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The multimodal majority? Driving, walking, cycling, and public transportation use among American adults

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Abstract Multimodality, the use of more than one mode of transportation during a specified time period, is gaining recognition as an important mechanism for reducing automobile dependence by shifting trips from automobiles to walking, cycling, or public transportation. Most prior research on multimodality focuses on Western European countries. Based on the 2001 and 2009 National Household Travel Surveys, this paper analyzes trends and determinants of multimodal car use in the U.S. during a typical week by distinguishing between (1) monomodal car users who drive or ride in a car for all trips, (2) multimodal car users who drive or ride in a car and also use non-automobile modes, and (3) individuals who exclusively walk, cycle, and/or ride public transportation. We find that during a typical week a majority—almost two thirds—of Americans use a car and make at least one trip by foot, bicycle, or public transportation. One in four Americans uses a car and makes at least seven weekly trips by other modes of transportation. Results from multinomial and logistic regression analyses suggest there may be a continuum of mobility types ranging from monomodal car users to walk, bicycle, and/or public transportation only users—with multimodal car users positioned in-between the two extremes. Policy changes aimed at curtailing car use may result in movements along this spectrum with increasing multimodality for car users.

Keywords Multimodality · USA · Trends 2001–2009 · Multimodal and monomodal car users · Walk, bicycle, and public transportation only users · Individual travel behavior

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Introduction

In the U.S., over 90 % of households own at least one automobile, most adults (89 %) are licensed drivers, and 86 % of trips are made by car (USCB 2009; USDOT 2009). Reliance on the automobile for the vast majority of trips is associated with social, environmental, and economic costs (Banister 2005; Forsyth et al. 2009; Lucas 2011; USDOT 2010). To combat these externalities, policymakers at all levels of government seek to reduce reliance on automobiles and increase the use of public transportation, walking, and cycling. Current high levels of car use and spread out low-density development patterns in the U.S. suggest that if policies to encourage alternatives to the car are successful, American car users will likely respond by switching some trips from the car to walking, cycling, or public transportation—while continuing to use a car for other trips.

Multimodality, the use of more than one mode of transportation during a specified time period, is gaining recognition as an important mechanism for reducing automobile dependence and increasing the sustainability of transportation systems by shifting some trips from automobiles to other modes (Chlond 2012; Kuhnimhof et al. 2012b; Nobis 2007). For example, stagnating overall travel demand in western European countries has been connected to young adults who are displaying increasingly multimodal travel behavior and more diverse use of modes of transportation including driving, walking, cycling, and public transportation (Kuhnimhof et al. 2012a; Nobis 2007). TRB (2002) highlighted multimodality as a central component of "smart growth" initiatives. Additionally, multimodality has been discussed as an important part of a resilient transportation system in the face of major external shocks to the system (IBM 2011; Rietveld et al. 2001). Greater consideration of multimodality in travel demand forecasting has been suggested as a strategy for better representing non-motorized modes in standard regional travel demand forecasting models (Clifton and Muhs 2012; Forsyth et al. 2009; Litman 2012).

Most research on multimodality focuses on Western European countries. To date little is known about the degree to which American adults combine different modes of transportation during a week, day, or chained trip. Only a few studies provide regional or local profiles of multimodal travelers in urban areas in the U.S. (Block-Schachter 2009; Diana and Mokhtarian 2009).

Based on the 2001 and 2009 National Household Travel Surveys (NHTS), this paper analyzes walking, cycling, public transportation use and car use (including both drivers and passengers) by American adults. For weeks, days, and chained trips, descriptive statistics identify levels and trends of multimodal travel behavior distinguishing among (1) *monomodal car users* who rely on the car for all trips, either as a passenger or driver, (2) *multimodal car users* who use the car and also walk, cycle, and/or ride public transportation, and (3) individuals who do not use a car and rely *exclusively on walking, cycling, and/or public transportation*. Next multinomial and logistic regressions help distinguish profiles of individuals in the different weekly modality groups. Weekly data tend to capture most of the typical variability in everyday habitual travel behavior (Block-Schachter 2009; Kuhnimhof et al. 2006; Nobis 2007).

The goals of the paper are to provide an overview of the recent multimodality literature and to identify levels and determinants of multimodal travel in the U.S. A better understanding of multimodal travel may facilitate the development of policies aimed at increasing walking, cycling, and public transportation use. The comparison of multimodal and monomodal car users are of particular interest for policymakers who seek to reduce car use. The analysis identifies differences between car users who already use other means of transportation and those who solely rely on their cars. This can help identify target groups for policies to encourage current monomodal car users to also use other modes for some trips. Moreover, car users already using other modes, at least occasionally, could be targeted to increase walking, cycling, and public transportation use. Even occasional use of alternatives to the car may have significant impacts on long-term travel behavior, because infrequent use of a mode may familiarize a traveler enough to enable increased use of that mode of transportation over time (Chlond 2012; Diana and Mokhtarian 2009; Kuhnimhof et al. 2006; Oram and Stark 1996).

Literature review

Research to date on multimodality suggests that travel over time is more varied than otherwise captured by the more common analyses focusing on individual trips (Block-Schachter 2009; Schonfelder and Axhausen 2010; USCB 2010). While a range of definitions are used, in general multimodality is understood as the use of at least two modes of transportation during a specified time period (Block-Schachter 2009). By contrast, monomodality is defined as the use of a single mode during a specified time period. Some studies incorporate intensity thresholds to further distinguish multi- and monomodality. For example, one study defined individuals as having a 'monomodal tendency' if they used a single mode for over 70 % of all trips (Nobis 2007). Some studies of multimodality exclude 'walking' as a mode of transport—based on the assumption that survey respondents often forget to report short walk trips (Kuhnimhof et al. 2006; Nobis 2007). Intermodality is a specific form of multimodal behavior referring to the use of multiple modes of transportation within one trip or a chain of trips. For example, public transportation trips are often intermodal trips, because individuals typically access public transportation stops or stations by foot, bicycle, or car (Clifton and Muhs 2012; Givoni and Rietveld 2007; Nobis 2007; Rietveld et al. 2001).

Data sources for the study of multimodality

Three main types of data are used in studies of multimodality: (1) multi-week travel surveys; (2) weeklong travel surveys; and (3) one-day travel surveys with questions about travel during longer time periods (Kuhnimhof et al. 2006; Nobis 2007). Most studies suggest that survey periods of one week tend to capture typical variability in everyday habitual travel behavior (Block-Schachter 2009; Kuhnimhof et al. 2006; Nobis 2007). Longer multi-week survey periods additionally capture occasional travel behavior (Schlich and Axhausen 2003).

