electronic ***International Journal of Time Use Research***
2006, Vol. 3, No. 1, 88-109 dx.doi.org/10.13085/eIJTUR.3.1.88-109

Multiway data analysis for comparing time use in different countries - Application to time-budgets at different stages of life in six European countries

Mary Fraire

Prof. Mary Fraire
Department of Social Research and Sociological Methodology (Ri.S.Me.S.)
University of Rome 'La Sapienza'
C.so Italia 38A – 00198 Roma, Italy
e-mail: Mary.Fraire@uniroma1.it

Abstract

Important time-budget methodological issues are concerned with analysing time use tables, obtainable from time-budget diaries to face the multipurpose nature, the size and the complexity of time-budget data. After a brief introduction to the main time use analysis the paper focuses on the cross-sectional analysis using the explorative multidimensional data analysis. The paper deals with the multiway methods suitable for comparing statistical studies (i.e. countries) when each of them has many variables (i.e. activities) observed on many cases (i.e. categories of population). This article examines an example of application to cross-national differences in time use in six European countries at different stages of life. The results are exemplary of the applicational steps and statistical aspects of the methods proposed rather than definitive findings.

JEL-Codes: C49, C89, J16, J19

Keywords: Cross-national, cross-sectional, explorative multidimensional data analysis, multiway analysis, statis method, multiple factor analysis method

Earlier version of this paper were presented at XXVI International Association of Time Use Research (IATUR) Conference 2004, 27-29 October 2004, Rome, Italy on 'Time use: what's new in methodology and application field'. The author would like to thank the anonymous eIJTUR reviewers for the helpful comments on previous versions of this paper.

1 Introduction

1.1 The international growing relevance of time use data

Since the mid-1920 – early in URSS, USA, UK and Poland and then in many other countries[1] – Time-Budget Studies (TBS) and Time Use Surveys (TUS) were used for analyzing peoples' behaviour, patterns of social life associated with the temporal distribution, the allocation and management of human activities.

Actually many countries collect time-budget data which are more and more relevant mainly to monitor similarities, differences or changements in the way of life of populations or social groups, documenting patterns of time use of total sample or subgroups, studying practical problems in order to face the problems related to urban environment (daily rhythm of urban traffic, opening and closing hours of public services, shops, entertainement etc., peak hours and duration of the activities connected with the electric power, water consumption, internet daily use and so on); and the problems related to health (i.e. studying the rhythm of daily activities as to sleeping, eating etc. related to special problems i.e. insomnia, obesity, cardiovascular illness and so on).

In this context countries are also fastly developing international websites (Multinational Time-Use Studies (MTUS), the International Association for Time Use Research (IATUR), Harmonised European Time Use Studies (HETUS), and more general international websites as to EUROSTAT and the National Statistical Institutes websites) that are essential for accessing original time use study data and information.

Therefore the experimentation and harmonization of suitable methodologies to analyzing complex data in view to exploring, comparing and synthesizing large volume of time use data are becoming more and more useful.

1.2 The object of the paper

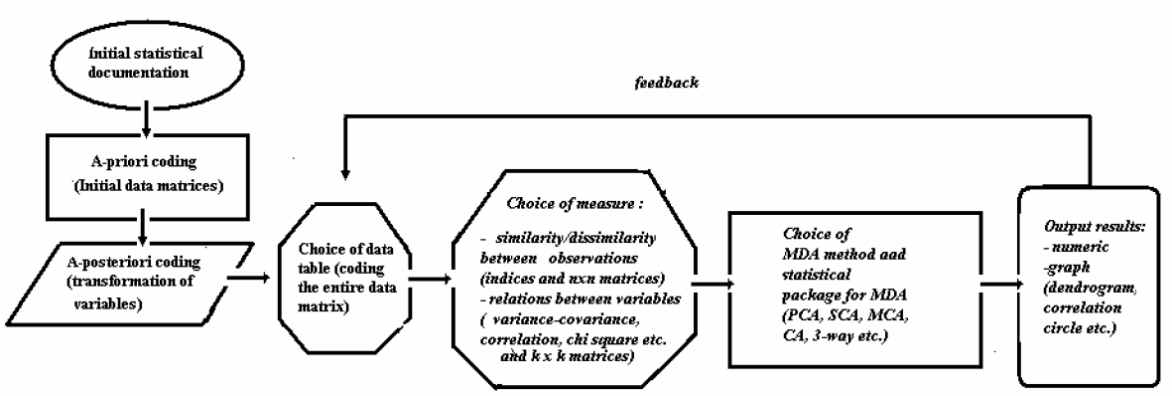
The paper proposes, in addition to the many other possible simple and multivariate statistical methods of analysis, the use of the explorative multidimensional data analysis (MDA) for the analysis of time use tables (matrices) when each of them is dealing with many cases: individuals (microdata) or categories of individuals or social groups (macrodata) and many variables (quantitative/ qualitative) simultaneously considered. MDA includes many multivariate techniques which can be classified into two main groups: classification analysis (cluster analysis)

[1] Further details on the history of Time Use Studies and on-line Survey Documentation can be found in the web site: http://www.iser.essex.ac.uk/misoc/timeuse/information/technical compiled by Fisher, Kimberly, Institute for Social and Economic Research, University of Essex.

and factorial analysis[2], each-one is a particular different way to analyse and synthesize the initial data set. Among the several factorial analysis techniques the paper considers the multiway analysis for multiple quantitative tables (see par. 4).

