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Intrapersonal variability in leisure activity-travel patterns: the case of one-worker and two-worker households

ABSTRACT: Using multi-week travel diary data from Germany, this study examines intrapersonal variability in leisure activity-travel behavior. In particular, it investigates whether individuals from one-worker households have greater intrapersonal variability in leisure activity-travel patterns than those from two-worker households. The paper examines differences in intrapersonal variability behaviors concerning trip frequency, activity duration, travel time and travel distance by comparing females from one-worker households and females from two-worker households in the context of leisure travel and activity. Similar analyses were also conducted for males. The results of analysis suggest that intrapersonal variability in leisure activity-travel patterns varies across individuals and households. The results further confirm the hypothesis that individuals from one-worker households had greater intrapersonal variability for several behavioral patterns than those from two-worker households. Social characteristics, auto ownership and location were found to statistically affect intrapersonal variability in leisure activities and travels.

KEYWORDS: .

1. BACKGROUND

An understanding of day-to-day, week-to-week and even season-to-season variability in activity-travel behavior over a span of time is crucial for the analytical framework of travel demand management (TDM) measures. This is in line with recommendations briefly discussed in previous studies (e.g. Jones and Clarke, 1988; Huff and Hanson, 1986; Pas, 1987; Kitamura and van der Hoorn, 1987) that urban and transport planners should not only consider the variability in activity-travel behavior across individuals on the same days (interpersonal variability) in behavior model systems, but also need to pay attention to the variability in activity and travel for a given individual over a span of time (intrapersonal variability).

Since travel demand is considered to be a demand derived from the needs and desires to participate in various activities at different times and locations (Hägerstrand, 1970), it is likely that both types of variability exist in everyday human travel patterns. In leisure activity, this assumption tends to be more obvious as individuals' travel-activity patterns are naturally more variable and flexible compared to obligatory activities such as school and work (Tarigan and Kitamura, 2009). However, there has been little research to examine how variable magnitudes of intrapersonal variability in activity-travel patterns across individuals and households, in particular, are related to leisure activities.

Investigating the nature of intrapersonal variability in travel-activity behavior may have significant policy relevance in the transportation arena. For example, consider its important contribution for traffic information and route advice to access leisure areas. The measures of intrapersonal variability in leisure travel and behavior (say, trip frequency or travel time) may help traffic engineers determine how regular traffic information should be provided for users over a span of time. A low magnitude of intrapersonal variability in trip frequency may indicate a stable travel pattern, meaning that one-day traffic information can be sufficient to represent behavioral rhythms made by the travelers to visit such places over a course of one week or multi-weeks. In contrast,

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providing multi-day, or even everyday traffic information according to the peak periods can be more reliable than single-day traffic information when the level of intrapersonal variability in leisure travel and activity behavior is considerably high. Furthermore, the results of variability's measures may be useful to capture behavioral responses and market trends from the public related to given mobility management policies (e.g. subsided public transport) over a span of time. This information is essential for policy planning and other improvements in order to guarantee the transportation system has a consistently good quality.

This study is driven by a conjecture that the intrapersonal variability in activity-travel behavior seems to vary across individuals and households. Individuals in one-worker households are likely to have greater intrapersonal variability than those from two-worker households. Males and females from two-worker households tend to coordinate with one another and share certain in-home as well as out-of-home activities due to their limited time allocation for non-work activities, implying that both groups may have stability in performing leisure travels and activities. On the other hand, females and males from one-worker households are likely to have great intrapersonal variability in their leisure activity-travel behavior. In particular, females in one-worker households may give much attention to in-home and out-of-home non-work time allocation and related activities, which then leads them to have high flexibility to engage in various types of leisure activity. This case may be consistent for males from one-worker households, as they may give more attention to work-related activities but put less effort into in-home activities, implying they have greater flexibility in pursuing leisure-related activities at different times.

Pas and Koppelman (1987) have observed daily intrapersonal variability in trip frequency and explain various factors affecting this behavioral pattern such as socio-demographic and car-ownership aspects. Basically, the analytical method and approach presented in this study is quite close to Pas and Koppelman's work. However, at least two substantial expansions of analysis are carried out through this paper. First, leisure activity-travel behavior is the main observation in the present study rather than a general travel pattern as was analyzed in the Pas and Koppelman's paper. Second, this paper expands the measurements of intrapersonal variability by not only focusing on trip frequency, but also by adding other important variables such as activity duration, travel time, and travel distance. The previous study also did not explore intrapersonal variability in leisure activities and travels considering household structure.

The rest of this paper is organized as follows. First, a literature review of past studies is briefly presented; the dataset, the hypothesis, and the methodology are explained; the empirical results are discussed; and finally the paper's conclusions are summarized.

2. LITERATURE REVIEW

This section elaborates past studies addressing structural change across households, leisure travel behavior, and intrapersonal variability in activity-travel patterns.

