Title
A Model of Household Interactions In Activity Patterns

Author
van Wissen, Leo J.

Publication Date
1991-09-01

A Model of Household Interactions In Activity Patterns

Leo J. van Wissen

September 1991
Working Paper, No. 15

The University of California Transportation Center

University of California
Berkeley, CA 94720

The University of California Transportation Center

The University of California Transportation Center (UCTC) is one of ten regional units mandated by Congress and established in Fall 1988 to support research, education, and training in surface transportation. The UC Center serves federal Region IX and is supported by matching grants from the U.S. Department of Transportation, the California State Department of Transportation (Caltrans), and the University.

Based on the Berkeley Campus, UCTC draws upon existing capabilities and resources of the Institutes of Transportation Studies at Berkeley, Davis, and Irvine; the Institute of Urban and Regional Development at Berkeley; the Graduate School of Architecture and Urban Planning at Los Angeles; and several academic departments at the Berkeley, Davis, Irvine, and Los Angeles campuses. Faculty and students on other University of California campuses may participate in Center activities. Researchers at other universities within the region also have opportunities to collaborate on selected studies. Currently faculty at California State University, Long Beach, and at Arizona State University, Tempe, are active participants.

UCTC's educational and research programs are focused on strategic planning for improving metropolitan accessibility, with emphasis on the special conditions in Region IX. Particular attention is directed to strategies for using transportation as an instrument of economic development, while also accommodating to the region's persistent expansion and while maintaining and enhancing the quality of life there.

The Center distributes reports on its research in working papers, monographs, and in reprints of published articles. For a list of publications in print, write to the address below.

University of California Transportation Center

108 Naval Architecture Building
Berkeley, California 94720
Tel: 415/643-7378
FAX: 415/643-5456

Authors of papers reporting on UCTC-sponsored research are solely responsible for their content. This research was supported by the U.S. Department of Transportation and the California State Department of Transportation, neither of which assumes liability for its content or use.

A Model of Household Interactions In Activity Patterns

Leo J. van Wissen

Institute of Transportation Studies
University of California at Irvine

Working Paper, No. 15

September 1991

The University of California Transportation Center
University of California at Berkeley

TABLE OF CONTENTS

1. INTRODUCTION

Time is an important aspect of the activity patterns of individuals. An activity pattern can be described by means of a time-space diagram (Hägerstrand, 1970), that describes, for each moment within a given time interval, the location and type of activity of an individual. These time-space patterns are the result of various decisions and events experienced by that individual. In this paper, we will focus on the time dimensions of the space-time activity patterns of individuals. More specifically, we will focus attention on the allocation of time to a number of out-of-home activities. Other aspects, such as the timing and scheduling of activities are outside the scope of this paper.

Hägerstrand (1970, 1975b, Szalai (1973), and Chapin (1974), among others, have pointed out the importance of time in studying human behavior. Hägerstrand and other members of the Lund School stress the impact of constraints on human behavior. The social and economic environment of an individual determine, to a large degree, these time constraints. The household and the occupational status play a major role in creating constraints. Chapin and Hägerstrand (1975a) also stress the role of the household life cycle in the allocation of time. People behave differently in space and time at various stages in the life cycle. Therefore, it is not surprising that life cycle and related household characteristics are key variables in empirical work explaining differences in activity patterns (Jones, et al., 1983; Damm, 1979, 1980; Kostyniuk and Kitamura, 1984; Pas, 1984; Zimmerman, 1982). These studies, largely from the geographical or transportation field, are not the only evidence of the intricate relationship between the household and the usage of time. Soule (1955) appears to be the first to have discovered time as a scarce resource in economics. Becker (1965) and Linder (1970) developed microeconomic theories bringing time into microeconomics. In Becker's approach, the household is viewed as a production unit. Goods and time are inputs in a production process that produces commodities. Household utility is derived from the consumption of these commodities. In these types of studies, the household is the decision unit. Little attention is paid to interdependencies that may exist among members of the household. Samuelson (1956) was the first to use a household utility function with individual utilities as arguments (see also Becker, 1981, pp. 191-194). This approach was taken further by Townsend (1987), and by Koppelman and Townsend (1987), who developed a theory of activity behavior of household members by explicitly taking into account various types of interdependencies within a household. While this research provides a theoretical basis for studying interrelationships in the allocation of time by household members, much is still unknown about the nature and form of these interrelationships. This paper tries to fill a part of this gap. A model is proposed and applied empirically to study the interactions among household members in allocating their time to various out-of-home activities. Special attention is given to the effects of life cycle and employment status on the interacting patterns of household members. The model is applied using longitudinal data on activity patterns from the Netherlands in the period 1984 to 1988.

2. THE ALLOCATION OF TIME WITHIN HOUSEHOLDS

In the analysis of travel demand, activity behavior, or related subjects, a decision usually has to be made between the household or the individual level of analysis. The household is more than a convenient aggregation unit to summarize the behavior of its members. Some characteristics only become visible at the household level. There is a fixed amount of household production activities ("maintenance activities") that have to be performed in the household. Therefore, it is possible that substitutable relations exist among its members. If substitutable relations exist, one would expect negative correlations between the allocated times of each member for these maintenance activities. If member "A" does all the shopping, there is no need for member "B" to engage in this activity. However, they may choose to shop jointly. These jointly performed activities are the result of what Townsend calls companionship relationships. In order to study these relationships, we have to distinguish between individually and jointly performed activities. A third type of relationship that can exist results from the common interests among household members. If all members share a common interest in, say, sports, this would most probably result in a relatively large portion of time of all members devoted to this activity. If the activity is performed jointly, we cannot distinguish between companionship and this type of relationship (companionship is usually the result of common interests). However, if the same type of activities is performed individually, we call these relationships complementary. Complementary relationships give rise to positive correlations among the allocated times of household members.

It is likely that these interrelationships within a household are dependent on the stage in the life cycle and the occupational status of its members. Empirical evidence suggests that the time allocated to nonwork activities is highly influenced by the amount of hours worked (Damm, 1980). While nonwork activities can be regarded as weak substitutes on an individual basis, the relation between work and nonwork time is of a different nature. Nonwork time is allocated conditional on the amount of time worked. In general, a strong negative relationship exists between work time and most nonwork activities. Therefore, working status and working hours have to be taken into account when studying interactions among nonwork activity times.

The effect of life cycle is mainly the result of the number and age of the children, and of the ages of the spouses. The amount of maintenance activities increases with household size. Further, the presence of young children in the household reduces the out-of-home activities drastically (van Wissen, et al., 1985; van der Hoorn, 1983). Therefore, in studying interrelationships among household members, the conditioning effects of these life cycle variables have to be taken into account.

3. A MODEL OF JOINT TIME ALLOCATIONS

The aim of the model to be developed in this section is the empirical estimation of the three types of interrelationships that exist among household members: (1)

substitutable relationships, (2) complementary relationships, and (3) companionship relationships.

Before outlining the model, a number of comments have to be made in order to define the problem more precisely. First, we shall confine ourselves to the interactions between adult members of the household. So, we exclude the activity patterns of children in our study. Although this limits the scope of the model significantly, it is necessary for reducing the size and complexity of the problem. In a household of size n there are n(n-1) pairs of interrelationships. It was decided to focus on the adult interrelationships and to study the impact of children through the inclusion of life cycle variables. Thus, the model describes the behavior of adults in two adult households. Further, we restrict ourselves to households with either one or two workers. This eliminates the complicating case of zero workers in the household, including retired persons. Thirdly, missing data in time allocations have to be taken into account explicitly in the model. This will be elaborated in more detail in Section Four, when describing the data. Since the total amount of time is fixed, the total size of nonreported activity times is known. By incorporating missing times in a model of activity time allocation, we control for possible biasing effects of reporting errors on known activity times.

We assume that the time data have a multivariate log-normal distribution. The log-normal form is appropriate given the highly skewed character of the time data. A number of authors (e.g., Kitamura, 1984; Damm and Lerman, 1982; Townsend, 1987) choose the log-normal form from utility maximizing principles. Further, it is assumed that the causal structure among the variables can be explored using a simultaneous linear equations approach. Throughout this paper, matrices and vectors are underlined.

Matrices are denoted by upper case and vectors by lower case characters. The model proposed has the following form:

$$\underline{y}_{it} = \underline{B}\,\underline{y}_{it} + \underline{\Gamma}\,\underline{x}_{it} + \underline{\alpha}_i + \underline{\epsilon}_{it} \qquad (1)$$

where $\underline{y}_{it}$ is a 7 x 1 vector of observed endogenous time variables for household i at time t:

$$\underline{y}_{it} = \{ w_1(t),\ s_1(t),\ m_1(t),\ w_2(t),\ s_2(t),\ m_2(t),\ s_3(t) \}' \qquad (2)$$

with $w_1(t)$, $s_1(t)$, and $m_1(t)$, being the log of the amount of minutes worked, shopping (individual), and missing for the first adult in the household, respectively. $w_2(t)$, $s_2(t)$, and $m_2(t)$ are similarly defined for the second adult in the household. The first adult in the household is always male. The second adult in the household is always female. $s_3(t)$ is the log of the joint shopping time. In the empirical section, we use a more elaborate notation for these variables (see Table 5). $\underline{B}$ is a 7 x 7 matrix of coefficients relating the endogenous time variables among themselves. A typical element of $\underline{B}$ is $\beta_{kk'}$, which gives the structural effect of time allocated to activity/adult indexed k' on activity/adult indexed k. Further, $\underline{\Gamma}$ is a coefficient matrix of size 7 x M, where M is the number of conditioning exogenous variables. A typical element of $\underline{\Gamma}$ is γ_{km}, which is the regression coefficient of the m'th exogenous variable on the k'th time variable. $\underline{x}_{it}$ is an M x 1 vector of exogenous variables for person i at time t.

The error structure of the time variables is decomposed into two components: $\underline{\alpha}_i$ and $\underline{\epsilon}_{it}$. $\underline{\alpha}_i$ is a 7 x 1 random vector of individual specific disturbances that is constant over time, and $\underline{\epsilon}_{it}$ is a 7 x 1 random vector of disturbances that varies over time and individuals. $\underline{\alpha}_i$ and $\underline{\epsilon}_{it}$ both have zero mean. $\underline{\alpha}_i$ has a variance-covariance structure $\underline{\Omega}$ (7 x 7) and $\underline{\epsilon}_{it}$ has variance-covariance structure $\underline{\Psi}_t$ (7 x 7).

If there was only cross-sectional data available, the $\underline{\alpha}_i$ and $\underline{\epsilon}_{it}$ could not be identified separately. With longitudinal data, it is possible to estimate $\underline{\Omega}$ and $\underline{\Psi}_t$ both. The variances $\omega_{kk'}$ of α_{ik} control for unobserved time stationary effects that might otherwise bias the structural parameter estimates. By restricting $\omega_{kk'} = 0$, for $k \neq k'$, the model generalizes to a variance-components structure (Maddala, 1987, p. 318). On the other hand, if $\underline{\Omega}$ is free, a factor analytic structure can be imposed on the errors. However, in this application we are primarily interested in the structural parameters of the model, i.e., the interactions among household members and the conditioning effects of life cycle and occupational status. Therefore, we restrict $\underline{\Omega}$ to be diagonal. Thus, in addition to the $\underline{\Psi}_t$ matrix, we have 7 additional parameters to be estimated.