From a methodological and applicational point of view besides the specific MDA technique which will be carried out it is useful to see multidimensional data analysis as a system composed of various steps equally important and interdependent. At each step it is necessary to make choices and to carry out operations having statistical and computational aspects not always governed by fixed rules or single criteria. In other words we can list seven main steps (Figure 1) which make up an MDA and special emphasis is given to the preliminary four steps often considered the 'hotspot' of the entire process (Fraire, 1995)[3].

Figure 1
The seven phases of Multidimensional Data Analysis (MDA)



Source: own elaboration.

Very synthetically, the above phases (in brackets the paragraphs corresponding to the stepsreferring to the application) in Figure 1 are defined as follows:

- The first step is related to the initial statistical documentation and it is concerning the definition of the object and the scope of the study, the survey plan and the actual data collection i.e. the questionnaires filled out, data downloaded from internet web sites, data bases etc. (par. 2);
- The second step concerns the 'a priori' coding i.e. the transposition of all raw data collected in the form of the initial data matrix or matrices (par. 3.1);

---

2 Among the factorial analysis there are several methods: Principal Component Analysis (PCA), Canonic Correlation Analysis (CCA), Simple and Multiple Correspondence Analysis, Multidimensional Scaling, Multiway analysis including many different techniques (see par. 4). Many of them were developed in the first half of the century from conceptual and methodological point of view but seldom utilized. Nowadays the great and generalized capacity to process large volume of data and to carry out complicated calculation rapidly by the hardware and software available have created the conditions for further diffusion of their applications.

3 We shall not dwell here upon this argument which can be deepened in Fraire (1995, p.5-51).

- The third step concerns the 'a posteriori coding' as transformation of variables with different aims (i.e. dividing a variable into classes, transforming a variable into ranks, standardizations etc.). This phase includes the first descriptive univariate and bivariate statistics generally carried out on the 'columns' (variables) of the initial data matrix (par. 3.2);
- The fourth step concerns the 'a posteriori coding' of the whole data matrix concerning the choice of the data table generally different from the initial data matrix (i.e. generalized contingency table, complete disjunctive table etc. or table obtained as feedback from preceding multivariate analysis carried out on the initial data matrix i.e. factor scores matrix). In the multiway analysis considered in the paper this step concerns the choice of one of the possible research situations (par. 4.2) as starting point data table and the tables obtained as feedbacks of the three aspects characterizing the multiway analysis (par. 4.3, 4.4, 4.5);
- The fifth step concerns the choice of the measure of relation between cases (distances, similarities etc.) or between variables (correlation coefficients, variances and covariances etc.) according to the data table obtained in the fourth step (par. 4.3, 4.4, 4.5);
- The sixth step is related to the choice of the method and software of MDA (CA, PCA, MFA etc.) (see par. 4.1);
- The seventh step is devoted to results (i.e. eigenvalues, factor loadings etc.) and graphic (i.e. factorial planes, dendrograms etc.) (par. 4.3, 4.4, 4.5, 5).

As to time use methodological point of view it is important distinguish two different but complementary aspects which can characterize time use data analyses:

1. Cross-sectional time use analysis: based on average duration for each activity (referred to all persons or only to those who have performed the activity with the percentage of population engaged in the daily activities). These tables are fitting for analysing time allocation, time management, typical time-budgets, time use structures of various categories of population, social groups etc.;
2. Longitudinal time-use analysis (temporal sequences of daily events): based on percentages of the population or social groups engaged in single or all daily activities at selected time-points during the day. These tables are fitting for analysing as the daily rhythm (distribution shape) of a specific daily activity, or the global sequence patterns of daily life. In the last case we analyse simultaneously the all daily activities performed at selected timepoints during the day by the population or by the social groups considered.

In the paper we focus only on cross-sectional time use analysis and in particular on the multiway data analysis which is suitable for comparing statistical studies (i.e. referring to different countries at the same time) when each of them has many variables (i.e. activities) observed on many cases (i.e. population at different stages of life)[4].

[4] Statistical aspects and applications concerning Cluster Analysis and Principal Component Analysis can be seen in Fraire M.(2004), I Bilanci del Tempo e le indagini sull'uso del tempo. Time-Budget Studies(TBS)

The application considered concerns cross-national comparison in time use crossing employment status and different stages of life by gender in 6 European countries in 2003.

2 Source of data, sample size, cases and analysis variables

2.1 Source of data, sample size and the countries considered

The data used for the application is a sub-file extracted from Eurostat, 'Time-use at different stages of life in 13 European countries in 2003', downloaded from Eurostat web site (http://europa.eu.int). The Eurostat data referred to 13 countries time use surveys but only six followed very closely the harmonized guidelines issued by Eurostat. This means that they are comparable between countries concerning the slight differences in age group covered. In the application we consider for simplicity only six countries: Belgium (BE), Estonia (EE), Finland (FI), Norway (NO), Slovenia (SI), United Kingdom (UK).

It is to remark that the data analysis considered could be applied to much more countries as well. In Table 1 we report the sample size and survey characteristics of the six European countries.