Multi-week surveys tend to have comparatively small sample sizes. For example, the six week MobiDrive data set is based on 361 individuals in two German cities (Axhausen et al. 2002). Moreover, compared to single-day travel surveys, multiday data collection efforts may face greater difficulty in recruiting participants, and suffer from a higher rate of participant drop out (Schonfelder and Axhausen 2010). Multimodality has also been studied using data derived from large single-day travel surveys that additionally contain questions about habitual or occasional mode use (Kuhnimhof et al. 2006; Nobis 2007). A limitation of this type of data is that reporting on travel behavior during the prior week is more prone to recall error, particularly for short trips, than data collected from travel diaries for a specific travel day.

Key findings on multimodal car users in the recent literature

Since the 1990s, improved travel surveys that better capture non-automobile travel and variability of travel over time have facilitated an increasing number of studies of multimodality. Our analysis is informed by key findings about multimodal car users published since 2005. Table 1 highlights the authors, year, geographic area of the study, and findings on the relationship between explanatory variables and multimodal car use. Most studies in Table 1 have examined data from Germany or The Netherlands. Only a few have analyzed multimodal car use in the U.S. These studies have been focused on specific urban areas or regions in the U.S. and not nationally representative samples (Block-Schachter 2009; Diana and Mokhtarian 2009).

Household car availability and having a driver's license are negatively associated with multimodal car use and positively correlated with monomodal car use (Block-Schachter 2009; Chlond 2012; Diana and Mokhtarian 2009; Kuhnimhof et al. 2006, 2012a; Nobis 2007; Vij et al. 2011). Authors argue that having a driver's license and easy access to a car increases the convenience of driving for all trips and reduces the likelihood of choosing other modes of transportation—even for some trips (Kuhnimhof et al. 2006).

Younger age, higher education, living in households without children, and better public transportation access are positively associated with multimodal car use. The authors hypothesize that more multimodal car travel among the young is explained by lower car availability and incomes among young people, access to steeply discounted public transportation tickets for students, and increased awareness of the negative externalities of car travel among this group (Chlond 2012; Kuhnimhof et al. 2006, 2012a; Nobis 2007). Only one recent study suggests that the elderly may also be multimodal car users at higher rates than the middle-age group (Nobis 2007).

Several studies indicate that increased educational attainment is positively associated with multimodal car use (Diana and Mokhtarian 2009; Kuhnimhof et al. 2006, 2012a). College students often live on or near campus, do not own a car, have free or reduced transit passes, and get around campus by walking, cycling, or riding public transportation. The authors speculate that this experience may familiarize students with alternatives to the car and make it more likely that they will continue to combine walking, cycling, or riding public transportation with car use after graduation.

Several studies evaluate the effect of a household's life cycle "stage" on multimodal car use (Kuhnimhof et al. 2006; Nobis 2007; Vij et al. 2011). Kuhnimhof et al. (2006) found that adults in a household with children were more likely to be car users. Nobis (2007) found lower rates of multimodal car use and more monomodal car use among individuals in households with children—likely due to more complicated travel patterns involving dropping-off and picking-up children. Public transportation access has also been highlighted as an important factor contributing to multimodal car use (Block-Schachter 2009; Brons et al. 2009; Givoni and Rietveld 2007; Kuhnimhof et al. 2006). The authors suggest that easy access to public transportation makes public transportation an attractive substitute for car use for at least some trips.

Gender differences in multimodal car use are small and may be diminishing, and often seem to depend on the particular modal combinations examined. Nobis (2007) found men to drive and cycle more than women; but her study also showed that women were generally more likely to combine driving with other modes than men. Vij et al. (2011) found multimodal car use to be significantly higher among women. Kuhnimhof et al. (2012a) found men travel more by car than women, but also that the gender gap was diminishing regarding licensure, car availability, and automobile travel. A study of multimodal

Table 1 Key determinants of multimodal car use identified in selected studies published since 2005

Factor	Studies	Level of analysis (study area)	Multimodal car use findings
Age	Kuhnimhof et al. (2006), Nobis (2007), Kuhnimhof et al. (2012); Chlond (2012)	National (Germany); Sub-National (Karlsruhe, Germany)	Consensus that younger individuals are more likely multimodal drivers; some evidence that older adults (65+) may be more multimodal drivers
Car availability	Kuhnimhof et al. (2006), Nobis (2007), Block-Schachter (2009); Diana and Mokhtarian (2009), Vij et al. (2011), Chlond (2012), Kuhnimhof et al. (2012)	National (Germany); Sub-National (Karlsruhe and Halle/Salle, Germany; Massachusetts Institute of Technology university community; San Francisco Bay Area, CA, and France)	Car availability is negatively associated with multimodal car travel (and positively associated with monomodal driving)
Education	Kuhnimhof et al. (2006), Diana and Mokhtarian (2009), Kuhnimhof et al. (2012)	National (Germany); Sub-National (San Francisco Bay Area, CA, and France)	Higher education is positively associated with multimodal car use
Gender	Nobis (2007), Block-Schachter (2009), Vij et al. (2011), Kuhnimhof et al. (2012)	National (Germany); Sub-National (Karlsruhe and Halle/Salle, Germany; Massachusetts Institute of Technology university community)	Women are slightly more likely to be multimodal drivers than men, though differences may be small and/or diminishing
Licensure	Kuhnimhof et al. (2006), Nobis (2007), Kuhnimhof et al. (2012)	National (Germany)	Having a driver's license is negatively associated with multimodal car use
Life cycle stage	Kuhnimhof et al. (2006), Nobis (2007), Vij et al. (2011)	National (Germany); Sub-National (Karlsruhe and Halle/Salle, Germany)	Smaller households are more likely multimodal car users
Public transport access	Kuhnimhof et al. (2006), Givoni and Rietveld (2007), Brons et al. (2009), Block-Schachter (2009)	National (Germany; The Netherlands); Sub-National (Massachussetts Institute of Technology university community)	Better access to public transport is positively associated with multimodal car use

commuting based on the MIT university community found differences in combinations of modes of transportation by gender (Block-Schachter 2009).

Analysis

Data sources and definitions of multimodality

Our analysis of multimodal car use in the U.S. utilizes data from the chained-trip, daily trip, and person data files of the 2001 and 2009 NHTS. Most of the data collection methods and variable definitions are similar between the two surveys, allowing an analysis of trends over time (Buehler and Hamre 2013; USDOT 2001, 2009). Each survey combined telephone interviews with single-day travel diaries to collect information about household members and their travel behavior during a randomly assigned travel day. The surveys also included questions about the number of trips made by different modes of transportation in the past week or months. The final 2001 sample included 160,758 individuals and 642,292 daily trips, while the 2009 sample included 324,184 individuals and 1,167,321 daily trips. Both surveys used stratified sampling and are representative of the U.S. Our analysis applies the relevant 2001 and 2009 weights to ensure statistically representative estimates.