Model (1) can be estimated using the LISREL framework developed by Jöreskog (1970, 1977) and Jöreskog and Sörbom (1977). The model formulated in LISREL format has the following form:

$$\begin{bmatrix} \underline{y}_1 \\ \hline \underline{y}_2 \\ \hline \underline{\alpha}_2 \end{bmatrix} = \begin{bmatrix} \underline{B} & \underline{\emptyset} & \underline{I} \\ \hline \underline{\emptyset} & \underline{B} & \underline{I} \\ \hline \underline{\emptyset} & \underline{\emptyset} & \underline{\emptyset} \end{bmatrix} \begin{bmatrix} \underline{y}_1 \\ \hline \underline{y}_2 \\ \hline \underline{\alpha} \end{bmatrix} + \begin{bmatrix} \underline{\Gamma} & \underline{\emptyset} \\ \hline \underline{\emptyset} & \underline{\Gamma} \\ \hline \underline{\emptyset} & \underline{\emptyset} \end{bmatrix} \begin{bmatrix} \underline{x}_1 \\ \hline \underline{x}_2 \end{bmatrix} + \begin{bmatrix} \underline{\epsilon}_1 \\ \hline \underline{\epsilon}_2 \\ \hline \underline{\omega} \end{bmatrix} \qquad (3)$$

where the subscripts of the vectors and matrices refer to the time period.

$\underline{I}$ is the 7 x 7 identity matrix, $\underline{\emptyset}$ is the null matrix, and $\underline{\omega}$ = diag $\{\omega_{11}, \omega_{22}, \omega_{33}, \omega_{44}, _{55}, \omega_{66}, \omega_{77}\}$ is the vector of random individual specific effects. The system can be estimated using maximum likelihood. In general, the system cannot be identified unless certain restrictions are imposed on the $\underline{B}$, $\underline{\Gamma}$, and $\underline{\Psi}_t$ matrices. The specific form of these matrices will be discussed in Section Five, when discussing the empirical results.

A variant of model (1) is to make $\underline{B}$ and $\underline{\Gamma}$ time specific. While this is a less parsimonious model, it allows us to test the joint stationarity of the interrelationships in time allocated to activities by household members. A suitable test statistic for this purpose is the χ^2 test. With each model is associated a χ^2 value, measuring the distance between the observed sample variance-covariance matrix and the model generated matrix. For two nested models, the difference in χ^2 value in association with the difference in degrees of freedom can be used to test whether the models are different. This test tells us if the parameters of the time interactions model are the same at the two time points.

Before discussing the modeling results, we discuss first the data used in the estimations.

4. DATA DESCRIPTION

Surveys on activity patterns are relatively scarce. Usually, trip diaries are used to infer activity information from the reported trips. That procedure was also applied to obtain the time data needed for this study. The survey used here is the Dutch

Longitudinal Mobility Panel (Golob, et al., 1986; van Wissen and Meurs, 1989). This panel involves the repeated measurement of one week of travel diaries of households in the Netherlands. The first panel wave started in March 1984; since then, each year, a repeated survey was held in the same period. In addition to these spring questionnaires, a number of waves were conducted in the fall (in 1984 and 1986). However, only data from the five March panel waves in the period 1984 to 1988 will be used in this analysis. These spring waves are odd numbered: 1-3-5-7-9. For the analysis reported here, the sample was transformed into a wave-pair sample with each pair consisting of two waves two years apart. So, all relevant households were selected who were in waves one and five, or in waves five and nine. These two subsamples were then pooled. A two-year time interval was judged to be preferable to a one-year interval. For life cycle and occupational status, a one-year time period is too short to observe many transitions. As discussed in the previous section, the sample consists of all two-adult households with at least one person working. The total sample size thus selected was 635 households: 287 from subsample one (wave 1-5 pair) and 348 households from subsample two (wave 5-9 pair). By pooling the two subsamples, we ignore the autocorrelation among the observations (178 households appear in both subsample one and two). Tables 1, 2, and 3 present some data on transitions in employment status, household size, and life cycle in the sample. These variables will be the main conditioning variables in the analysis.

The figures on employment status (Table 1) show that the highest turnover occurs with the female persons in the households. There is hardly any turnover for men. Table 2 shows the dynamics in household size. Due to the character of the subsample chosen,

TABLE 1

CHANGES IN EMPLOYMENT STATUS
IN TWO-YEAR INTERVAL

ADULT 1: MALE

		T = 2 Unemployed	T = 2 Employed	$\Sigma_{T=1}$
T=1	Unemployed	6	15	21
T=1	Employed	7	607	614
$\Sigma_{T=2}$		13	622	635

ADULT 2: FEMALE

		T = 2 Unemployed	T = 2 Employed	$\Sigma_{T=1}$
T=1	Unemployed	344	62	406
T=1	Employed	32	197	229
$\Sigma_{T=2}$		376	259	635

TABLE 2

CHANGES IN HOUSEHOLD SIZE
IN TWO-YEAR INTERVAL

T = 2

		2 persons	3 persons	4 persons	5 persons	6 persons	7 persons	Σ T = 1
T=1	2 persons	143	22	7				172
	3 persons	1	52	40	3			96
	2 persons		2	264	20	1		287
	3 persons			1	57	5	1	64
	3 persons				1	10	4	15
	2 persons						1	1
	Σ T = 2	144	76	312	81	16	6	635

TABLE 3

CHANGES IN LIFE CYCLE
IN TWO-YEAR INTERVAL

T = 2

T=1	Young households, no kids	Households with kids <12 years	Households with kids ≥12 years	Older households, no kids	$\Sigma_{T=1}$
Young households, no kids	55	25		17	97
Households with kids <12 years		297	48		345
Households with kid(s) ≥12 years		2	114		116
Older households, no kids	1	3	2	71	77
$\Sigma_{T=2}$	56	327	164	88	635

a general increase in household size can be envisaged. However, this is not a completely representative sample of the Netherlands. The same pattern emerges from the changes in life cycle (Table 3). There is a high turnover from households without children to households with children, or from households with younger children to households with older children. There is no transition from households with children to households without children.

The trip information in the panel was transformed into individual activity profiles. An activity profile consists of time-distance coordinates. Distance instead of space is used here, because the trips are not geocoded. The only spatial information available is distance traveled.

Each coordinate in the time-distance profile marks a discrete change in the activity profile: a change from activity to trip, or vice versa; or a change of mode within a trip. Here, only activity information is relevant. Each activity is defined in terms of time (the elapsed time between two trips) and the type of activity performed. Although this method of obtaining activity time data from trips is relatively straightforward, there are some problems that need to be resolved. If a trip diary is inconsistent, not all activity data can be inferred from the trips. For instance, if a person fails to report a return home trip, the actual time at the activity and at home cannot be computed. Consequently, the total time between the two reported trips has to be labeled "missing," or some other method of correcting the missing data has to be applied. For this study, a further requirement was the consistency of the activity profiles across household members. Otherwise the calculation of joint times and other interrelationships would be biased by the difference in correction factors applied to different household members. It was therefore decided not to correct for missing times, but to control for the possible effects of nonreporting by inclusion of missing times in the analysis. Table 4 presents some figures on the relative amount of time that each adult household member spends on activities and what is reported as missing. On average, the amount of missing time per adult varies between 10 and 15 percent. This percentage is somewhat larger for women than for men, and drops after the first wave. For the male adult in the household, the major activities are: home, work, recreation, visits, and travel. Very little time is spent alone at home. The female partner spends much more time at home without the male partner. Other important categories for her include work, visits, and travel.

Joint time in activities is only relevant for home, recreation, visits, and shopping. Figures 1 through 3 depict the relative amount of time spent individually or jointly for these activities. Apart from activities at home, visits are also spent predominantly by both members together. the male adult spends very little time in individually visiting friends, relatives, etc. Recreation, on the contrary, is performed much more individually, especially by the male. Finally, shopping is mostly a female activity. The male spends as much time shopping individually as jointly.

TABLE 4

AVERAGE TIME ALLOCATIONS AND MISSING TIME IN THE SAMPLE

	TYPE OF ACTIVITY		TIME In minutes per week: WAVE 1	WAVE 3	WAVE 5	WAVE7	WAVE9	TIME In percent of total known time: WAVE 1	WAVE 3	WAVE 5	WAVE7	WAVE9
MALE:												
	home	individually	556	496	483	501	467	6.3	5.5	5.3	5.5	5.1
	work	individually	1912	1985	1929	1885	1967	21.8	22.0	21.3	20.8	21.7
	personal business	individually	28	20	25	19	19	0.3	0.2	0.3	0.2	0.2
	shopping	individually	33	24	34	28	30	0.4	0.3	0.4	0.3	0.3
	recreation	individually	146	148	153	155	130	1.7	1.6	1.7	1.7	1.4
	visits	individually	72	66	62	73	60	0.8	0.7	0.7	0.8	0.7
	serve passenger	individually	25	24	24	32	29	0.3	0.3	0.3	0.4	0.3
	travel time	individually	501	491	476	461	456	5.7	5.4	5.2	5.1	5.0
	other	individually	71	82	100	110	100	0.8	0.9	1.1	1.2	1.1
	home	jointly	5122	5363	5489	5449	5452	58.4	59.4	60.5	60.1	60.1
	work	jointly	30	38	33	33	39	0.3	0.4	0.4	0.4	0.4
	personal business	jointly	8	5	7	9	7	0.1	0.1	0.1	0.1	0.1
	shopping	jointly	31	33	36	37	38	0.4	0.4	0.4	0.4	0.4
	recreation	jointly	58	62	55	68	63	0.7	0.7	0.6	0.8	0.7
	visits	jointly	164	177	152	182	194	1.9	2.0	1.7	2.0	2.1
	serve passenger	jointly	3	4	4	4	6	0.0	0.0	0.0	0.0	0.1
	other	jointly	16	16	14	24	18	0.2	0.2	0.2	0.3	0.2
	total known time:		8776	9035	9077	9070	9074					
	missing time:		1304	1045	1003	1010	1006					
	as % of total week:		13	10	10	10	10					
FEMALE:												
	home	individually	1859	1788	1720	1701	1646	21.8	20.5	19.3	19.2	18.6
	work	individually	427	432	536	512	551	5.0	5.0	6.0	5.8	6.2
	personal business	individually	25	25	26	24	23	0.3	0.3	0.3	0.3	0.3
	shopping	individually	114	117	125	117	114	1.3	1.3	1.4	1.3	1.3
	recreation	individually	85	74	88	103	96	1.0	0.8	1.0	1.2	1.1
	visits	individually	145	142	163	143	136	1.7	1.6	1.8	1.6	1.5
	serve passenger	individually	32	34	43	39	50	0.4	0.4	0.5	0.4	0.6
	travel time	individually	350	337	345	330	319	4.1	3.9	3.9	3.7	3.6
	other	individually	72	69	84	93	109	0.8	0.8	0.9	1.1	1.2
	home	jointly	5122	5363	5489	5449	5452	60.0	61.5	61.5	61.4	61.5
	work	jointly	30	38	33	33	39	0.4	0.4	0.4	0.4	0.4
	personal business	jointly	8	5	7	9	7	0.1	0.1	0.1	0.1	0.1
	shopping	jointly	31	33	36	37	38	0.4	0.4	0.4	0.4	0.4
	recreation	jointly	58	62	55	68	63	0.7	0.7	0.6	0.8	0.7
	visits	jointly	164	177	152	182	194	1.9	2.0	1.7	2.1	2.2
	serve passenger	jointly	3	4	4	4	6	0.0	0.1	0.0	0.0	0.1
	other	jointly	16	16	14	24	18	0.2	0.2	0.2	0.3	0.2
	total known time:		8543	8716	8920	8868	8862					
	missing time:		1537	1364	1160	1212	1218					
	as % of total week:		15	14	12	12	12					