Table 1
Sample size and survey characteristics of 6 European countries

Country - Source	Fieldwork period	Population covered: age	Sample size: respondents
Belgium (BE) National Institute of Statistics and Free University Brussels	December 1998 - February 2000	12-95	8392
Estonia (EE) Statistical Office of Estonia	April 1999- March 2000	10 -	5728
Finland (FI) Statistic Finland	March 1999- February 2000	10-	5332
Norway (NO) Statistics Norway	February 2000- February 2001	10-79	3211
Slovenia (SI) Statistical Office of the Republic of Slovenia	Aprila 2000- March 2001	10-	6190
United Kingdom (UK) Office for National Statistics	June 2000- September 2001	8-	10366

Source: Eurostat, 'Time-use at different stages of life in 13 European countries in 2003' from Eurostat web site (http://europa.eu.int), own calculation.

and Time-Use Surveys, Ed. CISU, 2004, Roma in particular Part III concerning Paths of Time Use Multidimensional Data Analysis.

2.2 Defining the cases

The cases considered in the application concern 14 categories of population obtained crossing by sex: the employment status and the 'compositional' variables represented here by lifecycle variables obtained crossing (non exhaustively) age class/ civil status/ presence of child living with parents according to youngest age.

The N=14 cases are detailed as follows (in brackets are reported the labels of the cases):

1. Women (W);
2. EmployedWomen (EmplW);
3. Women less than 25 years old, Not having Child<18 years old living with parents (W<25NCh<18);
4. Women of any age living in Couple and having the youngest Child of 0-6 years old living with parents (WCACh0-6);
5. Women of any age living in Couple and having youngest Child of 7-17 years old living with parents (WCACh7-17);
6. Women 45-64 years old living in Couple Not having children <18 years old living with parents (W4564CN<18);
7. Women more than 65 years old living in Couple, Not having children<18 years old living with parents (W>65CN<18).

The same categories have been obtained for Men:

8. Men (M);
9. Employed Men (EmplM);
10. Men less than 25 years old, Not having Child<18 years old living with parents (M<25NCh<18);
11. Men of any age living in Couple and having youngest Child of 0-6 years old living with parents (MCACh0-6);
12. Men of any age living in Couple and having youngest Child of 7-17 years old living with parents (MCACh7-17);
13. Men 45-64 years old living in couple Not having Children <18 years old living with parents (M4564CN<18);
14. Men more than 65 years old living in Couple, not having children<18 years old living with parents (W>65CN<18).

2.3 Defining the variables

The variables considered in the application concern the activities collapsed in 12 primary activity groups exhaustive of all daily activities. In Table 2 is reported the classification of the activities.

The classification of the activities derives from the Eurostat more analytical classification (12 activities groups instead of 8) employed in the above mentioned study and it is suitable for the purpose of the present application concerning the explorative description and comparative analysis of time-budgets of different categories of individuals in the six countries considered with respect to the main time use areas characterizing the daily activities.

Finally the type of day considered is the average day of the week over the whole year.

Table 2
Classification of primary activities

Primary activity groups (labels)	Primary activities
1. Sleep (Sleep)	Sleep
2. Eats (Eats)	Meals and personal care
3. Work (Work)	Gainful work
4. Study (Stud)	Study
5. Housework & Family care (H&Fa)	Household work and family care
6. Volunteer work (FreV)	Volunteers work and informal help to other households
7. Socializing (Soci)	Socializing (participatory activities, social life and entertainment and culture)
8. Leisure Time (Leis)	Sports and outdoor activities, hobbies and games, unspecified leisure time and resting
9. TV (Tv)	TV and video
10. Other media (OMed)	Other mass media (radio, music, reading)
11. Travel (Trav)	Travel including travel for work
12. Other unspecified (OUns)	Other, unspecified and filling in TUS diary

Source: Own definitions.

3 The initial data matrix

3.1 The initial data matrix of the application

Considering the cases (N=14) and the variables (Xj (j=1, 2, …, k=12)) the activities above defined in Table 2 are arranged together with the N=14 cases in a matrix forma (initial data matrix) as start point for the application (Figure 2).

The matrix has the following statistical characteristic:

1. The matrix is composed of 6 basic tables (six two-indices matrix: cases × variables foreach country) put one upon the other;
2. The rows are the time-budgets of the categories of population considered and therefore the row-sum is equal to 1440 minutes. The raw is the time use profile (description) of the categories considered;
3. Comparisons among rows (also transforming data in % of the 24 hours=100) give the differences in the time-budgets of the 14 categories of population;
4. The columns represent the distributions of each activity group among the N=14 categories of population;
5. Each column gives the consistency (amount of time spent) and the dispersion of the activity among the 14 categories considered;
6. The data considered in the matrix are the average duration in minutes of the primary activity groups computed dividing the total duration of time devoted to that activity group to the whole category of population considered (including persons who has not performed the activity).

The use of means instead of individual duration means that the correlations are not perturbed by large numbers of zeros in the data.

Referring to the average duration of activity to the whole population or only to those who have performed the activity has the following main meanings:

1. Average durations referred to the whole population is suitable to focusing the analysis on time-budget in other words it allows us to analyse the incidence of average duration of each activity on the 1440 minutes= 24 hours= 100.
2. Average durations referred only to those who have performed the activity is suitable to focusing the analysis on time use structure. In other words it allows us to analyse the typical duration of each activity.

In the application average durations referred to the whole population have been considered.

3.2 Descriptive statistics for the first analysis of data

Univariate descriptive statistics such as arithmetic mean, range, min-max, standard deviation, coefficient of variation, % doers etc. give an important frame of the time-use matrices. These statistics are necessary also in view to further ‘a posteriori’ data matrix codings (i.e. transformation of the original data in deviations from the mean, standardization, dividing into classes, change of scale, ranging etc.). Bivariate statistics such as correlations and partial correlations, scatter diagram show the relationship (shape and intensity) between primary activities and represent an important first analysis of data. However for the sake of brevity we shall not

dwell on these statistics and in Table 3 we report only the means, standard deviations and coefficient of variation of the 12 activity groups for each country.