As for most studies of multimodality, the main focus of our analysis is on the weekly data to capture variability in habitual travel; but we also provide descriptive statistics about multimodal car use during days and for chained trips. Table 2 presents our definitions of the three modality groups at the week, day, and chained trip levels. We distinguish: (1) *monomodal car users* who used a car for all trips; (2) *multimodal car users* who used a car and at least one other mode of transportation; and (3) *walk, bicycle, public transportation only users (wbt-only)* who did not use a car. Because some studies classify drivers who only occasionally use other modes as individuals with strong 'monomodal' tendencies, part of our analysis additionally investigated the intensity of multimodality. We used different cut-off values for multimodality, requiring 3, 5, or 7 trips by foot, bicycle, or public transportation in addition to car use. Our definitions were guided by the previous research presented above as well as data availability in the NHTS.

The analysis of multimodal car use at the day level relies on mode use data gathered from the NHTS trip file, which is based on a trip diary recording all trips made and mode(s) chosen during a randomly assigned travel day. NHTS defines trips as travel between two addresses, thus excluding trips within one address, such as trips within a shopping mall or from a building to the mailbox at the end of the driveway. An exception to this rule were walk and bike trips that originated and ended at home without any intermediate stops (e.g. "going for a walk"). Such trips were split into two trips, one defined as the ''outgoing trip'' to the farthest distance from home, and the other trip defined as the ''in-bound trip'' back home. NHTS only recorded the main mode of transportation for trips from one address to another, thus excluding short access and egress trips, such as trips between buildings and the car or trips to and from public transportation. We aggregated the trip level data to the person level, by counting the number of trips made by mode of transportation for each respondent—excluding trips by intercity rail and intercity bus, as well as air planes to be consistent with the NHTS definition of public transportation used for the weekly data.

Table 2 Overview of definitions of modality groups for chained trips, days, and weeks

Level	Monomodal car users	Multimodal car users	Walk, bicycle, and/or public transportation only users
Week	All daily trips by car and no weekly trips by walking, bicycle, or public transportation	At least one daily trip by car and at least one weekly or daily trip by walking, bicycle or public transportation	Weekly trips by one or a mix of bicycle, foot, and/or public transportation (but not by car)
Day	All daily trips by car	At least one daily trip by car and at least one trip by walking, bicycle, or public transportation	Daily trips by one or a mix of bicycle, foot, and/or public transportation (but not by car)
Trip chain	All trips in a chain of trips by car	At least one trip in a chain of trips by car and at least one trip in the trip chain by bicycle, foot, or public transportation	Trips in a chain of trips by one or a mix of bicycle, foot, and/or public transportation (but not by car)

Our analysis of multimodal car use at the week level relies on the NHTS person file, which contains questions about the number of trips made by walking and cycling during the previous week and the number of trips by public transportation in the past one or two months (2001 and 2009 dataset respectively) (USDOT 2001, 2009).[1] NHTS also includes information about the usual main commute mode of transportation during the previous week—including driving to work. However, NHTS did not provide data about overall frequency of car use in the previous week or month. Thus, our data for weekly driving are based on car use during the assigned travel day gathered from the trip diary as well as information about the usual mode for the commute to work during the last week. The lack of additional weekly car-use information for trips other than the usual commute implies that we may overestimate the share of those who solely rely on walk, bicycle, and public transportation during the week and underestimate the share of weekly multimodal car users.

The analysis of multimodal car use at the trip-chain level uses a special NHTS dataset of chained trips prepared by USDOT. In compiling this dataset, USDOT defines chained trips as "trips that are linked together (chained) between two anchored destinations (home, work, other)" (USDOT 2009). A chained trip is considered "a series of trips between two anchors" where the dwell time at intermediate destinations is 30 min or less (USDOT 2009). For example, walking to a neighbor's house and then carpooling to work would constitute an intermodal trip chain combining walking and driving. USDOT's classification resulted in a special dataset comprised of only trips that were part of a chained trip—about 18 % of all trips.

The NHTS limits our analysis of multimodality in several ways. First, weekly data included in the NHTS rely on self-reported estimates of the number of past trips by walking, cycling, and public transportation. These estimates are likely not as reliable as information from travel diaries, where respondents record each trip made. Our analysis attempts to mitigate this potential problem by defining multimodality based on making at least one trip by walking, cycling, or public transportation during the last week. Thus, accuracy about the exact number of walk, bike, and public transportation trips made in the previous week and associated recall errors are less relevant as long as respondents remember that they made at least one trip by that mode. Second and as explained above, NHTS did not include any information about car use during the past week (other than driving for the usual commute to work). Thus, our weekly data likely overestimate the share of those who did not drive. Third, we excluded individuals who did not report any trips for the assigned travel day. Even if they reported walk, bike, or public transportation trips during the week, missing information about their car use during the travel day inhibited analysis at the day and chained trip levels as well as accurate categorization into one of the modality groups at the week level. Last, the 2009 NHTS survey only asked respondents older than 15 about travel during the last week. Thus, our analysis excludes children 15 years of age and younger. Many analyses of multimodality exclude children who cannot drive, because children legally have to rely on others (often their parents) if they wish to travel by automobile (Kuhnimhof et al. 2006; Vij et al. 2011).

[1] We divided the frequency of public transportation use for one or two months by four or eight weeks to get average weekly rates. If our calculations yielded less than one public transportation trip per week, individuals were classified as not weekly public transportation users. NHTS data for public transportation use in the past 4 or 8 weeks only include local public transportation.

Descriptive results

Trends in mono- and multimodality

Figure 1 presents trends in mono- and multimodality at chained trip, day, and week levels between 2001 and 2009. As reported by other studies, longer time periods of observation capture more variability in mode choice. In 2009, most chained trips were made exclusively by automobile (89.8 %). During a travel day a large majority of Americans also relied solely on automobiles to get around (77.9 %). However, less than a third (28.0 %) reported exclusively using the car for all trips during the past week. In fact, during the past week the majority of respondents (64.9 %) made at least one trip by another mode of transportation in addition to car use. The share of those who combined driving with at least one other mode is much smaller at the day (14.1 %) and chained trip (4.0 %) levels. In 2009, during a typical week 7.1 % of Americans did not drive at all and relied solely on walking, cycling, and/or public transportation.

Compared to 2001, monomodal car users comprised a smaller share of the population in 2009 at the chained trip (−1.7 %), day (−1.8 %), and week (−1.4 %) levels, while wbt-only users accounted for a greater share at the chained trip, day, and week levels. The share of multimodal car users fell at the chained trip level (−0.6 %) and increased slightly at the day (+0.2 %) and week level (+0.2 %) between the two years.

A comparison of respondents classified as monomodal during the travel day and multimodal during the week (not displayed in Fig. 1) shows that in both survey years a significant portion of daily monomodal car users were weekly multimodal car users: 63.1 % in 2001, 64.1 % in 2009. These are individuals who indicated that they used at least one mode of transportation in addition to the car during the week, but drove exclusively during the travel day. Similarly, about one tenth of daily walk, bicycle, and/or public transportation only users were weekly multimodal car users (9.8 % in 2001, 11.2 % in 2009).