2.1. Household structural change

Women's participation in the labor market has increasingly grown over the last several decades. For example, the US Department of Labor (2004) reports that female labor participation in the US had significantly increased from 40% in 1970 to 60% in 2002. This report also notes that the most dramatic increase occurred among married women, leading to a growing number of dual-career households. The most likely explanation for this increase may the growing number of educated women in urban areas and the increasing demand on female professionals to fulfill the labor market gap. Social and household constraints (e.g. household expenditure and social status) could also be factors why many married women participate in work activities.

Levine (1998) reveals that changes in family structure from one-worker to two-worker households has substantially changed individuals' travel patterns in many American cities. Since activity-travel behaviors executed by two-worker households are quite different from one-worker households, decisions by individuals in two-worker households to engage in various activity types may not be similar to traditional types of households in terms of location decision (Huff and Hanson, 1986), commuting behavior (Johnston-Anumonwo, 1992), and built environment (Dubin, 1991; Giuliano and Small, 1993; Waddell, 1996; Green, 1997).

Transport researchers should therefore be cautious in assuming that traditional models of travel behavior were established when only one adult in the households participated in work-related trips (Giuliano, 1991). The fundamental challenges of the current models are how such an ongoing shift toward dual-worker households will be considered in the next generation of activity-travel models.

2.2. Leisure activity-travel patterns

Studies on leisure travel behavior report that leisure trip making, travel time and distance travelled have significantly increased in recent decades. For instance, Molitor (2000) has shown that individuals' leisure-related activities have dominated total traffic per day in the US, because the share of personal consumption attributed to leisure activities has

increased over the years. Based on an empirical case from the US, Mallett and McGuckin (2000) note that the distance travelled by individuals for social and recreational purposes comprises 30% of total distance travelled. In Germany, 48% of total person kilometers were executed for leisure purposes (Schlich et al., 2004). This type of travel accounts for 65% of the total distance travelled in Finland (Kiiskilä and Kalenoja, 2001). Using the UK case, Anable and Gatersleben (2005) report that about 50% of the total mileage travelled for each individual is associated with leisure trips. Schlich et al. (2004) point out that the demands on leisure activity participation have increased over the last 30 years because of significant changes in personal needs and the desires among German individuals to travel. The study reports that the number of leisure activity types has increased rapidly and they tend to be more diverse and more specialized than in the previous decade.

Studies on leisure travel behavior have been explored by many researchers using various approaches (Lanzerdorf, 2002; Ettema and van der Lippe, 2009). Several studies explore the individual characteristics of leisure travel and behavioral patterns across various segments population using one-day survey data (e.g. Lanzendorf, 2002). These reports note that socio-demographic and household constraints are significant factors that influence leisure travel patterns. For example, Ettema and van der Lippe (2009) have indicated that work commitment, sex, marital status, and the presence of children are attributes that may relate to the total trips and the timing of travel for leisure activity participation. This study further reported that mutual interactions across household members (e.g. between adult females and males in households) influence personal and household strategies to pursue non-work activities.

Leisure activity and travel behavior have also been explored from other perspectives. These reports show that motives (Stauffacher et al., 2005), lifestyle and orientation (Lanzendorf, 2002; Ohnmacht et al., 2009), attitudes (Anable and Gatersleben, 2005), mode choice, and space (Schlich et al., 2004) all play essential roles in behavioral decisions regarding leisure activity participation. Moreover, leisure travel behavior studies have considered the relationships between leisure and work activity patterns because both activities are related (Kitamura and Fujii, 1998; Yamamoto and Kitamura, 1999). For instance, the amount of time allocated for work activity commitment affects how an individual determines leisure activity duration and trip making during weekdays. Time constraints imposed by work activities therefore affect spatial and temporal flexibility in leisure activity participation choices. The shift in spatial behavior for leisure trips from weekdays to weekends is also partly influenced by work activities engaged in during weekdays (Schönfelder and Axhausen, 2002). According to Susilo and Kitamura (2005), workers perform more stable action spaces on leisure activity than non-workers do on weekdays; however, the action space of all individuals is quite random on weekends. Tarigan and Kitamura (2009) have shown the nature of trip making in certain leisure activities, indicating that an increase in the number of trips per week leads to a higher variation in the related trips over the weeks.

2.3. Intrapersonal variability in activity and travel patterns

There is much transportation research related to intrapersonal variability in activity and travel patterns over multi-day periods (Pas, 1984; Koppelman and Pas, 1984; Pas and Koppelman, 1986; Pas, 1986; Pas, 1988). Huff and Hanson (1986) note that since activity and travel behaviors are a continuous learning and adapting process, understanding the repetition and the variability of individual activity-travel behavior becomes necessary in order to provide efficient and sustainable transportation planning. Ignoring the existence of variability would give an inappropriate travel behavior description, which leads to a misleading policy of transportation planning and infrastructure management.