Figure 2
The initial data matrix of the application (synthetic example)

Cases	Sleep	EatPers	Work	Study	HFamCare	VolontWork	Socializ	Leisure	TV	OthMedia	Travel	OthUnsp
						BELGIUM						
Women	521	162	88	41	238	8	65	68	132	34	76	7
EmplWomen	495	156	232	4	226	6	61	43	94	25	92	6
W<25NCh<18	548	154	27	231	83	7	77	76	108	36	86	7
WCACh0-6	502	145	157	4	319	8	59	37	92	18	93	6
WCACh7-17	499	160	133	4	298	10	63	45	109	30	85	4
W4564CN<18	512	167	71	2	297	12	55	66	148	33	71	6
W>65CN<18	536	171	0	0	282	9	63	97	193	40	42	7
Men	507	157	158	45	143	9	59	78	144	44	91	5
EmplMen	481	154	300	4	135	9	54	47	115	32	103	6
M<25NCh<18	548	140	44	202	54	7	69	117	124	40	89	6
MCACh0-6	481	151	287	4	173	8	50	43	110	25	102	6
MCACh7-17	482	154	277	4	147	12	53	52	124	32	98	5
M4564CN<18	503	163	150	3	181	10	54	66	164	51	89	6
M>65CN<18	534	178	2	3	194	16	60	112	204	63	67	7
						ESTONIA						
Women	530	129	120	27	267	13	51	54	135	49	60	5
EmplWomen	503	126	249	5	241	10	45	31	113	41	71	5
...	...	...	...	...	...	...	...	...	...	...	...	...
M>65CN<18	558	148	44	0	207	13	37	105	179	95	49	5
						FINLAND						
Women	522	126	124	36	212	14	68	72	128	60	66	12
EmplWomen	502	122	247	13	201	11	60	52	100	47	76	9
...	...	...	...	...	...	...	...	...	...	...	...	...
M>65CN<18	534	152	21	1	175	21	50	123	193	97	48	25
						NORWAY						
Women	500	121	140	38	196	9	135	73	105	47	70	6
EmplWomen	488	111	219	19	199	7	132	57	87	38	77	6
...	...	...	...	...	...	...	...	...	...	...	...	...
M>65CN<18	494	163	41	2	184	15	95	100	180	102	58	6
						SLOVENIA						
Women	520	127	133	44	265	6	68	72	110	31	61	3
EmplWomen	484	118	279	7	250	4	60	52	88	22	74	2
...	...	...	...	...	...	...	...	...	...	...	...	...
M>65CN<18	535	163	48	0	197	12	61	142	165	76	39	2
						UNITED KINGDOM						
Women	523	136	116	40	221	12	73	57	136	33	81	12
EmplWomen	505	126	237	12	207	10	67	41	110	23	93	9
...	...	...	...	...	...	...	...	...	...	...	...	...
M>65CN<18	515	170	19	2	214	16	62	83	203	79	63	14

Source: sub-file extracted from the EUROSTAT 'Time-use at different stages of life in 13 European countries in 2003' Data File, Eurostat, downloaded from Eurostat web site: http://europa.eu.int
Note: the meaning of labels is reported in par. 2.2. Own calculations.

From univariate statistics it is to remark that among the mean durations of the activities: Sleep, Eats and personal care, Work, Housework and Family care, TV have overall average durations higher than Study, Volunteers activities, Socializing Leisure, Other Media, Travel; for this reason the coefficient of variation fit well and better than the standard deviation for measure the dispersion of each activity among the cases considered. Because the categories of population considered in the application are obtained crossing employment status and different lifecycles by gender: particularly high result the coefficients of variation for the activities Work, Study, Household work and Family care in all six countries.

Table 3
12 primary activity groups in 6 European countries in a weekday in 2003. Univariate statistics: mean (in minutes and in percent of 1440= 100), standard deviation (in minutes), coefficient of variation CV (in percent).

Activity / Country	Sleep	Eats and personal care	Work	Study	Household & family care	Volunteer works	Socializing	Leisure	TV	Other media	Travel	O. Unspecified
Belgium												
mean	516	158	137	39	197	9	60	67	132	35	84	6
%	36	11	9	3	14	1	4	5	9	2	6	0
std	22	9	101	73	79	3	6	25	33	11	15	1
CV%	4.3	5.7	73.7	187	40.1	33.3	10.0	37.3	25.0	31.4	17.8	17.0
Estonia												
mean	529	131	159	26	216	12	46	61	143	47	65	5
%	41	9	10	2	14	1	3	4	9	2	5	0
std	27	7	94	48	96	4	15	28	22	17	11	1
CV%	5.1	5.3	59.1	181	44.4	25.0	32.6	44.3	14.7	34.0	15.4	20.0
Finland												
mean	521	122	170	32	179	13	58	81	130	54	67	13
%	36	8	12	2	12	1	4	6	9	4	5	1
std	25	12	107	52	80	5	11	33	26	18	12	5
CV%	4.8	9.8	62.9	163	44.7	38.4	19.0	40.7	20.0	33.3	17.9	38.4
Norway												
mean	499	116	172	32	178	9	120	74	115	45	72	8
%	35	8	12	2	12	1	8	5	8	3	5	1
std	25	20	93	49	67	3	15	25	24	22	12	3
CV%	5.0	17.2	54.0	153	37.6	33.3	12.5	33.7	20.8	48.8	16.6	25.0
Slovenia												
mean	518	127	180	34	215	7	65	80	118	29	65	2
%	37	9	13	2	16	0	4	5	8	2	4	0
std	26	12	103	61	97	3	11	26	23	15	15	7
CV%	5.0	9.4	57.2	179	45.1	42.8	16.9	32.5	19.4	51.7	23.0	35.0
UK												
mean	515	129	172	34	184	10	62	3	141	31	83	10
%	36	9	12	2	13	1	4	4	10	2	6	1
std	31	20	107	58	88	5	8	23	26	17	12	1
CV%	5.7	15.5	62.2	171	47.8	50.0	12.9	36.5	18.4	54.8	14.4	10.0

