the first discusses behavioral change over diverse life stages, the second compares travel behavior at different life stages and the third analyses persons at a specific life stage, namely couple households living with or without children. The results emphasize that persons behave differently at distinct life stages. For instance, as the second article reveals, the share of active travelers decreases throughout life stages. Millennials who lived alone or in shared apartments also experienced more life events than other life stage groups. Other studies provide divergent findings on the frequency of life events along the life course. While Oakil et al. (2016) explained a higher likelihood of switching from bicycling to car commuting at earlier life stages (persons aged 30 years or less) by more frequent changes in employment or residential location, Verhoeven et al. (2005) observed an increase in the number of life events with age. The second article of this thesis highlights that, contrary to our hypothesis, life stage does not alter the effect of life events on travel behavior change. This finding may be explained by the fact that life events and life stage can be correlated since life events may trigger a transition from one life stage to another.

The three articles take a different temporal perspective: while the first article analyzes behavior and attitudes over the life cycle of an individual, the second compares travel behavior over several years reflecting the medium run and the third article concentrates on a specific point in time. The longitudinal perspective allows detecting more complex relationships between life events and behavioral and attitudinal change. For instance, the qualitative, longitudinal approach of analysis in the first article allows detecting non-linear effects of children on parental bicycling that evolve, increase and decrease along the development stages of children. Comparing behavior and attitudes in the medium run allows assessing the effects of changes in the external environment on travel behavior while the cross-sectional data of the third article enables to explore more complex interaction between partners' travel behavior and attitudes.

This doctoral thesis revealed four causal mechanisms that explain how life events cause change in travel behavior and attitudes. Although the first paper in this doctoral thesis discussed these four causal mechanisms in relation to bicycling and attitudes towards bicycling they may also apply to other transport modes. The conceptual approach of this thesis (Chatterjee et al., 2013a) and particularly

findings in the first article emphasize that life events trigger a deliberation process though deliberative decisions may not always precede behavioral or attitudinal change. Persons may adopt a certain transport behavior because it is the common mode of transport in the city as highlighted by our findings. Social norms and networks may indirectly influence these decisions making them less deliberate (Goetzke and Rave, 2011).

Comparing the cause-effect relationship between attitudes and behavior, the theory of planned behavior suggests that attitudes influence and partly predict behavior. The results of this thesis generally support this reasoning and found evidence for the attitudinal influence on travel behavior. In addition, this thesis identifies a bi-directional relationship between bicycling attitudes and the level of bicycling. These findings corroborate the results by Kroesen et al. (2017) which point to a reverse causality between attitudes and behavior. In a different way, the third article also provides evidence for a reverse causality since travel attitudes influence a life event, in this case residential location, that in turn affects travel behavior. The causal direction of influence between life events, travel attitudes and behavior may change depending on the context.

The role of gender emerged in all three articles to explain the relationship between life events, travel attitudes and behavior. The first article shows that more women than men related their bicycling to their children, a result even more pronounced for bicycling attitudes and well documented by other studies (e.g. Chatterjee et al., 2013b). The second article reveals that the share of women in the active travelers group decreases throughout life stages. Interestingly, female and male millennials are equally represented in the active travel group though the share of female millennials significantly decreases when they have children. It seems that millennials show the same gender disparities with respect to active travel of older generations when they become parents. These results, however, are based on few observations and should be considered with caution and tested with a larger sample. With respect to residential location, the third article indicates that female and male partners differently influence residential location choices. Intra-household interaction matters for location choices since heterogeneity in travel attitudes among partners partly explains residential dissonance. The gender effects revealed by this thesis may be difficult to capture by only including a gender variable and provide support for methodological approaches that explicitly distinguish between female and male attributes and choices.

5.3 Policy recommendations

Most studies in the mobility biography literature highlight the “window of opportunity” for policy intervention that life events create by inducing travel behavior change (Müggenburg et al., 2015). Planners may make use of the deliberation processes triggered by life events to break with traveling routines and try out of other transport alternatives. This thesis supports this view and suggests potential policy interventions for different life events. Residential relocation stands out as a life event since planners at city and district level or the real estate industry already make use of this

momentum of change and have developed specialized mobility offers for new residents. Instead of constructing parking lots, real estate developers provide mobility concepts and special offers at the residence including offers to share modes between residents (e.g. electric vehicles, bikes) and transport infrastructure such as charging infrastructure for electric vehicles or bike repair stations (VCÖ, 2016). For instance, in the Hunziker Areal in Zurich (Switzerland), new residents do not own cars and may use electric (freight) bikes, bike trailers or rent an electric vehicle from the real estate cooperative that manages and owns the apartments (Mehr als Wohnen, 2020). Likewise, a mobility agency in a new district in Mannheim (Germany) offers mobility packages including the use of electric freight bikes or electric vehicles (Petermann, 2018). In residential districts in Freiburg (Germany) planners disincentivize car use in residential districts by limiting car access and by providing car parking only in garages at the district fringe (Petermann, 2018). Multimodal offers at the residence may provide alternatives for strict car users to switch at least in part to other modes as supported by the results of this thesis.