Modes of transportation used by multimodal car users

In 2009, the vast majority of multimodal car users reported walking as their only non-automobile mode of transportation at the chained trip (83.3 %), day (84.9 %), and week (79.8 %) levels (Fig. 2). The use of three different modes of transportation was more common during the week (17.1 %) than at the day (5.4 %) and chained trip (2.8 %) level. In 2009, during the last week 7.9 % of respondents used a car, walked, and cycled, and 8.0 % combined car use, walking, and public transportation. In 2009, only 1.0 % of respondents reported the use of all four modes—car use, walking, cycling, and public transportation—during a typical week.

Variability of multimodality by driver versus passenger status and trip purpose

Our definition of car users and the NHTS data on the week level combine both drivers and passengers into one group. Day level data allow for a comparison of car drivers and passengers: 73 % of daily monomodal car users reported driving for all trips, 11 % were passengers on all trips; and 16 % reported trips as both a driver and passenger. Among multimodal car users, 66 % reported driving only, 11 % were passengers only, and 23 % reported trips as both car passengers and drivers.

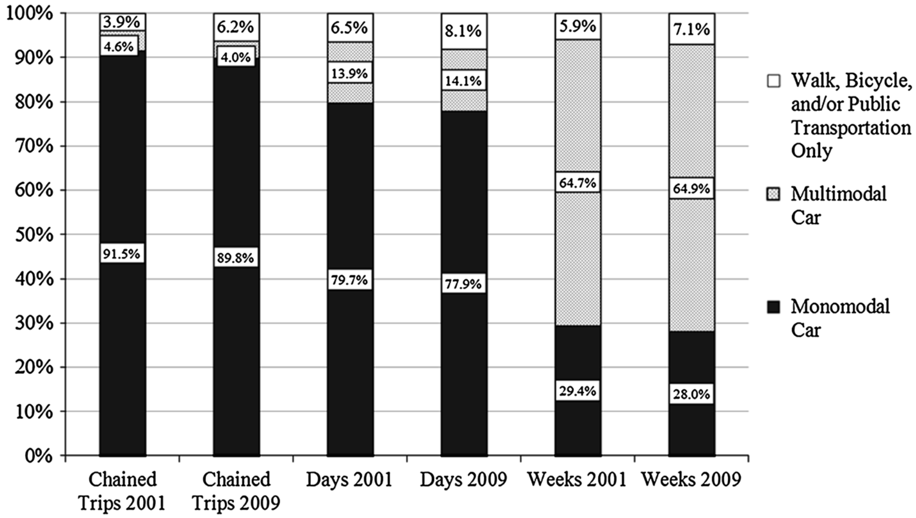

Fig. 1 Trend in shares of monomodal car users, multimodal car users, and walk, bicycle, and/or public transportation only users at chained trip, day, and week levels in the U.S., 2001–2009. *Source* calculated by authors based on NHTS 2009 Version 2.0

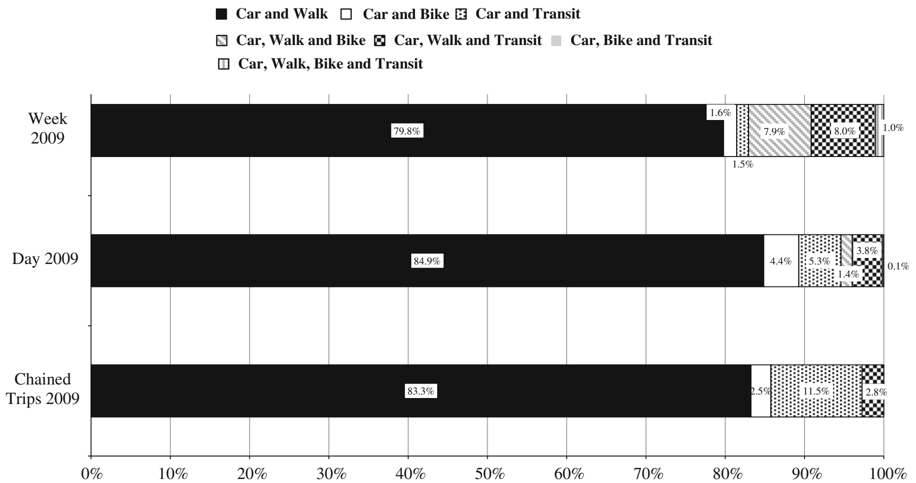

Fig. 2 Combinations of modes of transportation used by multimodal car users at chained trip, day, and week levels in the U.S., 2009. *Source* calculated by authors based on NHTS 2009 Version 2.0

Combining utilitarian and recreational trip purposes in our analysis may hide distinctions between groups of multimodal individuals. For example, multimodal car users whose only non-car trips are for recreational purposes such as ‘walking the dog’ or ‘going for a walk/bike ride’ may be different from multimodal car users who report non-car trips for utilitarian purposes. However, our ability to investigate these differences is limited, as NHTS week level data do not report trip purpose. Nevertheless, day level trip purpose data are available, albeit in categories that combine recreational and utilitarian purposes such as ‘walking the dog’ and ‘going to the veterinarian’. Excluding walk and bicycle trips with the purpose ‘walking the dog/visit to veterinarian’ from our analysis decreases the share of multimodal car users at the day level from 14.1 to 12.8 % and increases the share of monomodal car users from 77.9 to 80.0 %. Additionally excluding the trip purposes ‘go to gym/exercise/sport’ and ‘rest/relaxation’ results in an 8.0 % share of multimodal car users and an 84.9 % share of monomodal car users. However, because the trip purpose categories do not completely isolate recreational and utilitarian trips, these estimates can only serve as approximations. Because the distinction between recreational and utilitarian trips may relate to occasional versus regular use of non-car modes, we investigated intensity levels of multimodality, as described in the next section.

Intensity of multimodality for multimodal car users

The analysis above defines multimodal car users as those who drive and make at least one trip by another mode of transportation. Some studies classify drivers who only occasionally use other modes as individuals with strong ‘monomodal car use tendencies’. Figure 3 shows how the share of those classified as multimodal car users decreases if the cut-off for the multimodal car user category requires at least 3, 5, or 7 trips by non-automobile modes. For example, in 2009, at the week level 48.2 % reported car use in combination with at least 3 trips without a car—compared to 64.9 % who use a car and make at least 1 trip by an alternative to the car. Only 23.3 % of multimodal car users report car use in combination with 7 or more trips by another mode of transportation during the week. At the week level the population shares of multimodal car users increased more significantly between 2001 and 2009 for those making 5+ and 7+ walk, bicycle, and/or public transportation trips ($\sim$+2 %) than for those making 1+ or 3+ trips by those modes.