Based on intrapersonal variability in individuals' activity and travel patterns, transportation researchers argue that there are two sources of day-to-day variability in travel patterns. First, personal needs and desires may vary over a span of time, implying that everyday constraints and environments are likely to be heterogeneous. There are highly routine trips such as regular social meetings with families or friends executed independently from other trip purposes. Also, there are activities that have no regular commitments and take place in a haphazard manner, such as incidental leisure trips for window shopping. Second, activity-travel patterns may vary over time due to the effect of transportation systems. For example, if there was congestion yesterday on one's usual route, then one might change the route for today's trip to work.

Previous multi-day studies of travel patterns can be classified into three broad groups. The first group uses descriptive analysis technique to measure the extent of day-to-day variability in activity and travel characteristics. For example, Recker et al. (1986) classify such time-space paths using pattern recognition techniques. Transformation is used first to simplify the space-time path, and then similar paths are clustered based on selected characteristics of paths. They use a combination of the simultaneous approach with pattern recognition, multi-objective optimization and the disaggregate choice model to examine household travel/activity patterns. Hirsh et al. (1986) analyze weekly travel patterns by

utility maximizing theory. They define an activity program as the collection of all activities undertaken during a certain period of time, independent of the order of their occurrence. Zhou and Golledge (2000) apply discriminant analysis to analyze day-to-day activity variability with respect to time duration and frequency during the week using GPS-collected data. Kitamura et al. (2002) introduce PCATS (The Prism-Constrained Activity-Travel Simulator) by dividing the day into two types of periods: open and blocked periods. Open periods are times of day when an individual has the option of travelling and engaging in flexible activities. Blocked periods are times when an individual is committed to performing fixed activities. A study conducted by Buliung et al. (2008) using the Toronto Travel-Activity Panel Survey (TTAPS) measures activity-travel behavior during the off-peak and weekend time periods with a specific focus on spatial properties. They found that weekday-to-weekend and day-to-day does exist in spatial properties of individual activity-travel behavior. A recent analysis in exploring day-to-day variability in time use for household members is presented by Kang and Scott (2010), arguing that incorporating variations in interactions between household members in engaging activities and travels are crucial to gain better activity time-use estimation approaches. The study further suggests that it is very crucial to avoid combining independent and joint activities when estimating activity time-use patterns.

The second group accommodates unobserved heterogeneity across individuals. Kitamura (1988) and Bhat (1999) contribute to the significance and improvement of models by including such unobserved heterogeneity in various types of travel behavior. For example, Kitamura (1988) describes the variation in travel as a stochastic process and uses the Markovian process to define the latent (representative) pattern and its recurrence structure. Bhat (1999) examines unobserved variation across individuals by utilizing non-work stops as the dependent variable. Employing a San Francisco Bay Area database, the latter model provides a superior fit to one that ignores the unobserved variation. Using the same dataset, Bhat (2000) examines unobserved heterogeneity in choice of commute mode. Using the same dataset that has been discussed in the present paper, Bhat et al. (2004) measure the rhythms in the shopping activity participation of individuals over a multiweek period and model its activity duration between successive shopping participations. The paper introduces a hazard-based duration model and a latent segmentation method to distinguish between erratic shoppers and regular shoppers. In addition, another study by Kitamura et al. (2006) indicates the presence of unobserved heterogeneity in prism vertices.

The last group of multi-day analysis examines both the extent of day-to-day variability in activity-travel patterns as well as the influence of individual characteristics on the extent of variability using different approaches (Herz, 1983; Bonsall et al., 1984; Mannering, 1989; Schlich and Axhausen, 2003).

It can be concluded so far that previous empirical findings in multi-day behavior models have been accumulated. The measures of leisure activity behavior governing different aspects of analysis are also crucial to obtain the most suitable transportation demand management (TDM) formulas as reported by past studies. Nevertheless, there is still lack of knowledge that addresses the relationships among activity participation, travel engagement, and intrapersonal variability factors from the leisure travel behavior perspective.

3. METHODOLOGY

The Mobi*drive* dataset, a continuous 6-week travel diary survey conducted in 1999 in two German cities–Halle and Karlsruhe–is used. The project recorded trip-based information including leisure activities of 326 persons (162 households). Details of the Mobi*drive* project and the resultant dataset can be seen in Axhausen et al. (2002).

The present analysis concentrates on married individuals from one-worker and two-worker households and investigated trip frequency, activity duration, travel time and travel distance for leisure activity purposes. A total of 136 persons (68 households) were successfully screened as samples, aged from 18 to 65.

The current study examines whether intrapersonal variability in leisure travels and activities (trip frequency, activity duration, travel time and travel distance) varies across individuals and how these patterns are related to household structure and gender division of labor. The study assumes that work activity participation affects week-to-week intrapersonal variability in leisure travel and activity. Employed individuals are generally required to make regular work trips. Consequently, they have less flexibility than non-employed individuals to undertake leisure travels and activities.