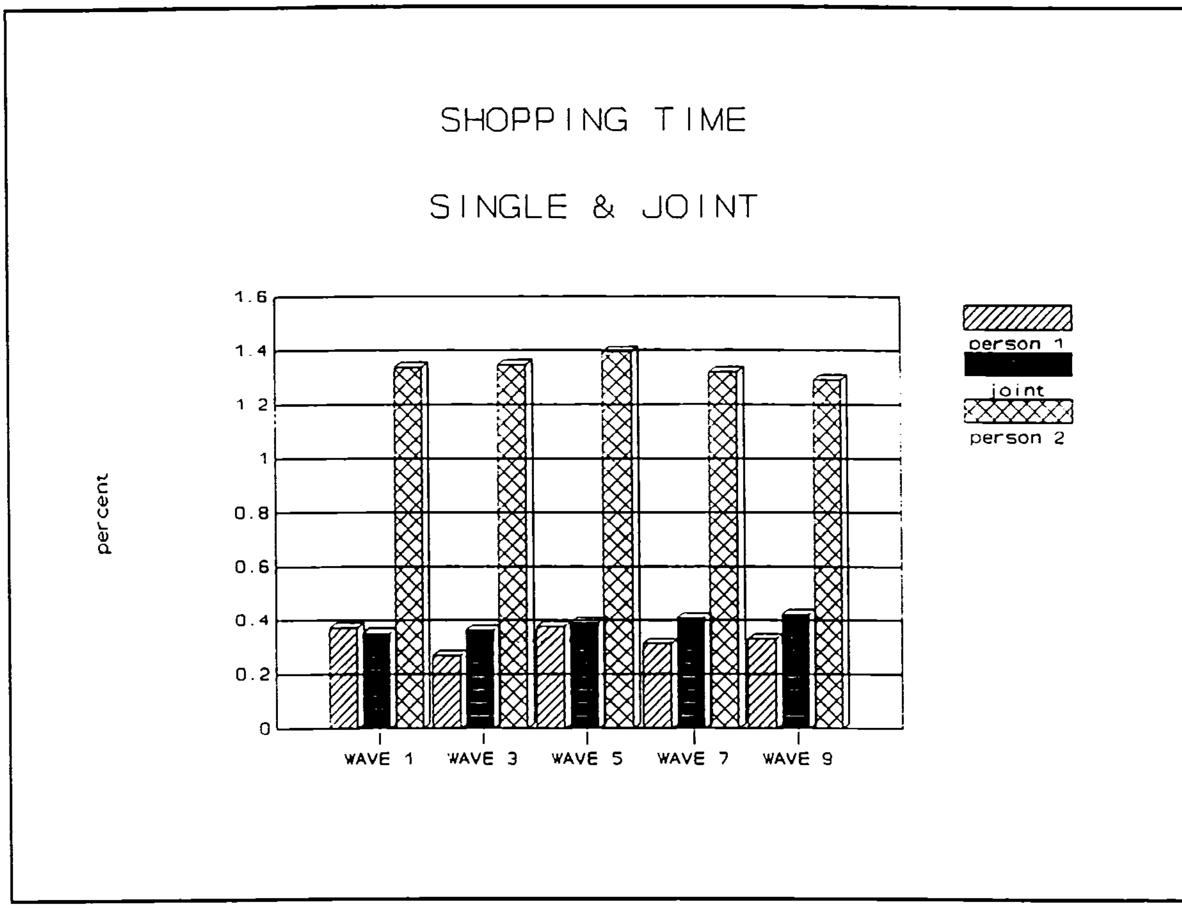

FIGURE 1

INDIVIDUAL AND JOINT TIME ALLOCATED TO SHOPPING

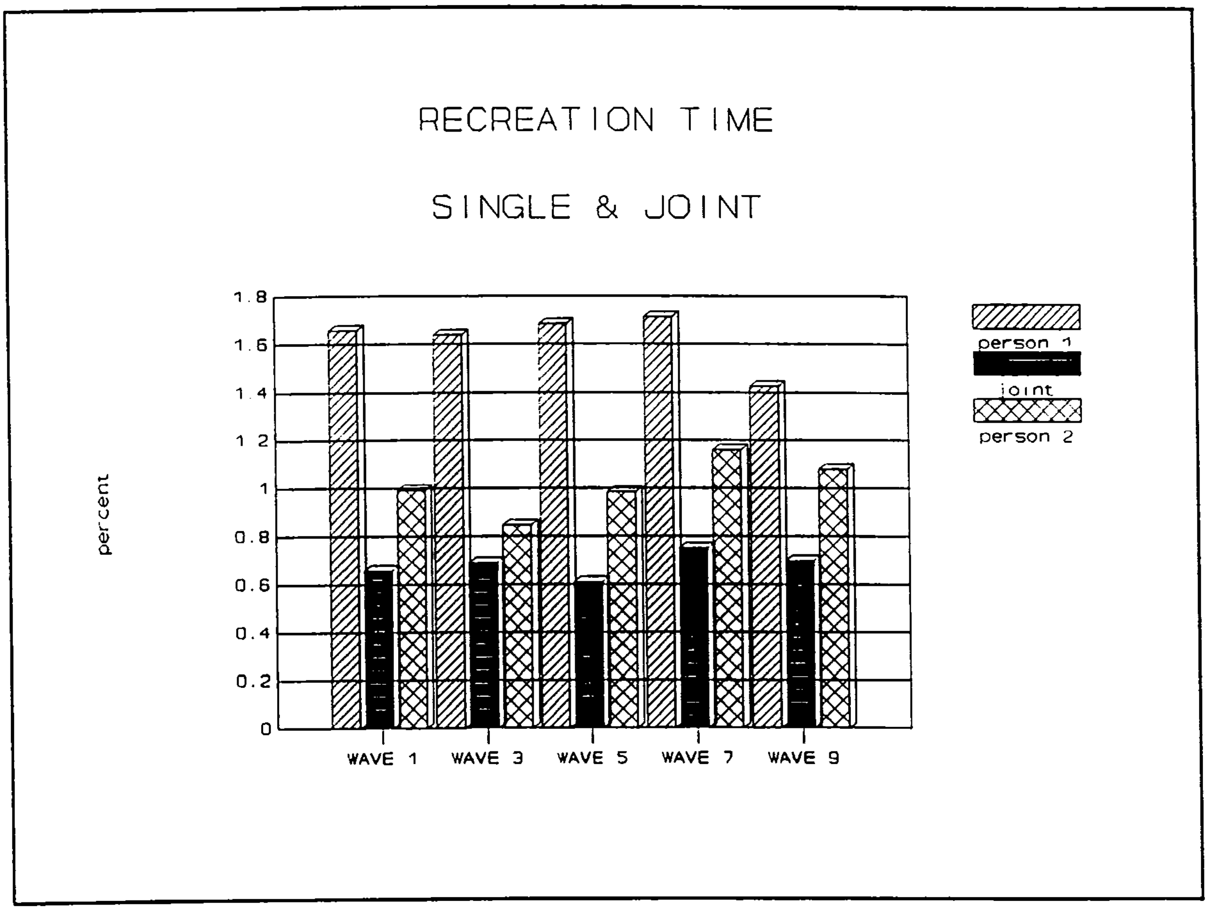

FIGURE 2

INDIVIDUAL AND JOINT TIME ALLOCATED TO RECREATION

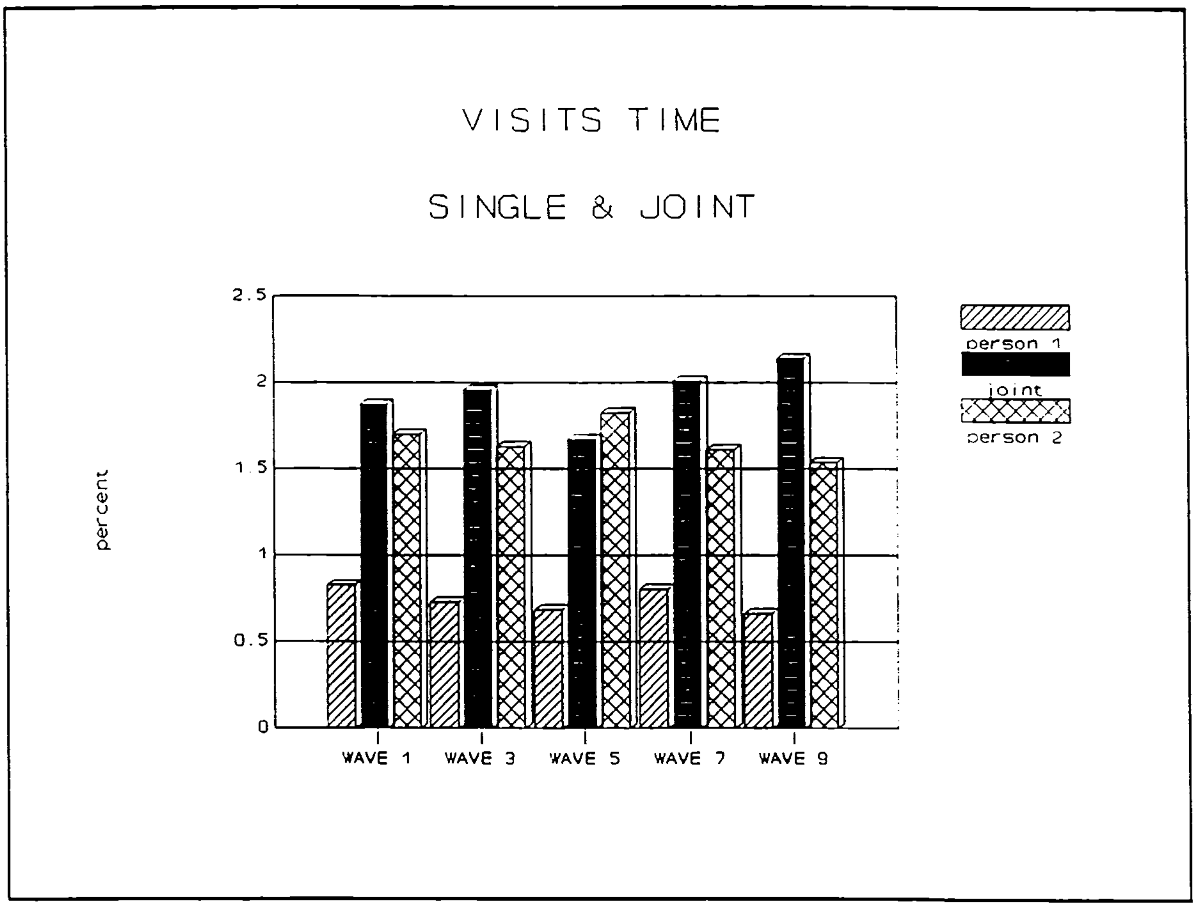

FIGURE 3

INDIVIDUAL AND JOINT TIME ALLOCATED TO VISITS

5. EMPIRICAL RESULTS

In this section, the model results will be presented for three types of activities: shopping, recreation, and visits. For each of these activities we estimate a multivariate model that also includes working time, missing time, and joint activity time for the two adults at two points in time. Table 5 lists the y-variables used in the three models. The multivariate structure among this set of 14 y-variables is estimated conditional on a series of exogenous x-variables that reflect the impact of employment status, demographic, and life cycle variables. These are listed in Table 6. The age of both adults is included as a polynomial to capture nonlinear effects. Employment status of person one (the male) is not included, since almost all male adults are employed (see Table 1). The variance of employment status for female adults is much larger, both across persons and across time. Therefore, both EMP_{p1} (1) and EMP_{p2} (2) are included in the analysis. There are three variables describing the life cycle status of the household: the log of the household size at two points in time, HHS(t), and two life cycle dummies. LC^y (t) indicates young households without children and LC^o (t) indicates households with children over 12 years of age. Originally, a third dummy was included to indicate older households (head over 35 years of age) without children. No significant relations could be found and consequently this variable was dropped from the analysis. Finally, there are two variables included to control for certain bias effects in the sample. In a study of measurement errors in the panel (Meurs, et al., 1989), two important relations were found affecting

TABLE 5

ENDOGENOUS VARIABLES

VARIABLE	DESCRIPTION	USED IN Shopping Model	Recreation Model	Visits Model
$SHOP_{p1}(t)$	Logarithm of individual shopping time in 7 days: person 1; time t	x		
$SHOP_{p2}(t)$	Logarithm of individual shopping time in 7 days: person 2; time t	x		
$SHOP_{J}(t)$	Logarithm of joint shopping time in 7 days: time t	x		
$RECR_{p1}(t)$	Logarithm of individual recreation time in 7 days: person 1; time t		x	
$RECR_{p2}(t)$	Logarithm of individual recreation time in 7 days: person 2; time t		x	
$RECR_{J}(t)$	Logarithm of joint recreation time in 7 days: time t		x	
$VIST_{p1}(t)$	Logarithm of individual visits time in 7 days: person 1; time t			x
$VIST_{p2}(t)$	Logarithm of individual visits time in 7 days: person 2; time t			x
$VIST_{J}(t)$	Logarithm of joint visits time in 7 days: time t			x
$WORK_{p1}(t)$	Logarithm of individual working time in 7 days: person 1; time t	x	x	x
$WORK_{p2}(t)$	Logarithm of individual working time in 7 days: person 2; time t	x	x	x
$MISS_{p1}(t)$	Logarithm of missing time time in 7 days: person 1; time t	x	x	x
$MISS_{p2}(t)$	Logarithm of missing time time in 7 days: person 2; time t	x	x	x

TABLE 6

EXOGENOUS VARIABLES

VARIABLE	DESCRIPTION
AGE_{p1}	Age at time 1 of person 1 (x 0.01)
AGE_{p2}	Age at time 1 of person 2 (x 0.0001)
AGE^2_{p1}	Age squared at time 1 of person 1 (x 0.01)
A^2_{p2}	Age squared at time 1 of person 1 (x 0.0001)
$EMP_{p2}(t)$	Employment status of person 2 at time t (t = 1, 2); 0 = unemployed; 1 = employed
HHS (t)	Logarithm of household size at time t (t = 1, 2)
$LC^y(t)$	Dummy variable (0/1) indicating young households (head under 35 years of age) without children at time t (t = 1, 2)
$LC^o(t)$	Dummy variable (0/1) indicating households with at least one child 12 year or older at time t (t = 1, 2)
TOTL	Logarithm of total length of stay in the panel
GRP	Subsample indicator: 0 = subsample including waves 1-5; 1 = subsample including waves 5-9

nonreporting of trips: total length of participation in the panel (TOTL) and length of stay up to that wave. The first variable is constant across waves for each individual. The second variable increases over time. It was found that total participation positively affected trip reporting in all waves. Length of stay in the panel had a negative and diminishing effect. As a person's participation increases, he/she tends to leave out certain trips in later waves. For our sample, the length of stay is highly related to subsample variable GRP (subsample indicator). In addition, GRP also captures possible temporal effects. By including TOTL and GRP as conditioning variables, we control for total participation effects and temporal effects. We control only partially for the length-of-stay effect.