Source: own elaborations.

Among the 'a posteriori coding' of the initial data matrix (the third phase of MDA par. 1.2) because of the great differences of the means and dispersions of the 12 activities considered the data have been transformed in standard deviations (mean= 0 and std= 1).

In view to compare the time-budgets of the six European countries more easily the 12 activities have been classified in the following five daily activity areas:

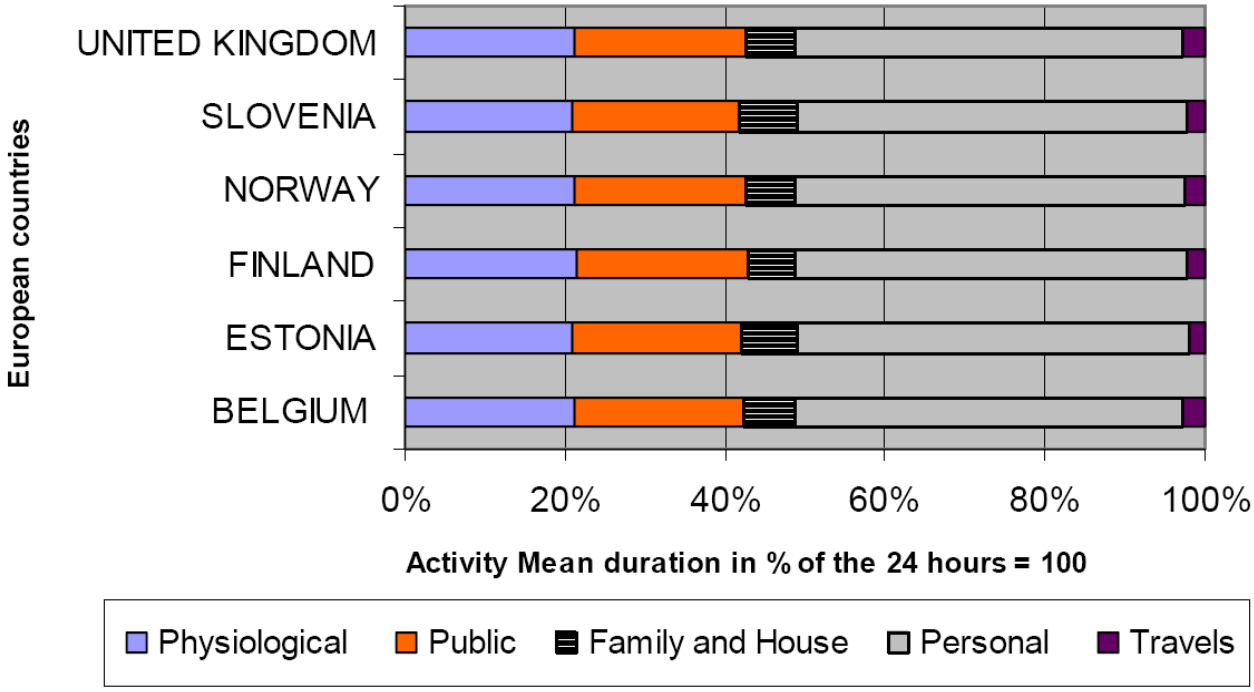
Table 4
Codes and Activities

Codes and Activity groups	Activity areas	Codes
1. Sleep	Physiological area	1-2
2. Eats and personal care	Physiological area	1-2
3. Work	Public area	3-4
4. Study	Public area	3-4
5. Housework and family care	Family area	5
6. Volunteers	Personal area	6-10, 12
7. Socializing	Personal area	6-10, 12
8. Leisure	Personal area	6-10, 12
9. Television	Personal area	6-10, 12
10. Other mass-media	Personal area	6-10, 12
11. Travel	Travels or Mobility area	11
12. Other unspecified activities	Personal area	6-10, 12

Source: own definitions.

In Figure 3 the six time-budgets are reported.