In the context of one-worker households, both males and females are prone to establish their household tasks. Males have great responsibility as a single-wage earner in the households. As consequence, males have less responsibility for in-home activity and children control, but they may have greater opportunity for leisure activity engagement. On the other hand, women in one-worker households are unlikely to have work activity commitment. This group may have great responsibility for household-related duties and taking care of children, resulting in higher intrapersonal variability in weekly leisure trips and durations than females from two-worker households.

Table 1. Descriptive statistics (n=136)

Intrapersonal variability variables	Mean	SD	Min.	Max.	Percentiles		
					25	50	75
Trip frequency	1.13	0.65	0.41	3.39	0.56	0.98	1.51
Activity duration	408.47	301.76	12.25	1717.51	182.62	351.46	502.05
Travel time (min.)	91.84	44.67	10.57	198.05	57.42	89.06	116.77
Distance traveled (km)	64.15	23.02	15.20	134.43	45.43	60.63	79.81

In two-worker households, both males and females tend to have equal roles for in-home and out-of-home responsibilities (e.g. child control and household maintenance) and activities are also more transferable across these two groups. Females spend a certain proportion of total time per day on work activities and tend to transfer some parts of home duties to their male counterparts. As a consequence, two-worker households seem likely to have smaller intrapersonal variability in leisure trips and durations than one-worker households.

In order to quantify the variability of leisure activity-travel behavior over weeks, we introduce a basic formula as presented below:

$$\sigma_{iLAD} = \frac{1}{w_i - 1} \sum_{j=1}^{w_i} (LAD_{ij} - \overline{LAD_i})^2,\ LAD_i > 0 \qquad (1)$$

$$\sigma_{iLTF} = \frac{1}{w_i - 1} \sum_{j=1}^{w_i} (LTF_{ij} - \overline{LTF_i})^2,\ LTF_i > 0 \qquad (2)$$

$$\sigma_{iLTT} = \frac{1}{w_i - 1} \sum_{j=1}^{w_i} (LTT_{ij} - \overline{LTT_i})^2,\ LTT_i > 0 \qquad (3)$$

$$\sigma_{iLDT} = \frac{1}{w_i - 1} \sum_{j=1}^{w_i} (LDT_{ij} - \overline{LDT_i})^2,\ LDT_i > 0 \qquad (4)$$

where

σ_{iLAD} = observed intrapersonal variability of leisure activity duration over 6 weeks by person i,
σ_{iLTF} = observed intrapersonal variability of leisure trip frequency over 6 weeks by person i,
σ_{iLTT} = observed intrapersonal variability of leisure travel time over 6 weeks by person i,
σ_{iLDT} = observed intrapersonal variability of leisure distance traveled over 6 weeks by person i,
LAD_{ij} = total leisure activity duration for week j and by person i,
$\overline{LAD_i}$ = average leisure activity duration per week by person i,
LTF_{ij} = total leisure trip frequency for week j and by person i,
$\overline{LTF_i}$ = average leisure trip frequency per week by person i,
LTT_{ij} = total leisure travel time for week j and by person i,
$\overline{LTT_i}$ = average leisure travel time per week by person i
LDT_{ij} = total leisure distance traveled for week j and by person i,
LDT_{ij} = average leisure distance traveled per week by person i,
w_i = number of weeks for which observation is available for person i (6 weeks in this study for all i).

4. EMPIRICAL RESULTS

The mean and standard deviation in intrapersonal variability in leisure trip frequency, activity duration, travel time and distance traveled over the six weeks for the overall sample are reported in Table 1. The results show that individuals allocated 29.1% of total trip frequency to leisure activities, or at least once a week they participated in leisure trip activity. They also allocated around 6 hours per week to leisure activity duration, and they travel around 1.5 hours per week to reach various leisure locations.

Table 2 tabulates the results of one way analysis of variance (ANOVA) tests between females and males and between one-worker and two-worker households. As expected, levels of intrapersonal variability in leisure activity duration, trip frequency, travel time and distance traveled were different in individuals from one-worker households compared to those from two-worker households. Females and males were significantly different in terms of intrapersonal variability in trip frequency and travel time, but there was not a significant difference in intrapersonal variability of activity duration and travel distance. Overall, the ANOVA tests tend to support our assumption that intrapersonal variability in leisure activity and travel behavior was heterogeneous between males and females and between one-worker and two-worker households.

An attempt was made to examine if females and males within the same households tend to correlate with respect

Table 2. ANOVA results: Comparing variability in activity-travel patterns between: (1) people in one-worker household and those in one-worker household, (2) males and females.