Shopping

The specification of the shopping model is given in Table 7. As described in Section Three, there are four parameter matrices: $\underline{B}$, $\underline{\Gamma}$, $\underline{\Psi}$, and $\underline{\Omega}$. The three types of relationships hypothesized in Section Two are contained in $\underline{B}$, the structural parameters matrix. Conditioning effects of employment status and life cycle variables appear in $\underline{\Gamma}$, the matrix of regression parameters. $\underline{\Psi}$ is the variance-covariance matrix of all time variables, and $\underline{\Omega}$ contains the random individual specific effects.

Two models were estimated: the restricted case, with $\underline{B}$ and $\underline{\Gamma}$ equal across the two time periods (Equation (1)); and the unrestricted case, where $\underline{B}$ and $\underline{\Gamma}$ are allowed to vary over time. The model results are given in Tables 8, 9, and 10. First the structural parameter matrix will be discussed. Turning first to the shopping variables, it can be

TABLE 7

SPECIFICATION OF SHOPPING INTERACTIONS MODEL

$$
\underline{B} = \begin{bmatrix}
0 & 0 & 0 & \beta_{1,4} & 0 & 0 & 0 \\
\beta_{2,1} & 0 & 0 & 0 & \beta_{2,5} & 0 & 0 \\
\beta_{3,1} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\beta_{5,1} & 0 & 0 & \beta_{5,4} & 0 & 0 & 0 \\
0 & 0 & 0 & \beta_{6,4} & 0 & 0 & 0 \\
\beta_{7,1} & \beta_{7,2} & 0 & 0 & \beta_{7,5} & 0 & 0
\end{bmatrix}
$$

$$
\underline{\Gamma} = \begin{bmatrix}
\gamma_{1,1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\gamma_{2,1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \gamma_{2,9} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \gamma_{3,10} \\
\gamma_{4,1} & 0 & \gamma_{4,3} & \gamma_{4,4} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \gamma_{5,4} & 0 & 0 & 0 & 0 & \gamma_{5,9} & \gamma_{5,10} \\
0 & \gamma_{6,2} & 0 & \gamma_{6,4} & 0 & 0 & 0 & 0 & 0 & \gamma_{6,10} \\
0 & \gamma_{7,2} & 0 & \gamma_{7,4} & \gamma_{7,5} & \gamma_{7,6} & \gamma_{7,7} & \gamma_{7,8} & 0 & 0
\end{bmatrix}
$$

$$
\underline{\Psi} = \begin{bmatrix}
\psi_{1,1}(1) & & & & & & & & & & & & & \\
0 & \psi_{2,2}(1) & & & & & & & & & & & & \\
0 & 0 & \psi_{3,3}(1) & & & & & & & & & & & \\
0 & 0 & 0 & \psi_{4,4}(1) & & & & & & & & & & \\
0 & 0 & 0 & 0 & \psi_{5,5}(1) & & & & & & & & & \\
0 & 0 & \psi_{6,3}(1) & 0 & 0 & \psi_{6,6}(1) & & & & & & & & \\
0 & 0 & 0 & 0 & 0 & 0 & \psi_{7,7}(1) & & & & & & & \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{1,1}(2) & & & & & & \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{2,2}(2) & & & & & \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{3,3}(2) & & & & \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{4,4}(2) & & & \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{5,5}(2) & & \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{6,3}(2) & 0 & 0 & \psi_{6,6}(2) & \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{7,7}(2)
\end{bmatrix}
$$

$$
\underline{\Omega} = \begin{bmatrix}
\omega_{1,1} & & & & & & \\
0 & \omega_{2,2} & & & & & \\
0 & 0 & \omega_{3,3} & & & & \\
0 & 0 & 0 & \omega_{4,4} & & & \\
0 & 0 & 0 & 0 & \omega_{5,5} & & \\
0 & 0 & 0 & 0 & 0 & \omega_{6,6} & \\
0 & 0 & 0 & 0 & 0 & 0 & \omega_{7,7}
\end{bmatrix}
$$

TABLE 8

STRUCTURAL PARAMETERS ($\underline{B}$)
OF SHOPPING INTERACTIONS MODEL

PARAMETER	EFFECT	RESTRICTED MODEL	UNRESTRICTED	
			T = 1	T = 2
$\beta_{2,1}$	$WORK_{p1} \longrightarrow SHOP_{p1}$	-0.037 (-3.248)	-0.041 (-2.539)	-0.032 (-2.083)
$\beta_{3,1}$	$WORK_{p1} \longrightarrow MISS_{p1}$	-0.133 (-6.046)	-0.141 (-4.635)	-0.124 (-4.052)
$\beta_{5,1}$	$WORK_{p1} \longrightarrow SHOP_{p2}$	0.100 (5.870)	0.095 (4.043)	0.106 (4.396)
$\beta_{7,1}$	$WORK_{p1} \longrightarrow SHOP_{J}$	-0.013 (-2.923)	-0.023 (-3.607)	-0.005 (-0.861)
$\beta_{7,2}$	$SHOP_{p1} \longrightarrow SHOP_{J}$	0.304 (27.828)	0.293 (19.726)	0.312 (21.041)
$\beta_{1,4}$	$WORK_{p2} \longrightarrow WORK_{p1}$	0.239 (2.329)	0.151 (1.013)	0.316 (2.361)
$\beta_{5,4}$	$WORK_{p2} \longrightarrow SHOP_{p2}$	-0.184 (-4.232)	-0.195 (-3.227)	-0.176 (-3.095)
$\beta_{6,4}$	$WORK_{p2} \longrightarrow MISS_{p2}$	-0.183 (-3.104)	-0.156 (-1.816)	-0.205 (-2.621)
$\beta_{2,5}$	$SHOP_{p2} \longrightarrow SHOP_{p1}$	0.122 (6.647)	0.131 (5.052)	0.120 (4.857)
$\beta_{7,5}$	$SHOP_{p2} \longrightarrow SHOP_{J}$	0.093 (12.704)	0.097 (9.402)	0.090 (9.217)