Similar to the week level, the day and chained trip levels show lower shares of multimodal car users when applying more stringent cut-off criteria. For example, only 0.2 % of multimodal car users reported 3+ trips by alternative modes of transportation during a chained trip—compared to 4.0 % making at least 1 additional trip by walking, cycling, and/or public transportation. During a day 3.0 % used a car and made 3+ trips by alternative means of travel—compared to 14.1 % who used a car and made at least 1 trip by another mode of transport.

Multivariable analysis of modality groups by demographic, socioeconomic, and land-use characteristics

Two multinomial logistic (MNL) regressions compare determinants for individuals to fall into the following categories. Model 1 compares weekly multimodal car users who make at least one trip without a car (*multimodal 1+*), weekly monomodal car users, and weekly wbt-only users (Model 1). Model 2 compares weekly multimodal car users who make between one and six trips without a car (*multimodal 1–6*), weekly multimodal car users who make at least seven trips without a car (*multimodal 7+*), weekly monomodal car users, and weekly wbt-only users (Model 2). To further distinguish between groups of multimodal car users and monomodal car users, we estimated a series of logistic regressions comparing sub-groups of multimodal to monomodal car users.

The literature review and data availability in the NHTS guided the choice of explanatory variables. Demographics are measured through gender (male/female), race/ethnicity (white/non-white), age group (16–24, 25–34, 35–49, 50–64, 65+), household life cycle (singles, 2+ adults no children, and adults with children), driver’s license status (yes/no), and education beyond high school (yes/no). Socio-economics of respondents are captured

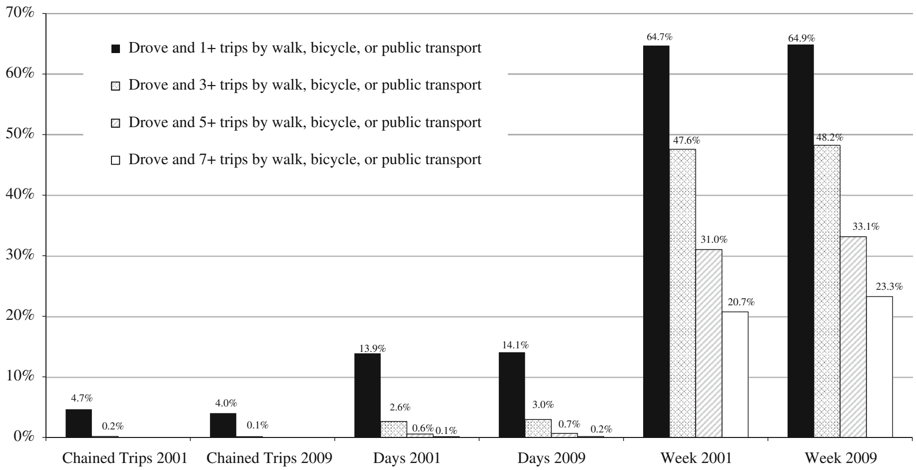

Fig. 3 Trend in share of multimodal car users by different intensity cut-off values at chained trip, day, and week levels in the U.S., 2001–2009. *Source* calculated by authors based on NHTS 2009 Version 2.0

through employment status (yes/no), household income quartiles, and car access (0, 1, 2, 3+ vehicles per household). Land-use is measured by population density at place of residence (<10,000 vs. 10,000+ people per square mile) and household access to rail-based public transportation (yes/no). Results are presented as adjusted odds ratios (AORs) identifying each population sub-group's likelihood of falling into a modality group relative to a specific reference group assigned the base value 1.00. For each AOR the level of statistical significance is indicated at either $p < 0.01$ or $p < 0.05$.

Multinomial logistic regression analyses comparing monomodal car users, multimodal car users, and walk, bicycle, and/or public transportation only users

Table 3 presents results for two MNL regressions, which are based on the same weekly data from the 2009 NHTS and both use monomodal car users as the reference/base outcome. Model 1 combines all car users with at least one non-car trip during the previous week into one single multimodal car user category. By contrast, Model 2 distinguishes between multimodal car users with 1–6 trips by non-automobile modes and multimodal car users with 7 or more trips on foot, bicycle, and/or public transportation. Both models also compare wbt-only users to monomodal car users. Available statistics for each model indicate that all variables have joint significance (LR-Test $p < 0.01$) and that multicollinearity is not a significant concern (VIF <5, Tolerance >0.2, Condition Index <30). Pseudo R-squared values range between 0.04 and 0.15. Results from Hausman-McFadden and Small-Hsiao tests generally indicate that the independence of irrelevant alternatives (IIA) assumption holds.[2]

[2] As is not uncommon, some tests of the IIA assumption failed. We estimated a series of binary logistic regression models comparing individual pairs of modality groups, such as monomodal car users versus multimodal car users; and monomodal car users versus wbt-only users. Comparison of results of the MNL and the binary logistic models showed that the signs and significance of coefficients were stable and that the magnitude of coefficients was similar for most variables. The only dissimilarity was that the MNL showed smaller differences within the age and car ownership groups. The binary models had different sample sizes

Column 1 of Model 1 compares multimodal 1+ car users to monomodal car users. Men were more likely than women to be multimodal 1+ car users. Similarly, whites were more likely to be multimodal 1+ car users than other race/ethnicity groups. Compared to other age groups, individuals 65 and older were least likely to be in the multimodal 1+ car user category. Singles were more likely multimodal 1+ car users than persons in households with two or more adults and no children. Higher education and higher income levels were associated with a greater likelihood to be a multimodal 1+ car user. Employed individuals were less likely to be multimodal 1+ car users than persons not employed. Owning a car and higher levels of car ownership were associated with a lower likelihood to be a multimodal 1+ car user. Licensed drivers were more likely multimodal 1+ car users than those without a driver's license. Population density and rail access were positively associated with multimodal 1+ car use.

Odds ratios for the comparison between wbt-only and monomodal car users in column 2 of Model 1 show that the sign and significance for gender, age group, education, employment status, the highest income quartile, car ownership, population density, and rail access are similar to coefficients for the multimodal vs. monomodal 1+ car user comparison in column 1. The magnitude of coefficients for age, gender, employment status, population density, and rail access are greater ($p < 0.01$)[3] for the comparison of wbt-only users vs monomodal car users than in column 1. The magnitude of coefficients for car ownership is significantly smaller in column 2 than column 1 ($p < 0.01$). Significance and/or sign of coefficients in column 2 and 1 differed for some variables. In contrast to column 1, race/ethnicity was not statistically significant for the comparison of wbt-only and monomodal car users. In contrast to coefficients for multimodal 1+ car use in column 1, lower income was positively associated with wbt-only versus monomodal car use, while having a driver's license, being single, and being in households with children were negatively associated with wbt-only versus monomodal car use.