Variable	Trip frequency (σ_{LTF})	Activity duration [min] (σ_{LAD})	Travel time [min] (σ_{LTT})	Distance traveled [km] (σ_{LDT})
Household Type	F(1,132) = 3.60***	F(1,132) = 9.26***	F(1,132) = 11.48***	F(1,132) = 32.83***
Sex	F(1,132) = 0.54**	F(1,132) = 0.03	F(1,132) = 4.45**	F(1,132) = 1.39

NOTE: Significant coefficient values are: ***, p<1%;**, p<5%; *, p<10%

Table 3. Correlation results between intrapersonal variability properties and household type

Household Type	Trip frequency (σ_{LTF})	Activity duration [min] (σ_{LAD})	Travel time [min] (σ_{LTT})	Distance traveled [km] (σ_{LDT})
Individuals from 1-wh[1]	0.160	-0.270**	-0.203	-0.227*
Individuals from 2-wh[2]	-0.047	0.258**	-0.171	0.050

NOTE: Significant coefficient values are: ***, p<1%;**, p<5%; *, p<10%. [1]N = 54; [2]N = 82. 1-wh = one-worker household, 2-wh = two-worker household.

Table 4. Mean intrapersonal variability in weekly leisure trip frequency, activity duration, travel time and distance traveled.

	N	Trip frequency (σ_{LTF})	Ratio†	Activity duration (σ_{LAD})	Ratio†	Travel time (σ_{LTT})	Ratio†	Distance traveled (σ_{LDT})	Ratio†
Female									
1-wh	28	1.15	1.07	386.70	1.00	115.20	1.29**	81.72	1.49
2-wh	41	1.08		388.27		89.22		54.93	
Male									
1-wh	26	1.38	1.35	244.38	0.45***	98.76	1.33**	71.35	1.26*
2-wh	41	1.02		547.58		74.12		56.81	

NOTE: †T test, where: ***, p<1%; **, p<5%; *, p<10%. 1-wh = one-worker household, 2-wh = two-worker household.

to their intrapersonal variability in leisure activity and travel behavior (activity duration, trip frequency, travel time and travel distance). The results tabulated in Table 3 reveal that females' intrapersonal variability in leisure activity duration correlates with males' intrapersonal variability for each household. This indicates that females and males in the households have similar intrapersonal variability in leisure travel time. However, the correlation effects were diverse across household types. In one-worker households, an increase in females' intrapersonal variability of leisure activity duration is associated with a decrease in the males' intrapersonal variability in leisure activity duration. A positive association was found in two-worker households, indicating that greater intrapersonal variability in leisure activity duration for females is associated with greater intrapersonal variability in males' leisure activity duration. With respect to travel distance, the result exhibits that an increase in the level of males' intrapersonal variability in leisure travel distance affected stability in intrapersonal variability of leisure travel distance for females.

Tables 4, 5 and 6 report the results of an examination of intrapersonal variability across individuals. The results are presented based on the average level between males and females in one-worker and two worker households. The ratio was then obtained by comparing the average intrapersonal variability in one-worker households and two-worker households. These results were also verified with the two-sample t-tests (Snedecor and Cochrain, 1989) to examine the null hypothesis that the mean intrapersonal variability properties between two segments are equal.

4.1. Female segment

The results in Table 4 show the ratio of differences in average intrapersonal variability in activity duration, trip frequency, travel time and travel distance for the female group. The findings support our expectation because individuals from one-worker households were found to have greater average intrapersonal variability than those from two-worker households for leisure trip frequency, travel time and travel distance. In leisure activity duration, individuals in one-worker households had smaller average intrapersonal variability in leisure travel time compared to individuals from two-worker households. There were substantial differences

in intrapersonal variability across individuals from different household types for several tests. The study found that, in terms of the intrapersonal variability in travel time, females in one-worker households had greater average intrapersonal variability than females from two-worker households.

The intrapersonal variability in leisure activity-travel patterns was further examined based on several factors, such as social characteristics, auto ownership and household-based location (Table 5). In many cases, females in one-worker households were found to have greater intrapersonal variability in trip frequency, travel time and travel distance than females in two-worker households.

The presence of a child in the household signified differences of intrapersonal variability in leisure travel time between females in one-worker households and females from other group types. This evidence is in line with evidence presented by Pleck (1985) and Hochschild (1989), demonstrating that employed women tend to continue having primary responsibility for the home and children. Women's dual roles may therefore necessitate strategies for dealing with time pressures, such as avoiding travel time and limiting out-of-home activity duration, resulting in stable out-of-home travel patterns.

Income and education were found to affect differences in intrapersonal variability in leisure travel time between females in one-worker households and females from two-worker households. Women in one-worker households with low wages and low levels of education have more variable intrapersonal variability in leisure travel time than women from two-worker households with the same economic and social constraints. These signs indicate that low income and low education constraints affected differences in intrapersonal variability of leisure travel time. However, this was not the case for those with high income level and higher education.

The presence of a car affected differences in intrapersonal variability in leisure trip frequency and leisure travel time between females in one-worker households and females in two-worker households, as expected. Females from one-worker households had greater intrapersonal variability in trip frequency on a weekly basis than females from two-worker households when a household has one car. Quite consistent evidence with respect to travel time was also found when individuals owned two cars.