(t-values in parentheses)

TABLE 9

REGRESSION PARAMETERS ($\underline{\Gamma}$) OF SHOPPING INTERACTIONS MODEL

PARAMETER	EFFECT	RESTRICTED MODEL	UNRESTRICTED T = 1	UNRESTRICTED T = 2
$\gamma_{1,1}$	$EMP_{p2}(t) \longrightarrow WORK_{p1}(t)$	-2.887 (-3.670)	-2.964 (-2.566)	-2.890 (-2.920)
$\gamma_{2,1}$	$EMP_{p2}(t) \longrightarrow SHOP_{p1}(t)$	0.530 (2.399)	0.762 (2.362)	0.376 (1.388)
$\gamma_{4,1}$	$EMP_{p2}(t) \longrightarrow WORK_{p2}(t)$	5.416 (34.447)	5.547 (26.765)	5.291 (26.694)
$\gamma_{6,2}$	$HHS(t) \longrightarrow MISS_{p2}(t)$	0.690 (4.565)	0.521 (2.430)	0.852 (4.207)
$\gamma_{7,2}$	$HHS(t) \longrightarrow SHOP_{J}(t)$	-0.214 (-6.141)	-0.225 (-4.757)	-0.214 (-5.005)
$\gamma_{4,3}$	$LC^{y}(t) \longrightarrow WORK_{p2}(t)$	1.918 (4.119)	1.907 (3.828)	2.280 (2.445)
$\gamma_{4,4}$	$LC^{o}(t) \longrightarrow WORK_{p2}(t)$	0.789 (2.918)	1.354 (3.396)	0.519 (1.669)
$\gamma_{5,4}$	$LC^{o}(t) \longrightarrow SHOP_{p2}(t)$	1.713 (2.946)	2.309 (2.445)	1.460 (2.199)
$\gamma_{6,4}$	$LC^{o}(t) \longrightarrow MISS_{p2}(t)$	-2.776 (-3.519)	-2.711 (-2.028)	-2.918 (-3.088)
$\gamma_{7,4}$	$LC^{o}(t) \longrightarrow SHOP_{J}(t)$	0.490 (2.872)	0.919 (3.262)	0.348 (1.786)
$\gamma_{7,5}$	$AGE_{p1} \longrightarrow SHOP_{J}(t)$	-1.072 (-0.986)	-3.172 (-2.236)	0.615 (0.459)
$\gamma_{7,6}$	$AGE^2_{p1} \longrightarrow SHOP_{J}(t)$	1.749 (0.610)	7.043 (1.882)	-2.531 (-0.717)
$\gamma_{7,7}$	$AGE_{p2} \longrightarrow SHOP_{J}(t)$	1.408 (1.436)	3.059 (2.387)	0.034 (0.028)
$\gamma_{7,8}$	$AGE^2_{p2} \longrightarrow SHOP_{J}(t)$	-3.646 (-1.365)	-7.905 (-2.267)	-0.126 (-0.038)
$\gamma_{2,9}$	$TOTL \longrightarrow SHOP_{p1}(t)$	-0.191/-- * (-2.437)/--	-0.182 (-2.330)	-- --
$\gamma_{5,9}$	$TOTL \longrightarrow SHOP_{p2}(t)$	-0.216/-- * (-1.853)/--	-0.202 (-1.714)	-- --
$\gamma_{3,10}$	$GRP \longrightarrow MISS_{p1}(t)$	-0.801/-0.939 * (-1.837)/(-2.354)	-0.802 (-1.841)	-0.933 (-2.335)
$\gamma_{5,10}$	$GRP \longrightarrow SHOP_{p2}(t)$	0.543/-- * (1.775)/--	0.541 (1.770)	-- --
$\gamma_{6,10}$	$GRP \longrightarrow MISS_{p2}(t)$	-1.444/--* (-3.178)/--	-1.436 (-3.160)	-- --

(t-values in parentheses)

* These coefficients were unrestricted; both T=1 / T=2 values listed ("--" indicates constrained to zero).

TABLE 10

VARIANCE COMPONENTS
OF RESTRICTED SHOPPING INTERACTIONS MODEL

VARIABLE	TOTAL VARIANCE	VARIABLE INTERCEPT VARIANCE ω	RESIDUAL VARIANCE ψ	TOTAL % "EXPLAINED" VARIANCE R^2	TOTAL % "EXPLAINED" BY ω
$WORK_{p1}$ (1)	51.333	9.638	41.033	20.0	18.8
$WORK_{p1}$ (2)	49.870		39.568	20.6	19.3
$SHOP_{p1}$ (1)	9.346	2.451	6.385	31.3	26.2
$SHOP_{p1}$ (2)	8.315		5.589	32.5	29.5
$MISS_{p1}$ (1)	37.552	4.184	32.024	14.5	11.1
$MISS_{p1}$ (2)	34.948		29.614	15.0	12.0
$WORK_{p2}$ (1)	8.017	1.168	2.229	71.7	14.6
$WORK_{p2}$ (2)	9.371		2.957	67.2	12.5
$SHOP_{p2}$ (1)	19.832	3.817	14.742	25.4	19.2
$SHOP_{p2}$ (2)	19.956		15.150	24.1	19.1
$MISS_{p2}$ (1)	40.997	1.702	37.675	7.6	4.2
$MISS_{p2}$ (2)	39.176		35.338	9.1	4.3
$SHOP_{J}$ (1)	2.542	0.302	1.038	60.7	11.9
$SHOP_{J}$ (2)	2.338		0.890	62.5	12.9

noted that for both male and female adults, the amount of shopping time is negatively affected by their personal working times. The negative effect for the female adult is much stronger, however (-0.037 versus -0.184). This is plausible, given the low level of overall shopping time for the male. His working time has a positive effect on shopping time for the female. This can be explained by the income effect of more working hours. This is the only significant effect that individual time allocation of the male has on individual time allocation by the female. There are two interesting effects of the female time allocation on the male time allocation: working time and shopping time. Both are positive. The effect of female working time on male working time is somewhat instable over time, with a nonsignificant coefficient for time T = 1 in the unrestricted model. If true, this effect would imply that the number of working hours of the female has a positive effect on male working hours. The shopping effect is also positive. This is surprising, since it can be expected that household maintenance activities are substitution activities across household members. Contrary to that expectation, we find a complementary relation that is unidirectional, and stable over time, as shown by the unrestricted model.

Joint shopping time is a function of both individual shopping times, with a much stronger effect of the male individual shopping time (0.304 versus 0.093). There is a negative effect of the male working time on joint shopping time (although this effect is not significant in both time periods in the unrestricted model), but not of the female working time. Her working time only affects her individual shopping time. Finally, missing times are negatively affected by the amount of working time.

Table 9 gives the effects of exogenous employment status and life cycle on the multivariate y-variables. Employment status is a dummy variable. It has a number of additional effects over the actual amount of time worked. While the actual time worked by the female has a positive effect on male working time, the effect of employment status shows that being employed for the female implies less hours working for the male. In addition, the employment status of the female affects shopping behavior of the male. While there is no effect of actual hours worked, this result implies that there is a distinction between households with and without employed wives in male shopping behavior. However, the results of the unrestricted model show that this effect is not significant for time T = 2 (t-value of 1.388).

Household size has a positive effect on nonreporting of the female. She probably has less time to fill in the travel diary with an increasing number of children. There is also a negative effect on joint shopping time, which can be explained by the required time at home of one adult if the number of children increases.

There are two life cycle dummies that affect time allocations. First, wives in young households (head under 35 years) without children make relatively more working hours. This is also the case for wives in households with older children, although this coefficient is less strong. This last category spends more time shopping, either individually by the wife or jointly, and has less missing time for the wife. It is noteworthy that life cycle status does not affect the time allocation of the male in the household, except for joint shopping time. It is the female who adjusts working hours and shopping time to accommodate the life cycle requirements.

The age of both partners affects the joint shopping time, although these effects are not very stable over time. The results of age, treated as a polynomial, tentatively suggest that for the male the effect is u-shaped: high joint time allocation at young ages, lower at middle ages, and high again in the older ages. (N.B.: there are no ages above 65 in this sample.) For the wife, the pattern is reverse, but also not stable over time. The last two exogenous variables account for bias corrections. Due to the sample structure, these coefficients may change over time. No restrictions were imposed on these coefficients in the restricted model. Consequently, both T = 1 and T = 2 values are given in the restricted model column. The results show that total length of participation in the panel (TOTL) has a negative influence on shopping time reported (only at T = 1). Further, missing times vary over the two subsamples (GRP), as well as shopping time.

Finally, Table 10 gives the variance decomposition of the time variables, and the total "explained" variance by the model. In general, R^2 measures are not very high, with the exception of female working hours and joint shopping time. The contribution of the random effect can also be seen from this table. A greater part of the "explained" variance can be attributed to this effect in all male activity times. The importance of the variable intercept for the wive's time allocation seems to be much less. Table 11 shows that both the restricted and the unrestricted model describe the data appropriately. Both x^2 values are well below the critical level associated with the respective degrees of freedom. The probability values are p = 0.380 and p = 0.399 for the restricted and unrestricted cases, respectively. Moreover, the two models are not significantly different. By releasing the 24 equality constraints in $\underline{B}$ and $\underline{\Gamma}$, the x^2 value increases 25.45 points, which is not a significant improvement (p = 0.618).