As shown above, multimodal car use can be defined using different cut-off values based on the intensity of multimodality. Model 2 presents results from a MNL regression distinguishing monomodal car users as the base category from multimodal *car users who make 1-6 non-car trips* per week (labeled 'column 3'), multimodal *car users who make 7 or more non-car trips* per week (labeled 'column 4'), and *wbt only* users (labeled 'column 5'). Most coefficients for the multimodal car users in Model 2 (columns 3 and 4) are consistent in sign and significance with those presented in column 1 (for Model 1) ($p < 0.01$). For each independent variable, the odds ratio for the multimodal car 1+ users (column 1) falls in-between the odds ratios for the multimodal 1–6 (column 3) and 7+ (column 4) groups. Odds ratios distinguishing multimodal from monomodal car users for gender, race/ethnicity, employment status, car ownership, and density are stronger in column 4 for multimodal 7+ car users than in column 1 for multimodal 1+ car users or column 3 for multimodal 1–6 car users ($p < 0.01$). Signs and significance of the household life cycle variables differ between columns 1 and 4. The coefficient for singles was not statistically significant in column 4—but was positive and significant in column 1. By contrast, the coefficient for individuals in households with children is significant in column

Footnote 2 continued
because they excluded individuals from the modality group not analyzed in each specific model. Thus overall we prefer the MNL, because it enables us to evaluate differences between coefficients across the modality groups based on the same sample.

3 Significance was determined based on MNL results of the same sample using multimodal car users as the base group.

Table 3 Multinomial logistic regression analyses of modality groups in the U.S., NHTS 2009

Multinomial logistic regression (base outcome: monomodal car)	Model 1		Model 2		
	Column 1 Multi car 1+	Column 2 WBT only	Column 3 Multi car 1–6	Column 4 Multi car 7+	Column 5 WBT only
	Adjusted odds ratio				
Gender					
Female	1.000	1.000	1.000	1.000	1.000
Male	1.118**	1.406**	1.004	1.342**	1.415**
Race/ethnicity					
Non-White	1.000	1.000	1.000	1.000	1.000
White	1.109**	1.019	1.032	1.266**	1.026
Age group					
16–24	1.500**	3.403**	1.515**	1.465**	3.404**
25–34	1.630**	3.062**	1.655**	1.560**	3.061**
35–49	1.587**	2.419**	1.537**	1.670**	2.427**
50–64	1.438**	2.018**	1.370**	1.559**	2.026**
65 and older	1.000	1.000	1.000	1.000	1.000
Household life cycle					
Two adults no children	1.000	1.000	1.000	1.000	1.000
Singles	1.047*	0.702**	1.063**	1.021	0.702**
Households with children	1.024	0.776**	1.093**	0.911**	0.773**
Education					
High school degree or less	1.000	1.000	1.000	1.000	1.000
Education beyond H.S.	1.399**	1.354**	1.425**	1.355**	1.353**
Employment					
Unemployed, not in workforce	1.000	1.000	1.000	1.000	1.000
Employed	0.840**	0.363**	0.893**	0.758**	0.361**
Income					
Income quartile 1	0.906**	1.069*	0.870**	0.970	1.070*
Income quartiles 2 and 3	1.000	1.000	1.000	1.000	1.000
Income quartile 4	1.199**	1.221**	1.194**	1.209**	1.221**
Household automobiles					
0 cars	1.000	1.000	1.000	1.000	1.000
1 car	0.530**	0.059**	0.639**	0.413**	0.059**
2 cars	0.519**	0.026**	0.646**	0.384**	0.026**
3 or more cars	0.480**	0.018**	0.577**	0.377**	0.018**
Driver's license					
Unlicensed	1.000	1.000	1.000	1.000	1.000
Licensed	1.167**	0.618**	1.143**	1.205**	0.619**
Population density					
Density <10,000	1.000	1.000	1.000	1.000	1.000
Density 10,000 and above	1.172**	3.512**	1.110**	1.285**	3.525**
Access to rail					
Live outside MSA with rail	1.000	1.000	1.000	1.000	1.000
Live inside MSA with rail	1.065**	1.718**	1.050**	1.091**	1.719**

Table 3 continued

Multinomial logistic regression (base outcome: monomodal car)	Model 1		Model 2		
	Column 1 Multi car 1+	Column 2 WBT only	Column 3 Multi car 1–6	Column 4 Multi car 7+	Column 5 WBT only
	Adjusted odds ratio				
Goodness of fit measures					
McFadden's pseudo-R^2	0.058		0.040		
Nagelkerke pseudo-R^2	0.108		0.101		
LR Test (Pearson's) p value	0.000		0.000		
Number of observations	2,01,461		2,01,461		

Source calculated by authors based on NHTS 2009 Version 2.0

Excludes persons younger than 16 years

** $p < 0.01$; * $p < 0.05$

4, but was not in column 1. Coefficients for age, education, high income, driver's license, and rail access are statistically comparable between columns 3 and 4, while coefficients for household life cycle differ in significance or direction ($p < 0.01$).

Results in columns 2 and 5 compare wbt-only users with monomodal drivers and were virtually identical. For both Models 1 and 2, the magnitude of coefficients for age, gender, employment status, population density, and rail access were greater ($p < 0.01$) for the comparison of wbt-only users and monomodal car users than for any of the comparisons of multimodal and monomodal car users discussed above.

Logistic regressions comparing sub-groups of multimodal car users to monomodal car users

Column 1 in Table 4 presents results of a binary logistic regression comparing multimodal 1+ to monomodal car users (comparable to results in column 1 of Model 1 above). Subsequent columns present results of binary logistic regression analyses comparing sub-groups of multimodal to monomodal car users. Available statistics indicate that for each model variables have joint significance (LR-Test $p < 0.01$) and that multicollinearity is not a significant concern. Pseudo R-squared values range from 0.01 for the model distinguishing multimodal 1 + car users who only walk from monomodal car users to 0.22 for the comparison of multimodal car users who walk, cycle, and use public transportation to monomodal car users.