Figure 3
Time-budgets of six European countries at different stages of life and five areas of daily activities in a weekday in 2003



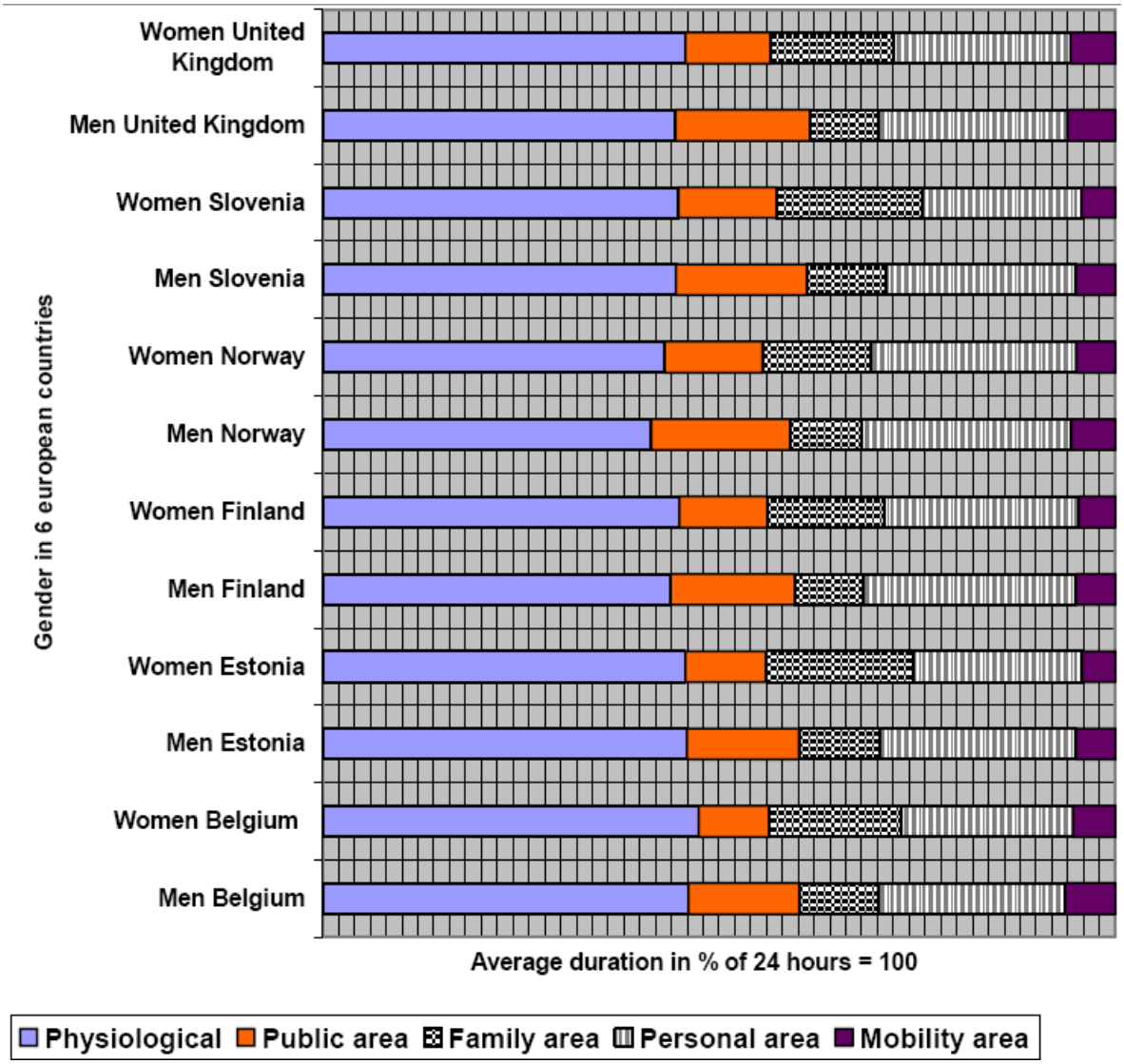
Source: EUROSTAT 'Time-use at different stages of life in 13 European countries in 2003, own elaborations.

It is possible to remark that the 6 countries notwithstanding their geographical and cultural differences have similar patterns of spending their time use (similar % of the 24 hours devoted to the 12 activity groups considered) in the average day of the week over the whole year.

Considering the time-budgets of the five activity areas: all countries devote almost 42-45% of the 24 hours to physiological activities, 14% to family and house activities, 20% to public activities and 20% to personal activities.

Comparing the time-budgets of men and women in the 6 countries (Figure 4) it is possible to remark that there are large differences in the gender division of gainful work and domestic work: in all countries men devote more time to gainful work/study than to domestic work. Men have overall more free time than women.

Figure 4
Gender differences in time use of six European countries in 2003 (weekdays)



Source: EUROSTAT 'Time-use at different stages of life in 13 European countries in 2003, own elaborations.

Multivariate Principal Component Analysis (PCA) and Cluster Analysis (CA) have been applied for the first explorative analysis of each of the six tables separately considered. The main results[5] (not reported for simplicity) are concordant (even if separately for each country) with the results of the multiway analysis allowing to compare simultaneously the timebudgets of the 14 categories of population in the 6 countries and exposed in the following paragraphs.

4 Multiway data analysis

4.1 The three-way matrix for multiway analysis

The multiway data analysis concerns the analysis of multiple tables. As above mentioned the multiway analysis is especially interesting when we are looking for trends in situations found in different countries at the same time or in a given country in varying moments of time. By the multiway matrix analysis it is possible to explore, compare and synthesize several multiple tables overall and simultaneously.

Many techniques for multiway data analysis are available in connection with the type of multiples tables to be analysed (Procrustean analysis, Tucker, 1958); Metrical and non metrical multi dimensional scaling (PARAFAC, Harshman, 1970), INDSCAL (Carrol and Chang, 1970); Multiple Factorial Analysis (Escofier and Pages, 1983); ACT-méthode STATIS e ACT-méthode STATIS-DUALE (Escoufier, 1980 and 1985); Generalised Canonical Analysis (Horst, 1961).