TABLE 11

χ^2-FIT OF SHOPPING MODELS

	χ^2	D.F.	P.
Restricted Model:	254.22	248	0.309
Unrestricted Model:	228.77	224	0.399
Difference:	25.45	24	0.618

Recreation

By replacing the shopping time data by recreation time data, we get the multivariate y-structure for the recreation model. So, elements of the shopping model only involving work and/or missing times are almost identical and will not be discussed here. For completeness, all coefficient values are presented in Tables 12 through 15 below. We will concentrate on the coefficients involving recreation times. Increasing the male's working hours has an unequal effect on both partners. While it has an increasing effect on his own recreation time (although not significant at time T = 1 in the unrestricted model), it has a marginally negative effect on the female's recreation time (not significant at time T = 2). While it is plausible that working hours and individual recreation

TABLE 12

SPECIFICATION OF RECREATION INTERACTIONS MODEL

$$
\underline{B} = \begin{bmatrix}
0 & 0 & 0 & \beta_{1,4} & 0 & 0 & 0 \\
\beta_{2,1} & 0 & 0 & 0 & \beta_{2,5} & 0 & 0 \\
\beta_{3,1} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\beta_{5,1} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & \beta_{6,4} & 0 & 0 & 0 \\
0 & \beta_{7,2} & \beta_{7,3} & 0 & \beta_{7,5} & 0 & 0
\end{bmatrix}
$$

$$
\underline{\Gamma} = \begin{bmatrix}
\gamma_{1,1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \gamma_{2,2} & \gamma_{2,3} & \gamma_{2,4} & \gamma_{2,5} & \gamma_{2,6} & 0 & 0 & \gamma_{2,9} & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \gamma_{3,10} \\
\gamma_{4,1} & 0 & \gamma_{4,3} & \gamma_{4,4} & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \gamma_{5,2} & \gamma_{5,3} & 0 & 0 & 0 & \gamma_{5,7} & \gamma_{5,8} & \gamma_{5,9} & \gamma_{5,10} \\
0 & \gamma_{6,2} & 0 & \gamma_{6,4} & 0 & 0 & 0 & 0 & 0 & \gamma_{6,10} \\
0 & \gamma_{7,2} & \gamma_{7,3} & \gamma_{7,4} & 0 & 0 & \gamma_{7,7} & \gamma_{7,8} & 0 & \gamma_{7,10}
\end{bmatrix}
$$

$$
\underline{\Psi} = \begin{bmatrix}
\psi_{1,1}(1) \\
0 & \psi_{2,2}(1) \\
0 & 0 & \psi_{3,3}(1) \\
0 & 0 & 0 & \psi_{4,4}(1) \\
0 & 0 & 0 & 0 & \psi_{5,5}(1) \\
0 & 0 & \psi_{6,3}(1) & 0 & 0 & \psi_{6,6}(1) \\
0 & 0 & 0 & 0 & 0 & 0 & \psi_{7,7}(1) \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{1,1}(2) \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{2,2}(2) \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{3,3}(2) \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{4,4}(2) \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{5,5}(2) \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{6,3}(2) & 0 & 0 & \psi_{6,6}(2) \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{7,7}(2)
\end{bmatrix}
$$

$$
\underline{\Omega} \quad \begin{bmatrix}
\omega_{1,1} \\
0 & \omega_{2,2} \\
0 & 0 & \omega_{3,3} \\
0 & 0 & 0 & \omega_{4,4} \\
0 & 0 & 0 & 0 & \omega_{5,5} \\
0 & 0 & 0 & 0 & 0 & \omega_{6,6} \\
0 & 0 & 0 & 0 & 0 & 0 & \omega_{7,7}
\end{bmatrix}
$$

TABLE 13

STRUCTURAL PARAMETERS (B) OF RECREATION INTERACTIONS MODEL

PARAMETER	EFFECT	RESTRICTED MODEL	UNRESTRICTED	
			T = 1	T = 2
$\beta_{2,1}$	$WORK_{p1} \longrightarrow RECR_{p1}$	0.029 (2.509)	0.021 (1.273)	0.038 (2.394)
$\beta_{3,1}$	$WORK_{p1} \longrightarrow MISS_{p1}$	-0.133 (-6.046)	-0.141 (-4.635)	-0.124 (-4.052)
$\beta_{5,1}$	$WORK_{p1} \longrightarrow RECR_{p2}$	-0.018 (-1.550)	-0.031 (-1.904)	-0.006 (-0.382)
$\beta_{7,2}$	$RECR_{p1} \longrightarrow RECR_{J}$	0.163 (15.957)	0.157 (11.248)	0.166 (11.775)
$\beta_{7,3}$	$MISS_{p1} \longrightarrow RECR_{J}$	-0.008 (-1.565)	-0.012 (-1.657)	-0.005 (-0.683)
$\beta_{1,4}$	$WORK_{p2} \longrightarrow WORK_{p1}$	0.239 (2.329)	0.151 (1.013)	0.316 (2.316)
$\beta_{6,4}$	$WORK_{p2} \longrightarrow MISS_{p2}$	-0.183 (-3.104)	-0.156 (-1.816)	-0.205 (-2.621)
$\beta_{2,5}$	$RECR_{p2} \longrightarrow RECR_{p1}$	0.440 (15.720)	0.431 (11.049)	0.445 (11.813)
$\beta_{7,5}$	$RECR_{p2} \longrightarrow RECR_{J}$	0.238 (21.330)	0.244 (15.889)	0.234 (15.353)

(t-values in parentheses)

TABLE 14

REGRESSION PARAMETERS ($\underline{\Gamma}$) OF RECREATION INTERACTIONS MODEL

PARAMETER	EFFECT	RESTRICTED MODEL	UNRESTRICTED T = 1	UNRESTRICTED T = 2
$\gamma_{1,1}$	$EMP_{p2}(t) \longrightarrow WORK_{p1}(t)$	-2.887 (-3.670)	-2.964 (-2.566)	-2.890 (-2.920)
$\gamma_{4,1}$	$EMP_{p2}(t) \longrightarrow WORK_{p2}(t)$	5.416 (34.446)	5.547 (26.765)	5.291 (26.694)
$\gamma_{2,2}$	$HHS(t) \longrightarrow RECR_{p1}(t)$	0.268 (2.424)	0.436 (2.651)	0.139 (1.041)
$\gamma_{5,2}$	$HHS(t) \longrightarrow RECR_{p2}(t)$	-0.082 (-0.787)	0.058 (0.377)	-0.156 (-1.235)
$\gamma_{6,2}$	$HHS(t) \longrightarrow MISS_{p2}(t)$	0.690 (4.565)	0.521 (2.432)	0.852 (4.207)
$\gamma_{7,2}$	$HHS(t) \longrightarrow RECR_{J}(t)$	-0.082 (-2.063)	-0.010 (-0.168)	-0.145 (-3.002)
$\gamma_{2,3}$	$LC^{y}(t) \longrightarrow RECR_{p1}(t)$	2.827 (2.816)	4.164 (3.373)	0.732 (0.407)
$\gamma_{4,3}$	$LC^{y}(t) \longrightarrow WORK_{p2}(t)$	1.918 (4.119)	1.907 (3.828)	2.280 (2.445)
$\gamma_{5,3}$	$LC^{y}(t) \longrightarrow RECR_{p2}(t)$	1.242 (1.267)	1.714 (1.398)	1.354 (0.772)
$\gamma_{7,3}$	$LC^{y}(t) \longrightarrow RECR_{J}(t)$	-0.179 (-0.487)	0.493 (1.063)	-1.568 (-2.420)
$\gamma_{2,4}$	$LC^{o}(t) \longrightarrow RECR_{p1}(t)$	-0.809 (-1.736)	-2.245 (-2.893)	-0.072 (-0.135)
$\gamma_{4,4}$	$LC^{o}(t) \longrightarrow WORK_{p2}(t)$	0.789 (2.918)	1.354 (3.396)	0.519 (1.669)
$\gamma_{6,4}$	$LC^{o}(t) \longrightarrow MISS_{p2}(t)$	-2.776 (-3.519)	-2.711 (-2.028)	-2.918 (-3.088)
$\gamma_{7,4}$	$LC^{o}(t) \longrightarrow RECR_{J}(t)$	-0.127 (-0.766)	-0.434 (-1.563)	0.059 (0.312)
$\gamma_{2,5}$	$AGE_{p1} \longrightarrow RECR_{p1}(t)$	2.780 (1.171)	5.348 (1.712)	0.036 (0.012)
$\gamma_{2,6}$	$AGE^{2}_{p1} \longrightarrow RECR_{p1}(t)$	-5.421 (-0.855)	-11.020 (-1.319)	0.889 (0.113)
$\gamma_{5,7}$	$AGE_{p2} \longrightarrow RECR_{p2}(t)$	6.163 (3.081)	5.315 (2.002)	6.869 (2.765)
$\gamma_{7,7}$	$AGE_{p2} \longrightarrow RECR_{J}(t)$	0.902 (1.200)	1.695 (1.696)	-0.080 (-0.084)
$\gamma_{5,8}$	$AGE^{2}_{p2} \longrightarrow RECR_{p2}(t)$	-16.236 (-2.847)	-13.652 (-1.813)	-18.150 (-2.562)
$\gamma_{7,8}$	$AGE^{2}_{p2} \longrightarrow RECR_{J}(t)$	-2.125 (-1.005)	-4.281 (-1.528)	0.479 (0.180)
$\gamma_{2,9}$	$TOTL \longrightarrow RECR_{p1}(t)$	–/0.148 * –/(1.893)	– –	0.167 (2.084
$\gamma_{5,9}$	$TOTL \longrightarrow RECR_{p2}(t)$	–/0.214 * –/(2.707)	– –	0.224 (2.781)
$\gamma_{3,10}$	$GRP \longrightarrow MISS_{p1}(t)$	-0.801/-0.939 * (-1.837)/(-2.354)	-0.802 (-1.841)	-0.933 (-2.335)
$\gamma_{5,10}$	$GRP \longrightarrow RECR_{p2}(t)$	-0.354/– * (-1.636)/–	-0.365 (-1.678)	– –
$\gamma_{6,10}$	$GRP \longrightarrow MISS_{p2}(t)$	-1.444/– * (-3.178)/–	-1.436 (-3.160)	– –
$\gamma_{7,10}$	$GRP \longrightarrow RECR_{J}(t)$	–/-0.179 * –/(2.382)	– –	-0.202 (-2.668)

(t-values in parentheses)

* These coefficients were unrestricted: both T=1 / T=2 values listed ("–" indicates constrained to zero)

TABLE 15

VARIANCE COMPONENTS
OF RESTRICTED RECREATION INTERACTIONS MODEL

VARIABLE	TOTAL VARIANCE	VARIABLE INTERCEPT VARIANCE ω	RESIDUAL VARIANCE ψ	TOTAL % "EXPLAINED" VARIANCE R^2	TOTAL % "EXPLAINED" BY ω
$WORK_{p1}$ (1)	51.333	9.638	41.033	19.8	18.8
$WORK_{p1}$ (2)	49.870		39.568	20.6	19.3
$RECR_{p1}$ (1)	11.907	2.214	7.476	35.9	18.6
$RECR_{p1}$ (2)	10.420		6.076	40.5	21.2
$MISS_{p1}$ (1)	37.552	4.184	32.024	14.1	11.1
$MISS_{p1}$ (2)	34.948		29.614	15.2	12.0
$WORK_{p2}$ (1)	8.017	1.168	2.229	70.8	14.6
$WORK_{p2}$ (2)	9.371		2.957	67.9	12.5
$RECR_{p2}$ (1)	9.444	2.083	7.220	23.8	22.1
$RECR_{p2}$ (2)	8.800		6.492	26.0	23.7
$MISS_{p2}$ (1)	40.997	1.702	37.675	8.3	4.2
$MISS_{p2}$ (2)	39.176		35.338	7.9	4.3
$RECR_{J}$ (1)	2.414	0.252	1.005	58.9	10.4
$RECR_{J}$ (2)	2.179		0.862	61.1	11.6

time are positively related (complementary relation between activities), this does not explain why the same relation does not hold for females, or why there is interaction between the male's working time and the female's recreation time. The results tentatively suggest that the female's individual recreation time is somewhat of a residual category. More working hours by the male increase his need for individual recreation time. For his female partner, the result is less time for recreation (and probably more time to spend at home, etc.) However, the coefficients only point tentatively in this direction. The results do not hold equally for both time periods.