Even though there is variability in the sign, significance, and magnitude of coefficients across the models, some patterns emerge. First, the sign and (with few exceptions) significance of coefficients for gender, age groups, education, income, car ownership, and population density are comparable across models. Second, compared to other models, significance tests for models that include public transportation indicate opposite or insignificant coefficients for race/ethnicity, household life cycle, employment status, and driver's license status variables. Third, rail access is either not associated or is negatively associated with multimodal car use that only involves walking and/or cycling. Fourth, the magnitude of coefficients for the multimodality bundle car, walk, and bicycle is greater than for the multimodal car use bundles with either walking or cycling alone. Fifth, the magnitude of the coefficients for the model including public transportation as the only non-car mode is greater than in the models that include either walking or cycling alone. Lastly,

Table 4 Binary logistic regression analyses comparing subgroups of multimodal car users to monomodal car users in the U.S., NHTS 2009

Binary logistic regression base outcome: monomodal car	Car and other (+1) Odds ratio	Car and walk Odds ratio	Car and bike Odds ratio	Car and transit Odds ratio	Car, walk, and bike Odds ratio	Car, walk, transit Odds ratio	Car, bike, transit Odds ratio	Car, walk, bike, transit Odds ratio
Male	1.119**	1.046**	3.033**	1.110	1.830**	1.214**	3.144**	2.257**
White	1.112**	1.122**	1.284**	0.763**	1.381**	0.871**	1.785	1.127
16–24	1.501**	1.290**	1.600**	3.626**	2.737**	5.793**	10.378**	9.952**
25–34	1.630**	1.506**	1.419**	2.497**	2.857**	3.753**	4.019**	6.141**
35–49	1.588**	1.463**	1.550**	2.292**	3.109**	3.087**	1.687	4.683**
50–64	1.440**	1.381**	1.273**	1.945**	2.044**	2.690**	1.794	3.423**
Singles	1.043*	1.063**	1.177	0.838	0.990	0.886**	1.727	0.802
Households with children	1.022	1.006	1.184**	0.900	1.254**	0.991	1.077	1.174
Education beyond H.S.	1.399**	1.344**	1.300**	1.518**	1.857**	2.165**	3.002**	2.432**
Employed	0.841**	0.824**	0.955	1.374**	0.759**	1.216**	1.573	1.354**
Income quartile 1	0.906**	0.920**	0.794**	0.875	0.773**	0.773**	0.643	0.747**
Income quartile 3	1.200**	1.132**	1.314**	1.725**	1.433**	2.021**	1.972**	2.201**
1 HH car	0.496**	0.635**	0.654	0.203**	0.504**	0.142**	0.162*	0.138**
2 HH cars	0.483**	0.648**	0.634	0.126**	0.486**	0.063**	0.154*	0.058**
3+ HH cars	0.447**	0.613**	0.608	0.109**	0.398**	0.044**	0.107**	0.035**
Licensed	1.202**	1.300**	1.716**	0.399**	1.288**	0.429**	0.268**	0.518**
Density 10,000+	1.182**	1.036	1.309*	1.803**	1.071	2.590**	1.598	2.217**
MSA with rail	1.066**	0.985	0.975	2.717**	0.926*	2.925**	3.153**	2.340**
McFadden's pseudo-R^2	0.02	0.01	0.04	0.08	0.07	0.17	0.10	0.14
Nagelkerke pseudo-R^2	0.03	0.02	0.05	0.09	0.10	0.22	0.12	0.15
LR Test (Pearson's) *p* value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Number of observations	1,93,562	1,73,520	62,783	62,092	70,615	67,018	60,942	61,698

Source calculated by authors based on NHTS 2009 Version 2.0

Excludes persons younger than 16 years

** $p < 0.01$; * $p < 0.05$

the magnitude of the coefficients is greater for the multimodality bundles that include public transportation than for the bundle with car use, walking, and cycling. Notably, this analysis of the sub-groups does not control for the total number of non-car trips during the previous week, which could be higher for sub-group multimodality bundles that include two or three non-automobile modes than for sub-groups that exclusively relied on one non-automobile mode. Before discussing the implications of the results, the section below addresses additional limitations for this analysis.

Limitations

This is the first multivariable analysis of monomodal car use, multimodal car use, and wbt-only travel based on a representative sample of the U.S. population. However, there are several important limitations of our analysis.

First, the limited information available in the surveys regarding weekly car use means that it is possible that some individuals categorized as wbt-only users in this study did in fact use a car during the previous week. To the degree that mis-categorization occurred, it had the potential to classify actual multimodal car users as wbt-only users. The significance and sign of most coefficients were similar for comparisons of both multimodal car users to monomodal car users and wbt-only users to monomodal car users. Thus, we expect that in spite of potential mis-categorization between wbt-only users and multimodal car users, the sign and significance of our estimated coefficients for the explanatory variables are likely robust.

Second, our study relies on cross-sectional data and only allows us to report correlation and not causation. Moreover, the surveys cannot trace changes in travel behavior of the same person over time, but can only report on changes at the population level.

Third, endogeneity and self-selection are problems of most studies on travel behavior—including ours. For example, the direction of causation between our explanatory and dependent variables may be reversed. Individuals who wish to solely rely on walking, cycling, and/or public transportation may decide to not own an automobile. Similarly, individuals who wish to be multimodal and not monomodal drivers may move into denser areas with public transportation access. Moreover, the NHTS did not include variables measuring attitudes or travel preferences.

Fourth, our analysis did not include some variables that were tested in prior studies in the European context, such as auto-restraint policies, quality of transit service, reliability of travel time for different modes, environmental awareness, or travel behavior of neighboring households. Including these variables in the future would enhance the analysis and shed more light on policy variables. Not including relevant variables in our analysis may lead to biased coefficients. However, NHTS data cannot necessarily be used to include all of these variables. For example, there were no strong instrumental variables in the dataset for preferences or attitudes.

Fifth, our measurement of multimodality could be enhanced by excluding non-utilitarian walk and bicycle trips, such as 'going for a walk/bike ride' or 'walking the dog'. However, weekly NHTS data do not distinguish by trip purpose and at the day level recreational and utilitarian trip purposes are combined into larger trip purpose categories. Our preliminary analysis at the day level (based on rough proxies) suggests that elimination of recreational trips would lower the share of multimodal car users.

Sixth, our analysis cannot distinguish between individuals who choose to live car-free and the car-less who cannot afford to own a car. The regression analysis controls for several factors associated with car use, such as income, race/ethnicity, and employment status, but NHTS did not include a variable assessing the desirability to live without a car or have increased access to a car. Additional information about 'captive versus choice' travelers may also help explain the relatively stable shares of wbt-only users at the chained trip, day, and week levels.

Many limitations of our study could be overcome with more and better data on weekly travel behavior and additional variables capturing quality of service and other transportation policies. For example, attribute-based information about the transportation modes not chosen, absent from our dataset, could allow for more advanced modeling techniques.

Discussion

Many of our findings from the regression analysis are consistent with previous multimodality research from Europe as well as regional and local studies from the U.S. However, our national level results also differ from and add to prior findings.

First, our multivariable analysis confirms the finding that car availability is a key determinant of individual mode use patterns. Particularly, we find a large difference between individuals in households without cars and households with one car. When compared to monomodal car users, the likelihood to fall in the multimodal car user category further decreases with additional cars in the household—but the difference between households without cars and one car appears to be the strongest. Policies that reduce the need to own a car may therefore be the most successful at promoting multimodality. Examples include measures to increase walkability, bikeability, bikesharing, and access to public transportation. Car-sharing could offer households the option of occasional vehicle use while mitigating the impact of car ownership on daily travel patterns (TCRP 2005).