Two points should be noted from intrapersonal variability of females in one-worker and two-worker households grouped according to spatial characteristics. Living in the suburbs led to differences of intrapersonal variability in leisure travel time. Living in the central business district or city center affected differences in intrapersonal variability in leisure trip frequency across females from both household types (Table 5).

Females in one-worker households have smaller intrapersonal variability in activity duration than females in two-worker households. This was found to be inconsistent with our hypothesis. However, the statistical analysis does not reject the hypothesis that the mean intrapersonal variability in leisure activity duration is equal. This then indicates that the results found in this part are not strongly conclusive.

(Table 5 about here)

4.2. Male segment

Tables 4 and 6 displayed males' intrapersonal variability in leisure behavior (trip frequency, activity duration, travel time and distance traveled) in one-worker households and two-worker households.

The results showed that intrapersonal variability in leisure trip frequency, travel time and distance traveled for males in one-worker households were greater than for males in two-worker households. Presence of children, education level, auto ownership and location were found to influence differences of intrapersonal variability in leisure travel time between different household types. This indicated that males in one-worker households pursued more variable week-to-week travel time for leisure purposes than males from two-worker households.

Males with children had greater intrapersonal variability in leisure travel time than males without children from two-worker households from the same social groups. Turner and Niemier (1997) reported that having children in two-worker households apparently affects not only females' travel behavior, but also influences males. For example, in terms of travel time, the study asserted that child-caring responsibilities affect women's travel time less than men's, as women tend to perform more in-home activities. Males' activity-travel patterns can obviously be expected to interact with children's activities such as dropping of or picking up children at school and recreational activities as part of their daily activity agenda as well.

Employed males in one-worker households had greater intrapersonal variability than males from two-worker households. Household location for males apparently signified differences in intrapersonal variability in leisure travel time. For example, living in the suburbs is associated with a greater intrapersonal variability in leisure travel time for males from one-worker households than for those in two-worker households.

Unlike the results presented in the female segment, the sign from statistical tests for the male segment reported that intrapersonal variability in leisure activity duration

Table 5. Mean intrapersonal variability in weekly leisure travel-activity behavior in one-worker and two-worker household (female case).

	N	Trip frequency (σ_{LTF})	Ratio†	Activity duration (σ_{LAD})	Ratio†	Travel time (σ_{LTT})	Ratio†	Distance traveled (σ_{LDT})	Ratio†
Have children									
1-wh	13	1.31	1.18*	363.57	0.94	122.48	1.33***	84.12	1.60
2-wh	28	1.11		386.01		91.86		52.60	
Have no child									
1-wh	15	1.02	1.01	406.75	1.03	108.89	1.30	79.65	1.33
2-wh	13	1.02		393.15		83.52		59.94	
High education									
1-wh	22	1.17	1.19	395.27	1.05	112.13	1.18	80.24	1.58
2-wh	27	0.99		376.90		94.67		50.84	
Low education									
1-wh	6	1.10	0.87	355.31	0.87	126.43	1.61**	87.17	1.39
2-wh	14	1.26		410.21		78.71		62.82	
High income									
1-wh	16	1.04	0.93	419.15	1.17	103.48	1.06	80.43	1.51
2-wh	21	1.12		359.53		97.30		53.26	
Low income									
1-wh	12	1.30	1.26	343.45	0.82	130.81	1.62**	83.45	1.47
2-wh	20	1.03		418.46		80.73		56.68	
Have 1 car									
1-wh	21	1.16	1.12*	418.96	0.99	110.50	1.18	79.14	1.36
2-wh	24	1.03		423.79		93.77		58.28	
Have 2 cars									
1-wh	6	1.06	0.89	278.26	0.84	126.60	1.46**	91.36	1.79
2-wh	14	1.18		330.01		86.50		50.94	
Suburb resident									
1-wh	16	1.18	1.05	333.67	0.97	130.48	1.46***	82.44	1.52
2-wh	28	1.12		342.75		89.51		82.44	
CBD/Inner city resident									
1-wh	12	1.12	1.13**	457.42	0.94	94.82	1.07	80.77	1.43
2-wh	13	0.99		486.32		88.59		56.50	
Karlsruhe resident									
1-wh	13	1.32	1.08	284.83	0.74	135.07	1.49***	83.78	1.47
2-wh	22	1.21		385.56		90.36		56.87	
Halle resident									
1-wh	15	1.01	1.10	475.00	1.21	97.97	1.11	79.94	1.52
2-wh	19	0.92		391.42		87.89		52.69	

NOTE: †T test, where: ***, $p<0.01$; **, $p<0.05$; *, $p<0.1$. The ratio was found by dividing magnitudes between one-worker households (1-wh) and two-worker households (2-wh) for each segment. 1-wh: one-worker household, 2-wh: two-worker household..

Table 6. Mean intrapersonal variability in leisure travel-activity behavior in one-worker and two-worker household (male case).