Similar to shopping are the effects of individual time on joint time. Here, the effect of the wife's individual time allocation is larger than the effect of the male's time. Also very strong is the effect of her individual recreation time on his individual recreation time, and not vice versa. The male's recreation is therefore largely dependent on his working hours and her recreation time allocation.

The effects of employment status and the life cycle variable are given in Table 14. Apart from working hours, there is no separate effect of employment status on recreation behavior. Household size has an increasing effect on the male's recreation time, but a nonsignificant decreasing effect on the female's time. The effect on joint recreation time is negative and significant in the restricted model, and at time $T = 2$ in the unrestricted model. In young couples without children, both partners spend more individual time in recreation, although the female's coefficients are not quite significant. The effect on joint time is mixed over time, with reverse signs for time $T = 1$ and $T = 2$. Households with older children tend to have less individual recreation time for the male and jointly, although the coefficients are marginally significant and have different levels over time.

Finally, age of both partners has the same effect on recreation time: relatively low levels at young and older ages, and relatively high levels at middle age. Again, significance levels vary over time.

Looking at Table 15, it can be observed that joint recreation time is well explained by the other variables: 58-9 and 61.1 percent of the total variance for time T = 1 and T = 2, respectively. The female's recreation time is least explained by the other variables. Moreover, the random effect accounts for most of this explanation.

The overall model performance is less satisfactory than the shopping model. Table 16 lists the χ^2 results. Both models fail to fit the data well, although the difference between the models is not significant (p = 0.731).

Visits

Results for the visits interaction model are given in Tables 17 through 21. We will briefly describe the results relating to the visits time. Individual visits time of both male and female are positively affected by the working time of the partner. This result holds for the restricted model, but is not significant for time T = 1. A plausible explanation for this effect could be that if the partner works more hours, the other adult spends more time socializing with friends and relatives. Similar to shopping and recreation, it is found that the joint time spent in visits is the result of the individual times allocated to visits. Further, working hours of the wife affects her individual visits time negatively. This is not the case for the male, who spends on average much less time individually in this activity.

TABLE 16

χ^2-FIT OF RECREATION MODELS

	χ^2	D.F.	P.
Restricted Model:	295.43	242	0.011
Unrestricted Model:	262.20	213	0.012
Difference:	33.23	29	0.731

Time spent jointly on visits is affected negatively by his working time. Finally, his individual visits time is affected by her individual visits time, but not vice versa. Again, the female's influence in the male's allocation of his time for nonwork activities is clear.

Turning to the influence of exogenous variables on visits time, Table 19 shows that the employment status of the wife only has a marginally significant influence (positive) on the male's time at time T = 1. An increase in household size reduces her time visiting friends or relatives. The male in young childless couples spends more time with friends and relatives, and the same is true for females in households with older children. Again, the effect of age is somewhat inconclusive. The effect of the male's age on joint visits time is weakly significant, showing a u-shaped curve (high levels at younger and older ages, low level at middle age). The female's age has a u-shaped effect on her visits time.

TABLE 17

SPECIFICATION OF VISITS INTERACTIONS MODEL

$$\underline{B} = \begin{bmatrix} 0 & 0 & 0 & \beta_{1,4} & 0 & 0 & 0 \\ 0 & 0 & 0 & \beta_{2,4} & \beta_{2,5} & 0 & 0 \\ \beta_{3,1} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \beta_{5,1} & 0 & 0 & \beta_{5,4} & 0 & 0 & 0 \\ 0 & 0 & 0 & \beta_{6,4} & 0 & 0 & 0 \\ \beta_{7,1} & \beta_{7,2} & 0 & 0 & \beta_{7,5} & 0 & 0 \end{bmatrix}$$

$$\underline{\Gamma} = \begin{bmatrix} \gamma_{1,1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \gamma_{2,1} & 0 & \gamma_{2,3} & 0 & 0 & 0 & 0 & 0 & \gamma_{2,9} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \gamma_{3,10} \\ \gamma_{4,1} & 0 & \gamma_{4,3} & \gamma_{4,4} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \gamma_{5,2} & 0 & \gamma_{5,4} & 0 & 0 & \gamma_{5,7} & \gamma_{5,8} & 0 & 0 \\ 0 & \gamma_{6,2} & 0 & \gamma_{6,4} & 0 & 0 & 0 & 0 & 0 & \gamma_{6,10} \\ 0 & 0 & 0 & 0 & \gamma_{7,5} & \gamma_{7,6} & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\underline{\Psi} = \begin{bmatrix} \psi_{1,1}(1) \\ 0 & \psi_{2,2}(1) \\ 0 & \psi_{3,2}(1) & \psi_{3,3}(1) \\ 0 & 0 & 0 & \psi_{4,4}(1) \\ 0 & 0 & 0 & 0 & \psi_{5,5}(1) \\ 0 & 0 & \psi_{6,3}(1) & 0 & 0 & \psi_{6,6}(1) \\ 0 & 0 & 0 & 0 & 0 & \psi_{7,6}(1) & \psi_{7,7}(1) \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{1,1}(2) \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{2,2}(2) \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{3,3}(2) \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{4,4}(2) \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{5,5}(2) \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{6,3}(2) & 0 & 0 & \psi_{6,6}(2) \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \psi_{7,7}(2) \end{bmatrix}$$

$$\underline{\Omega} \quad \begin{bmatrix} \omega_{1,1} \\ 0 & \omega_{2,2} \\ 0 & 0 & \omega_{3,3} \\ 0 & 0 & 0 & \omega_{4,4} \\ 0 & 0 & 0 & 0 & \omega_{5,5} \\ 0 & 0 & 0 & 0 & 0 & \omega_{6,6} \\ 0 & 0 & 0 & 0 & 0 & 0 & \omega_{7,7} \end{bmatrix}$$

TABLE 18

STRUCTURAL PARAMETERS (B)
OF VISITS INTERACTIONS MODEL

PARAMETER	EFFECT	RESTRICTED MODEL	UNRESTRICTED T = 1	UNRESTRICTED T = 2
$\beta_{3,1}$	$WORK_{p1} \longrightarrow MISS_{p2}$	-0.133 (-6.093)	-0.143 (-4.724)	-0.124 (-4.049)
$\beta_{5,1}$	$WORK_{p1} \longrightarrow VIST_{p2}$	0.044 (2.586)	0.038 (1.580)	0.049 (2.078)
$\beta_{7,1}$	$WORK_{p1} \longrightarrow VIST_{J}$	-0.016 (-2.658)	-0.025 (-2.875)	-0.009 (-1.004)
$\beta_{7,2}$	$VIST_{p1} \longrightarrow VIST_{J}$	0.510 (34.686)	0.500 (24.474)	0.520 (24.686)
$\beta_{1,4}$	$WORK_{p2} \longrightarrow WORK_{p1}$	0.239 (2.329)	0.151 (1.013)	0.316 (2.361)
$\beta_{2,4}$	$WORK_{p2} \longrightarrow VIST_{p1}$	0.077 (1.826)	0.011 (0.172)	0.122 (2.214)
$\beta_{5,4}$	$WORK_{p2} \longrightarrow VIST_{p2}$	-0.073 (-1.630)	-0.122 (-1.873)	-0.038 (-0.663)
$\beta_{6,4}$	$WORK_{p2} \longrightarrow MISS_{p2}$	-0.190 (-3.240)	-0.174 (-2.023)	-0.206 (-2.632)
$\beta_{2,5}$	$VIST_{p2} \longrightarrow VIST_{p1}$	0.508 (26.736)	0.496 (18.178)	0.517 (19.697)
$\beta_{7,5}$	$VIST_{p2} \longrightarrow VIST_{J}$	0.215 (17.146)	0.225 (12.837)	0.207 (11.585)

(t-values in parentheses)

TABLE 19

REGRESSION PARAMETERS (Γ) OF VISITS INTERACTIONS MODEL

PARAMETER	EFFECT	RESTRICTED MODEL	UNRESTRICTED T = 1	UNRESTRICTED T = 2
$\gamma_{1,1}$	EMP_{p2} (t) ⟶ $WORK_{p1}$ (t)	-2.887 (-3.670)	-2.964 (-2.566)	-2.890 (-2.920)
$\gamma_{2,1}$	EMP_{p2} (t) ⟶ $VIST_{p1}$ (t)	0.084 (0.262)	0.729 (1.450)	-0.367 (-0.901)
$\gamma_{4,1}$	EMP_{p2} (t) ⟶ $WORK_{p2}$ (t)	5.416 (34.447)	5.547 (26.765)	5.291 (26.694)
$\gamma_{5,2}$	HHS (t) ⟶ $VIST_{p2}$ (t)	-0.404 (-3.080)	-0.438 (-2.390)	-0.381 (-2.271)
$\gamma_{6,2}$	HHS (t) ⟶ $MISS_{p2}$ (t)	0.683 (4.528)	0.507 (2.371)	0.852 (4.205)
$\gamma_{2,3}$	LC^{y} (t) ⟶ $VIST_{p1}$ (t)	1.802 (2.528)	1.145 (1.356)	3.488 (2.637)
$\gamma_{4,3}$	LC^{y} (t) ⟶ $WORK_{p2}$ (t)	1.918 (4.119)	1.907 (3.828)	2.280 (2.445)
$\gamma_{4,4}$	LC^{o} (t) ⟶ $WORK_{p2}$ (t)	0.789 (2.918)	1.354 (3.396)	0.519 (1.669)
$\gamma_{5,4}$	LC^{o} (t) ⟶ $VIST_{p2}$ (t)	1.643 (2.571)	1.970 (1.849)	1.453 (1.936)
$\gamma_{6,4}$	LC^{O} (t) ⟶ $MISS_{p2}$ (t)	-2.725 (-3.461)	-2.596 (-1.946)	-2.929 (-3.098)
$\gamma_{7,5}$	AGE_{p1} — $VIST_{J}$ (t)	-1.741 (-1.795)	-0.898 (-0.655)	-2.387 (-1.829)
$\gamma_{7,6}$	AGE^{2}_{p1} ⟶ $VIST_{J}$ (t)	4.133 (1.581)	2.374 (0.642)	5.433 (1.545)
$\gamma_{5,7}$	AGE_{p2} ⟶ $VIST_{p2}$ (t)	-6.746 (-2.369)	-8.269 (-2.156)	-5.330 (-1.452)
$\gamma_{5,8}$	AGE^{2}_{p2} ⟶ $VIST_{p2}$ (t)	16.667 (2.053)	21.233 (1.947)	12.448 (1.188)
$\gamma_{2,9}$	$TOTL^{2}_{p2}$ ⟶ $VIST_{p1}$ (t)	0.244/-* (2.920)/-	0.232 (2.777)	- -
$\gamma_{3,10}$	GRP^{2}_{p2} ⟶ $MISS_{p1}$ (t)	-0.873/-0.939 (-2.022)/(-2.354)	-0.876 (-2.029)	-0.933 (-2.335)
$\gamma_{6,10}$	GRP^{2}_{p2} ⟶ $MISS_{p2}$ (t)	-1.424/-* (-3.148)/-	-1.414 (-3.126)	- -