Some researchers question the actual "window of opportunity" created by life events (De Haas et al., 2018, Scheiner, 2020). For instance, high state dependence among car users shows some limits of the flexibility to change even in the presence of life events (De Haas et al., 2018). For instance, Scheiner (2020) points to the difficulty of disincentivizing car use of parents particularly with two or more children. Relating to the life event of residential relocation, households may prioritize other than travel-related residential location criteria (Ettema and Nieuwenhuis, 2017) or trade off larger commute distance for more living space (Thierstein et al., 2016). Another limit to the "window of opportunity" of residential relocation relates to social and economic constraints of housing (Thierstein et al., 2016). Mobility packages for recent movers are often proposed in newly developed residential areas often not affordable by all population groups. The third article of this thesis indicates that a considerable part of households who dislikes traveling by car and prefers traveling by public transport or non-motorized modes lives in suburban areas in Vienna's agglomeration that are relatively poorly served by public transport. On the contrary, households with a college degree are less likely to locate in suburban areas. These results may indicate pressures on the housing market and show limits of the attitudinal influence on location and mode choices. Some persons may prefer to travel with more environmentally friendly modes but cannot afford to live in walkable and bicycling-friendly neighborhoods. These results emphasize the importance of integrating housing and transport planning and the provision of affordable housing to fully make use of the "window of opportunity" offered by residential relocation.

Another life event important for travel behavior change is parenthood. As the first article points out, children may foster parental bicycling and ameliorate their attitudes towards bicycling. Associations incentivize active travel to school and parents to bicycle to school with their children (e.g. in the US partners of the Safe Routes to School National Partnership). Though bicycling initiatives targeting children and their parents are rarely coordinated on district or high urban planning level. In the UK, recent efforts aim to deter parents from using their cars to bring children to school and try to increase road safety and air pollution around schools by limiting car access in these areas (Tayler, 2018).

Transport planning agencies and transport service providers may foster their efforts of providing women with a good public transport user experience. According to the results of this thesis, women's travel attitudes seem to be more influential than those of their male partner for selecting a neighborhood type for residential location. If women increasingly appreciate public transport use residential locations that are less well serviced by public transport may become less attractive in the long run. Consistent with the results of this thesis, several studies have demonstrated that women use more often public transport for commuting than men and car access improves women's access to labor markets (Chidambaram and Scheiner, 2020; Gil Solá, 2016, VCÖ, 2010). Providing women with good public transport service may reduce gender disparities in labor market access and may incentivize use of environmentally friendly modes of the whole household.

5.4 Suggestions for further research

It would be interesting to explore in more detail time-lagged effects of life events. Persons may adapt or react later to a life event making it more difficult to capture behavioral responses to life events with survey questions. For instance, persons may purchase a car in the perspective of the birth of a child (Oakil et al., 2014). Qualitative research insights could inform survey questions that consider prospective or delayed reactions. Another avenue for future research may relate to generational differences. Do millennials show the same gender differences in their travel behavior than older generations? Several studies have found differences in travel behavior and lifestyle choices between the millennial and older generations (Delbosc and Nakanishi, 2017; Kuhnimhof et al., 2012; Licaj et al., 2012). Are these differences due to more fundamental generational differences or due to a delay of life stages (parenthood, purchase of property)? It would be interesting to test the results about millennials, who reproduce gender disparities of older generations once they reached parenthood, with a larger sample. Future studies may further investigate reverse causality between attitudes and behavior since persons may adapt their attitudes towards a transport mode through the experience of using it as reported by the results of this doctoral thesis. The mobility biography approach provides a consistent analytical framework to study life events, travel attitudes and behavior and offers new research avenues to link short-, medium- and long-term decisions.

Chapter 6

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Appendix A

Statements of authors' contribution

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May 03, 2020

Author's contribution statement

I certify that Julia Janke contributed at least 50% of the work for the following article:

Janke, Julia, Thigpen, Calvin, Handy, Susan. 2020. Examining the effect of life course events on modality type and the moderating influence of life stage. Transportation (2020): 1-36. https://doi.org/10.1007/s11116-019-10077-9

I also certify that Julia Janke contributed at least 50% of the work for the following article:

Janke, Julia, Handy, Susan. 2019. How life course events trigger changes in bicycling attitudes and behavior: Insights into causality. Travel Behaviour and Society (16): 31-41. https://doi.org/10.1016/j.tbs.2019.03.004

Sincerely,

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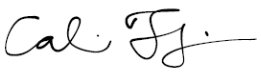
May 04, 2020

Author's contribution statement

I certify that Julia Janke contributed at least 50% of the work for the following article:

Janke, Julia, Thigpen, Calvin, Handy, Susan. 2020. Examining the effect of life course events on modality type and the moderating influence of life stage. Transportation (2020): 1-36. https://doi.org/10.1007/s11116-019-10077-9

Sincerely,



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