	N	Trip frequency (σ_{LTF})	Ratio†	Activity duration (σ_{LAD})	Ratio†	Travel time (σ_{LTT})	Ratio†	Distance traveled (σ_{LDT})	Ratio†
Have children									
1-wh	16	1.42	1.38	265.31	0.50**	98.00	1.25**	67.94	1.17
2-wh	30	1.03		531.26		78.30		57.91	
Have no children									
1-wh	10	1.31	1.29	210.89	0.36***	99.99	1.59	76.80	1.43
2-wh	11	1.01		592.09		62.73		53.80	
High education									
1-wh	22	1.41	1.39	241.33	0.43***	104.10	1.45**	73.94	1.31**
2-wh	38	1.01		566.73		71.99		56.31	
Low education									
1-wh	4	1.19	1.04	261.12	0.86	69.41	0.69	57.06	0.90
2-wh	3	1.14		305.05		101.08		63.17	
Low income									
1-wh	19	1.39	1.32	234.81	0.46***	103.10	1.23*	74.45	1.23
2-wh	20	1.05		509.50		83.86		60.34	
High income									
1-wh	7	1.34	1.35	270.36	0.46	86.99	1.34	62.92	1.18
2-wh	21	0.99		583.84		64.84		53.45	
Have 1 car									
1-wh	20	1.42	1.47	237.45	0.41***	99.51	1.39***	72.49	1.29
2-wh	24	0.97		582.49		71.41		56.19	
Have 2 cars									
1-wh	5	1.14	1.06	209.50	0.52	107.48	1.49	75.04	1.26*
2-wh	14	1.07		405.30		72.26		59.44	
Suburb resident									
1-wh	16	1.39	1.47	240.38	0.46***	95.47	1.26***	65.46	1.12
2-wh	28	0.94		526.96		75.61		58.63	
CBD/Inner city									
1-wh	10	1.35	1.13	250.78	0.42	104.04	1.47	80.77	1.53
2-wh	13	1.19		591.99		70.91		52.89	
Karlsruhe resident									
1-wh	11	1.61	1.37	219.77	0.42**	104.50	1.28***	66.60	1.10
2-wh	22	1.18		517.21		81.83		60.46	
Halle resident									
1-wh	15	1.21	1.43	262.43	0.45**	94.56	1.45	74.83	1.42
2-wh	19	0.84		582.75		65.19		52.59	

NOTE: †T test, where: ***, $p<0.01$; **, $p<0.05$; *, $p<0.1$.

from males in one-worker households was significantly smaller than that of males from two-worker households. The results were consistent for certain sub-segments of analysis. For example, males with high education and children had smaller intrapersonal variability in leisure activity duration than males in two-worker households. Similar results were obtained for the groups of car ownership, suburbs, and Karlsruhe residents. Thus, the results showed that intrapersonal variability varied between males in one-worker households and males in two-worker households for certain cases.

4.3. Multivariate analyses

To validate the results obtained so far in a multivariate context, a set of regression analyses of intrapersonal variability in leisure activity and travel patterns is examined to crosscheck the results with the previous sections. Four regression models are developed where the dependent variables are: (1) intrapersonal variability of trip frequency, (2) activity duration, (3) travel time and (4) distance traveled. It should be noted that the samples of the analysis utilized in this study used similar data as in the previous section.

Table 7 shows that the variability for trip frequency and distance traveled for males in one-worker households were significantly larger than those for males in two-worker households, while those for activity duration for males in one-worker households were smaller than those for males in two-worker households. These results are in line with the abovementioned analysis.

The results also indicate that intrapersonal variability in leisure travel time and distance traveled for females in one-worker households is larger than that of males in two-worker households. However, intrapersonal variability in leisure activity duration from females in two-worker households was smaller than that of males from the same household type. Females in one-worker households, who are probably mostly non-workers, seem to have flexibility to decide leisure destination, transportation mode, and weekly activity agenda, resulting in high intrapersonal variability in leisure travel time and distance traveled. These results are consistent with some findings in the literature that women tend to exhibit higher levels of intrapersonal variability in activity behavior. One, however, should note that interaction effects between males and females in both types of household related to the properties of behavior patterns may exist and these issues cannot be captured through these regression analysis approaches. This remains subjects for future study and some parts of this issue are investigated elsewhere (Tarigan et al. 2009).

Social descriptors have shown that individuals with high household income tend to have smaller intrapersonal variability in leisure travel time. These findings partly suggest that those with higher income tend to have a set of fixed leisure schedules as well as destinations for their activity purposes. Also, the presence of children is unlikely to influence intrapersonal variability in leisure activity and travel behavior.

The presence of a car in the household is statistically related to greater intrapersonal variability in distance traveled. However, adding an extra car apparently decreased intrapersonal variability in leisure distance traveled compared to those with one car in the household. This result partly implies that those with one car were engaged in various activity patterns that differed from those in heavily-car-dependent households.