Second, our study confirms four studies from Europe that identified younger age groups as being more multimodal than older individuals. We find that in the U.S. individuals in the age group 65+ were more likely monomodal car users than multimodal car users. There was no clear trend among younger age groups (<64) between monomodal and multimodal car use. However, the likelihood to be wbt-only decreased with increasing age.

Third, consistent with previous studies, we find that those with a college or university degree and those with higher incomes are more likely multimodal than monomodal car users. Findings from other studies reporting higher rates of walking and cycling among individuals with higher education and income help explain this difference (Buehler et al. 2011). One reason may be that college students often live on or near campus, do not own a car, have free or reduced transit passes, and get around campus on foot, by bicycle, or by public transportation (Khattak et al. 2011; TCRP 2004; Wang et al. 2012). This experience may familiarize students with alternatives to the car and make it more likely that they will continue to walk, bicycle, and ride public transportation after schooling. The difference between income groups may also be related to the expanded travel options in more expensive urban neighborhoods that offer shorter trip distances, better infrastructure for non-motorized modes, and more frequent public transportation service (Knaap 1998; Sohn et al. 2012). Low income individuals may often not be able to afford housing in dense mixed-use areas with access to high quality public transportation (Blumenberg and Waller 2003; McKenzie 2013).

Fourth, some European scholars suggest that employed individuals are more likely multimodal, because public transportation has a higher mode share for the commute than other trip purposes. However, consistent with empirical findings from one study from Europe, our analysis shows that employed individuals in the U.S. are more likely monomodal car users and less likely multimodal car users. Even though in the U.S. transit use is higher for the commute ($\sim$5 %) than for all trips ($\sim$2 %), the majority of commutes ($\sim$90 %) in the U.S. are by car (Buehler and Pucher 2012). Moreover, employed individuals may have less flexibility in travel time throughout the day and may therefore rely on the car more than those not in the workforce or the unemployed. Our analysis of multimodal car user sub-groups showed that employed individuals were more likely to be multimodal car users when mode choice bundles included public transportation. By contrast, being employed was negatively associated with multimodal car use for mode choice bundles without public transportation.

Fifth, several previous studies suggest that women are slightly more likely to be multimodal car users than men. By contrast, we find that in the U.S. men have a higher likelihood of being multimodal than women—based on the two MNL and the binary logistic sub-group regressions. This could be related to several factors. For example, the greater safety risks associated with cycling in the U.S. have contributed to a significant gender gap in cycling rates (Garrard et al. 2012). This is confirmed by the large odds ratio for the gender variable in the sub-group analysis looking at multimodal car users who report cycling as their only non-automobile mode. Moreover, in households with more traditional gender roles women may be responsible for grocery shopping or chauffeuring children to and from activities—in addition to other trips, such as the commute to work (Goddard et al. 2006; Turner and Grieco 2000). These responsibilities may make the scheduling of trips more difficult and travel to destinations by walking, cycling, or riding public transportation less feasible (Gossen and Purvis 2005).

Sixth, we find that individuals in households with children are more likely monomodal car users—or in the lower intensity category of multimodal driving. This is in line with prior findings from Europe showing that families have more complicated travel schedules that are more difficult to meet by walking, cycling, and/or riding public transportation alone. This may be exacerbated in the U.S. by lower population densities and longer trip distances (compared to Europe), which may make a car more necessary when chauffeuring children to and from different activities. The reverse appears to hold for singles, who are more likely multimodal car users than monomodal car users. Singles may find it easier to chain together multiple modes than families.

Seventh, similar to European studies we find that individuals with driver's licenses are more likely monomodal or multimodal car users than wbt-only users. It seems that those who do not want to or are unable to use a car may not get a driver's license and instead solely rely on walking, cycling, and public transportation. Our finding that licensed drivers are more likely multimodal than monomodal drivers differs from prior studies on multimodality from Europe. In the U.S., virtually all individuals in either group (multimodal and monomodal car users) have a license. Thus, the direction of the relationship in our analysis of NHTS 2009 picks up on small differences. However, our sub-group analysis showed that those without a license were more likely multimodal car users who also used public transportation than monomodal car users.

Eighth, similar to prior studies in Europe and at the regional level in the U.S., we find that access to public transportation and higher population density are associated with a greater likelihood of being a multimodal driver and wbt-only user. Dense areas typically have higher levels of traffic congestion along with car parking that is more expensive and in shorter supply, all of which make car use less attractive (at least for some trips) (Newman and Kenworthy 1996). Moreover, trip distances in dense areas are shorter and facilitate access to public transportation. Additionally, dense areas typically have better pedestrian and bicycling infrastructure that encourage the use of non-motorized modes along with public transportation.

Last, our analysis suggests that multimodal car users are a group in-between monomodal car users and wbt-only users. Coefficients for explanatory variables distinguishing multimodal car users or wbt-only users from monomodal car users show similar signs and levels of significance. The magnitude of coefficients for age, gender, employment status, car ownership, density, and rail access is significantly larger ($p < 0.01$) for comparisons between wbt-only users and monomodal car users than is found in models comparing multimodal to monomodal car users. Additionally, coefficients for gender, race/ethnicity, employment status, car ownership, and density were stronger for the contrast between multimodal 7+ car users and monomodal car users than for the comparison of multimodal 1+ car users to monomodal car users. This suggests that multimodal car users and wbt-only users differ from monomodal car users in similar ways, and that differences between wbt-only users and monomodal car users are stronger than differences between multimodal car users and monomodal car users. Thus there may be a continuum of mobility types ranging from monomodal car users at one end to wbt-only users at the other end. Multimodal 1–6 and 7+ car users are positioned in-between the two ends—with multimodal 1–6 car users closer to the monomodal car user end of the spectrum and multimodal 7+ car users closer to the wbt-only end.

Conclusions

Our descriptive analysis revealed that travel by individuals in the U.S. is more varied than trip-based analysis suggests. Only 28 % of Americans solely rely on a car during a week. The majority of Americans are multimodal car users who drive and make at least one weekly trip by foot, bicycle, or public transportation. Stricter definitions for multimodal driving additionally show that about one in four American car users make at least 7 trips by walking, cycling, or public transportation during the week. Walking was the dominant mode used by multimodal car users. In 2009, 79.8 % of weekly multimodal car users reported walking as their only other mode of transport. This is important for transportation planners and policy makers, because providing infrastructure for walking, but also cycling and public transportation, affects a larger share of the population than suggested by trip-based analysis.

Overall, our analysis suggests that multimodal car users are a group in-between monomodal car users and wbt-only users. Thus policy makers who wish to curtail car use should expect policy changes to move monomodal car users along the spectrum *towards* wbt-only users. Similarly, current multimodal car users may increase the intensity of their use of walking, cycling, and public transportation, but not necessarily transition to relying on those modes exclusively. Future research, based on weekly travel surveys, could help further investigate these types of transitions among monomodal and multimodal car users and identify the potential effect of policies to encourage multimodality.

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