(t-values in parentheses)

* These coefficients were unrestricted; both T=1 / T=2 values listed ("-" indicates constrained to zero)

TABLE 20

VARIANCE COMPONENTS
OF RESTRICTED VISITS INTERACTIONS MODEL

VARIABLE	TOTAL VARIANCE	VARIABLE INTERCEPT VARIANCE ω	RESIDUAL VARIANCE ψ	TOTAL % "EXPLAINED" VARIANCE R^2	TOTAL % "EXPLAINED" BY ω
$WORK_{p1}$ (1)	51.333	9.607	40.987	20.0	18.7
$WORK_{p1}$ (2)	49.870		39.520	20.6	19.3
$VIST_{p1}$ (1)	14.413	0.324	8.980	37.5	2.2
$VIST_{p1}$ (2)	13.240		7.659	42.0	2.4
$MISS_{p1}$ (1)	37.552	4.144	31.789	14.6	11.0
$MISS_{p1}$ (2)	34.948		29.648	14.9	11.9
$WORK_{p2}$ (1)	8.017	1.170	2.205	71.7	14.6
$WORK_{p2}$ (2)	9.371		2.955	67.2	12.5
$VIST_{p2}$ (1)	19.685	3.017	16.030	18.6	15.3
$VIST_{p2}$ (2)	18.385		14.893	18.9	16.4
$MISS_{p2}$ (1)	40.997	1.642	37.648	7.4	4.0
$MISS_{p2}$ (2)	39.176		35.295	8.9	4.2
$VIST_{J}$ (1)	9.411	0.124	2.422	74.0	1.3
$VIST_{J}$ (2)	8.771		2.173	75.3	1.4

TABLE 21

χ^2-FIT OF VISITS MODELS

	χ^2	D.F.	P.
Restricted Model:	265.46	248	0.213
Unrestricted Model:	244.33	224	0.168
Difference:	21.13	24	0.369

Table 20 shows the variance decomposition of all y-variables. Work and missing time are almost identical to previous activities. The male visits time has a relatively high R^2: 37.5 (T = 1) and 42.0 (T = 2). In addition, the random effect is not very important in explaining this variable. Contrary to this, the female's visits time is much less well explained (R^2 of 18.6 and 18.9, respectively), while the variable intercept accounts for most of this variance. Finally, joint visits time is very well explained with R^2 of 74.0 and 75.3, respectively. The random effect plays only a marginal role here.

Table 21 gives the overall fit of the models. Both the restricted and the unrestricted model describe the data well. Moreover, the difference between the models is not statistically significant. Thus, the hypothesis of time invariance of the model cannot be rejected.

6. SUMMARY OF RESULTS

Looking at the joint results of the three models, a number of conclusions can be drawn:

1. All relations between household members appear to be *complementary* relations. While this is plausible for leisure types of activities, it is not immediately clear why this is so for shopping. There is no substitution in shopping time across household members. One possible explanation for this is that shopping is largely a leisure type of activity, with pure maintenance elements taking relatively little time.

2. Joint activities are important for shopping, recreation, and visits. They are mainly influenced by the amount of time spent individually in these activities by both partners. The presence of children decreases the time spent jointly in shopping and recreation, but not in visits.

3. Working hours of the male are a primary factor shaping the activity patterns of both partners. As a male partner works more hours, his involvement in shopping and visits time decreases, but his recreation time increases. The consequences for the female are opposite. Her shopping time and visits time increase, and (tentatively) recreation time decreases. Thus, the male's working time is the causal factor for indirect substitution effects among these activities.

4. The working status of the female adult has two types of effects. First, being employed or not (in this analysis, it is treated as an exogenous variable) has important consequences for both partners. If the female is employed, the male works fewer hours, and does more shopping. this indicates that the employment status of the wife is important in determining household activity roles. On the other hand, actual hours worked by the wife affects mainly her own nonwork activity times. The more she works, the less time she has for shopping and visits. The male's nonwork activity times are not affected by the female's work status.

5. That husband and wife play different household roles is also shown by the impact of life cycle variables. Changes in life cycle status effect the wife's activity behavior much more than they do the husband's activities. Her working hours and visits time are both negatively affected by the presence of children.

6. Although the male's working time is the predominant factor in shaping the time allocation pattern, all *nonwork* activities by the male are influenced by the female's behavior. It appears that the female has the initiative of determining his shopping, recreation, and visits time.

These conclusions were drawn from a longitudinal data source. For shopping and visits, the pattern that emerged was clear and fitted both time periods well. For recreation, the model was less successful in terms of model fit and significance levels. Although the structure found was stable over time, there is reason to believe that for recreation, other factors play a major role. These factors vary across observations and time (e.g., weather conditions, locational factors). Time invariant factors appeared to be highly important, as shown by the variance components decomposition of the models. The use of the random effects specification successfully controlled for these effects.

7. FINAL REMARKS

In this paper, a model of joint time allocation by household members has been presented and applied to shopping, recreation, and visits activities. Three types of relations were hypothesized: complementary, substitutable, and companionship relationships. It was found that both complementary and companionship relations exist, but no evidence was found of direct substitutable relations among household members. Employment status of the female and life cycle status turned out to have a major impact on the joint allocation of time of the household members.

As pointed out in the introduction, time is one dimension of the activity profile of individuals. Time and space together define a time-space diagram. Both dimensions interact in many ways. A logical step is therefore to include travel and distance measures in the analysis. However, this is a complex problem and will probably not fit in the linear formulation used in this study.

8. ACKNOWLEDGMENTS

The author would like to thank the Project Bureau for Integrated Transport and Traffic Studies and the Office of the Director for Transport of the Dutch Ministry of Transport and Public Works for providing the data. Also, Bureau Goudappel Coffeng (Deventer, The Netherlands) was extremely helpful in preparing the files.

This research was sponsored by the U.S. Department of Transportation University Centers Grant. The participation of Leo van Wissen was made possible by a fellowship of the Royal Netherlands Academy of Arts and Sciences.

REFERENCES

BECKER, G. S. (1965). A theory of the allocation of time. Economic Journal. 75: 493-517.

BECKER, G. S. (1981). A Treatise on the Family. Cambridge, MA: Harvard University Press.

CHAPIN, F. S., Jr. (1974). Human Activity Patterns in the City: Things People Do in Time and Space. New York: John Wiley and Sons.

DAMM, D. (1979). Toward a Model of Activity Scheduling Behavior. PhD thesis, M.I.T., Cambridge, Massachusetts.

DAMM, D. (1980). Interdependencies in activity behavior. Transportation Research Record 750: 33-40.

DAMM, D., and LERMAN, S. (1982). A theory of activity scheduling behavior. Environment and Planning A, 13: 703-718.

GOLOB, J. M., SCHREURS, L. J. M., and SMIT, J. G. (1986). The design and policy applications of a panel for studying changes in mobility over time. In: Behavioral Research for Transport Policy, 81-95. VNU Press, Utrecht, The Netherlands.

HÄGERSTRAND, T. (1970). What about people in regional science? Papers of the Regional Science Association, 24: 7-21.

HÄGERSTRAND, T. (1975a). Survival and arena: On the life histories of individuals in relation to their geographical environment. The Monadnock, 49: 9-29.

HÄGERSTRAND, T. (1975b). Space, time and human conditions. In: A Karlquist, L. Lundquist, and F. Snickars (eds.), Dynamic Allocation of Urban Space, 3-13. Farnborough: Saxon House.

HOORN, T. van der (1983). Experiments with an activity-based travel model. Transportation 12: 61-77.

JONES, P. M., DIX, M. C., CLARKE, M. I., and HEGGIE, I. G. (1983). Understanding Travel Behaviour. Gower, Aldershot, England.

JÖRESKOG, K. G. (1973). A general method for estimating a linear structural equation system. In: A. S. Goldberger and O. D. Duncan (eds.), Structural Equation Models in the Social Sciences, 85-112. New York: Seminar Press.

JÖRESKOG, K. G. (1977). Structural equations models in the social sciences: Specifications, estimation and testing. In: P. R. Krishnaiah (ed.), Applications of Statistics, 265-287. Amsterdam: North-Holland.

JÖRESKOG, K. G., and SÖRBOM, D. (1977). Statistical models and methods for analysis of longitudinal data. In: D. Aigner and A. S. Goldberger (eds.), Latent Variables in Socioeconomic Models, 285-325. Amsterdam: North-Holland.

KITAMURA, R. (1984). A model of daily time allocation to discretionary out-of-home activities and trips. Transportation Research B, 18: 255-266.

KOPPELMAN, F. S., and TOWNSEND, T. A. (1987). Task Allocation Among Household Members: Theory and Analysis. Paper presented at the 5th International Conference on Travel Behavior, Aix-en-Provence, France, October 1987.

KOSTYNIUK, L. P., and KITAMURA, R. (1984). Life cycle and household time-space paths: Empirical investigation. Transportation Research Record, 879: 28-37.

LINDER, S. B. (1970). The Harried Leisure Class. New York: Columbia University Press.

MADDALA, G. S. (1983). Limited-Dependent and Qualitative Variables in Econometrics. Cambridge: University Press.

MEURS, H. J., VISSER, J., and van WISSEN, L. (1989). Measurement error in panel data. Transportation (forthcoming).

PAS, E. I. (1984). The effect of selected sociodemographic characteristics on daily travel-activity behavior. Environment and Planning A: 571-581.

SAMUELSON, P. A. (1956). Social indifference curves. Quarterly Journal of Economics, 1-22.

SOULE, G. (1955). Time for Living. New York: Viking Press.

SZALAI, A. (1973). The Use of Time. Mouton, The Hague.

TOWNSEND, T. A. (1987). The Effects of Household Characteristics on the Multiday Time Allocations and Travel Activity Patterns of Households and their Members. PhD Dissertation. Dept. of Civil Engineering, Northwestern University, Evanston, IL.

WISSEN, L. J. G. van, GOLOB, Th. F., and SMIT, H. J. (1985). Determination of differences in mobility variables among population groups. In: B. Jansen, P. Nijkamp, and C. Ruijgrok (eds.), Transportation and Mobility in an Era of Transition, 211-216. Amsterdam: North-Holland.

WISSEN, L. J. G. van, and MEURS, H. J. (1989). The Dutch Mobility Panel: Experiences and evaluation. Transportation (forthcoming).

ZIMMERMAN, C. A. (1982). The life cycle concept as a tool for travel research. Transportation, 11: 51-69.