Regarding the effect of a built environment, individuals who live in Karlsruhe have greater intrapersonal variability in leisure trip frequency than those who reside in Halle. Suburban residents also have smaller intrapersonal variability in leisure activity duration. These results partly suggested that leisure travel-activity patterns were found to be different in these cities, potentially because of differences of socialization systems in the past between the East German cities (such as Halle) which are more homogeneous (in terms of home-based and leisure-based locations) than in the West German cities (such as Karlsruhe) which are more dispersed, mixed and market oriented. However, a separate analysis should be carried out to explore this issue.

5. CONCLUSIONS

Using a continuous six-week travel diary data from the cities of Karlsruhe and Halle, Germany, this study has developed a framework for the analysis of intrapersonal variability in leisure activity-travel patterns over a span of time. The focus has been on differences in such patterns between individuals in one-worker and two-worker households. The hypotheses underlying this study were that females and males in one-worker households are likely to have greater intrapersonal variability in leisure activity and travel behavior than females and males from two-worker households.

The results have provided several insights into differences in intrapersonal variability of weekly leisure activity-travel patterns. First, intrapersonal variability in leisure activity-travel patterns were found to vary between individuals from one-worker households and those from two-worker households for certain behavioral patterns. Second, the empirical investigations of the specific segments provided interesting findings. For example, presence of children, social class (income and education) and auto ownership influenced the levels of intrapersonal variability for both males and females in both household types. The intrapersonal variability in

Table 7. Regression analyses of intrapersonal variability in leisure activity-travel patterns.

	Intrapersonal variability in leisure:											
Variable	**Trip frequency [no. of trips]** (σ_{LTF})			**Activity duration [minute]** (σ_{LAD})			**Travel time [minute]** (σ_{LTT})			**Distance traveled [km.]** (σ_{LDT})		
	B	**t-stat.**	**Sign.**	**B**	**t-stat.**	**Sign.**	**B**	**t-stat.**	**Sign.**	**B**	**t-stat.**	**Sign.**
(Constant)	1.33	4.03	***	699.06	4.65	***	68.57	3.21	***	49.30	4.50	***
Female from 1worker households (D)	0.14	0.68		-122.12	-1.35		46.72	3.64	***	22.78	3.46	***
Female from 2 worker households (D)	0.03	0.20		-123.33	-1.77	*	11.56	1.17		-3.95	-0.78	
Male from 1 worker households(D)	0.40	2.24	**	-291.05	-3.55	***	17.93	1.54		11.00	1.84	*
Male from 2 worker households (D)	0	-		0	-		0	-		0	-	
Presence of children (D)	0.14	0.96		45.87	0.71		7.28	0.79		-3.37	-0.72	
Household Income	-0.03	-0.86		16.76	1.15		-4.55	-2.19	**	-0.87	-0.82	
Have 1 car (D)	-0.39	-1.39		-133.96	-1.06		15.08	0.84		16.91	1.83	*
Have 2 cars or more (D)	-0.39	-1.32		-255.90	-1.92	*	17.70	0.93		16.94	1.74	*
Karlsruhe resident (D)	0.40	3.22	***	-73.91	-1.29		13.29	1.63		1.50	0.36	
Suburbs resident (D)	-0.10	-0.74		-121.45	-1.98	**	6.32	0.72		-1.78	-0.40	
F		2.02			2.72			2.67			3.21	
Degree of freedom		(9,99)			(9,99)			(9,99)			(9,99)	
R		0.39			0.45			0.44			0.48	
R square		0.16			0.20			0.20			0.23	
Adjusted R square		0.08			0.13			0.12			0.16	
Sample size		136			136			136			136	

NOTE: Significant coefficient values: ***, $p<0.01$; **, $p<0.05$; *, $p<0.1$. D=dummy.

daily travel was highly dependent on the individual's residence location. The application of this study could be helpful for travel demand management. For example, in order to increase the efficiency of measuring behavior change such as travel feedback programs or individualized marketing (e.g. Fujii et al. 2009), one can exclusively select individuals with low intrapersonal variability to determine information about their travel behavior, rather than providing information to random persons.

There are limitations to this exploratory study (e.g. small sample size, self-selection bias and generalization of the findings). However, the results of the present study provide substantial insights into the history of travel behavior studies and can be a bridge to inform further inquiry.

Overall, the study showed that intrapersonal variability is one of the important variables which should be taken into account in the history of travel behavior studies and transportation policy. This is also in line with previous studies which investigated temporal variability in trip frequency (Tarigan and Kitamura, 2009) and causal relationships across properties of intrapersonal variability in leisure activity-travel patterns (Tarigan et al., 2009). The relationship between intrapersonal variability and interpersonal variability in leisure activity-travel patterns is also a promising subject which should be addressed as future tasks to conduct a comprehensive investigation on the subject of intrapersonal variability in leisure activity-travel patterns.

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