The paper deals with the three-way data analysis referred to quantitative matrices and in particular with the ACT-Statis-Duale Method and the Multiple Factor Analysis carried out employing the softwares ACT-Statis and WinSPAD-Analyse Factorielle Multiple[6].

Usually three-way (or multi-way) data matrices have data classified according to three (or more) criteria or ways or dimensions. The same table (i.e. the basic table cases × variables which is a two-indices matrix) built up over several years or places or situations. In general this third criteria or way is called 'occasion'. Simplifying in Figure 5 is reported an example of the time use three-way data of the application proposed.

The initial three-way data matrix of the application ${}_{O=6}X_{N=14;\ K=12}$ has the following characteristics:

O= occasions= 6 European countries,

---

5 For example: in the PCA each country have a very similar two-dimensional time-budget structure underlying the time-budgets of the 14 categories of populations; in CA four clusters of individual can be identified in each country.

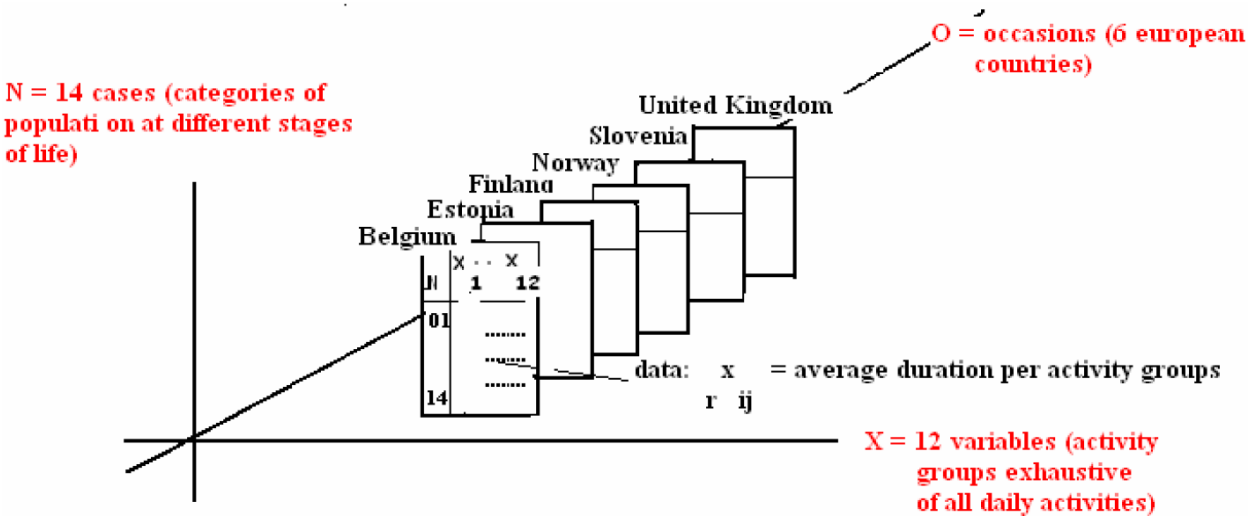
6 The acronym ACT means Analyses Conjointes des Tableaux and STATIS means 'Structuration des Tableaux A Trois Indices de la Statistique'. The two software mentioned are of the CISIA, Centre International de Statististques et d'Informatique Appliquée, France.

N= statistical units or cases= 14 categories of population;

K= variables= 12 primary activities

$_rX_{ij}$ (r=1, …, 6; i= 1, …, 14; j= 1, …, 12) are the data represented by the average duration (in minutes) computed on all persons of the category of population considered.

Figure 5
Time use three-indices data matrix of the application



Source: own elaboration.

In the multiway data analysis from a computational point of view the 'a priori coding' (the 2nd phase of AMD, see par. 1.2) of the initial data concerns the setting up of the initial data file (Figure 2).

4.2 'A-posteriori' codings of the initial data matrix

It is important to remark that the initial data matrices can have various a-posteriori codings according to three different research situations:

1. Three-indices matrix of dimension N, (K×O) in which in the various Occasions (i.e. years or places) the individuals N are the same and the variables are different;
2. Three-indices matrix of dimension (N×O), K in which in the various Occasions the individuals N are different and the variables are the same;
3. Three-indices matrix of dimension (N×K), O in which in the various Occasions the individuals N and the variables K are the same.

In this paper we will present an application in which the second situation (different cases and same variables across the different occasions O) is the a-posteriori coding that has been chosen for the application.

In particular the time-use three-way matrix $_{O=6}X_{N=14;\ K=12}$ considered in the application has been above defined. The 3-way data analysis and in particular the Act-Statis Method is developed into three different steps:

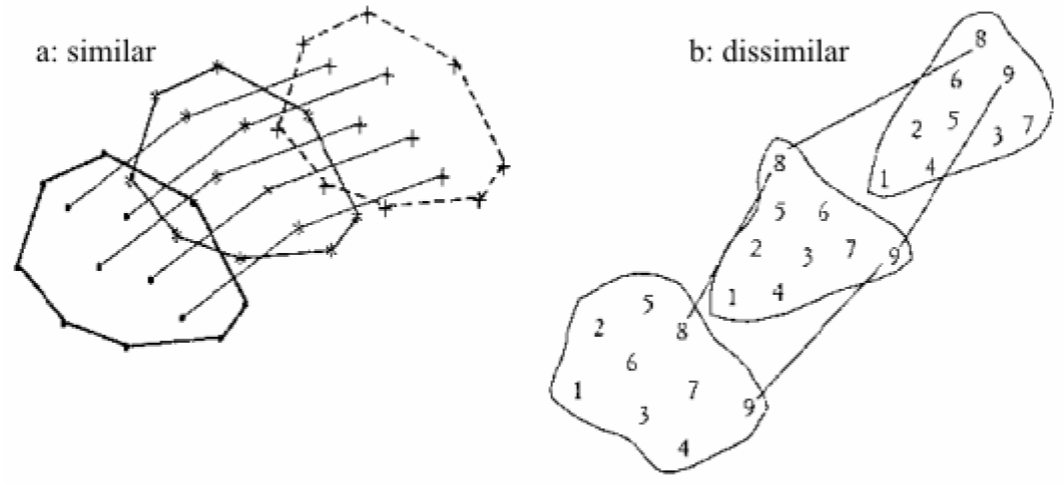
1. Inter-structure analysis;
2. Intra-structure (or compromise) analysis;
3. Trajectories analysis.

In the following paragraphs the three steps are detailed applied to the example.

4.3 The inter-structure analysis: the overall similarity and dissimilarity of the time use in the six countries

The inter-structure analysis want to do an overall comparison of the six statistical studies to recognize the studies which are near (they give similar representation of individuals) and those which are not (Escoufier, 1987). In the application it is possible to identify the overall distances among matrices in view to examine if each of the 14 categories of population has homologous (correspondent points) similar (near) or dissimilar across the 6 countries. In other words it means that if the categories of population (cases) develop thorough the occasions (six countries) in the same way or in different way they can be respectively represented (Bolasco, 1999) like in Figure 6.

Figure 6
Shapes of scatter diagrams in concomitance with no changes (similar) or changes (dissimilar) in the corresponding points of the basic tables



Source: own elaboration.

The distances of the correlation coefficients[7] reported in Table 5 (0=dissimilar matrices, 1=similar matrices) remark that the 6 tables concerning the time-budgets of the 14 categories

[7] The similarity or dissimilarity among the six time use table can be measured by between similarity/ dissimilarity measures (euclidean distances etc.) or by the distances between variances-covariances (V) or correla-

of populations in the 6 countries are very similar: the coefficients are all near 1. It means that countries with coefficients near to 1 have similar homologous points. In other words the same category of population across the 6 countries does not present structural changes in the time-budgets (% of 24 hours devoted to the 12 activities considered).

In particular the data of table 5 indicate that:

- the most similar time use tables are between the pairs of countries:
  - Finland/ Belgium (coefficient 0,906),
  - United Kingdom/ Finland (coefficient 0,906),
  - Norway/ Finland (coefficient 0,902);
- the most dissimilar:
  - Estonia/ Norway (coefficient 0,782),
  - Estonia/ United Kingdom (coefficient 0,734).

It is useful to represent the plot of the six matrices. In Figure 7 is reported the overall and simultaneous representation of the 6 time use tables on the first factorial plane explaining 93.15% of the total variance. The plot allows to examine the reciprocal position of the six countries and their position with respect to the mean (compromise) matrix (V in the plot) (see par. 4.4).

Table 5
Distances matrix of correlation coefficients
(range: 0= max. distance (dissimilarity), 1= max. similarity between pairs of tables)

	Belgium	Estonia	Finland	Norway	Slovenia	UK
Belgium	1.000					
Estonia	0.806	1.000				
Finland	0.906	0.818	1.000			
Norway	0.863	0.782	0.902	1.000		
Slovenia	0.900	0.864	0.860	0.894	1.000	
UK	0.899	0.734	0.906	0.893	0.809	1.000

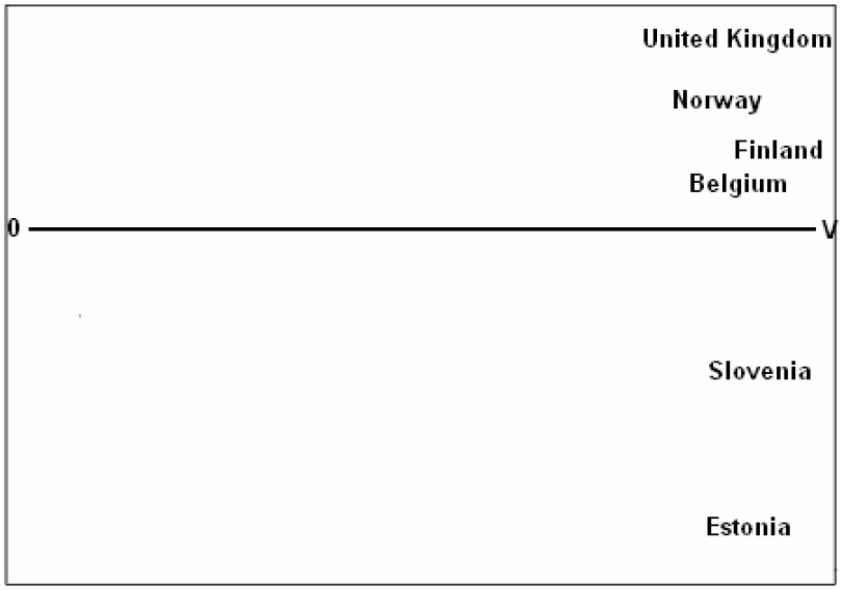
Source : own elaboration on sub-file extracted from the EUROSTAT 'Time-use at different stages of life in 13 European countries in 2003' Data File. 3-way analysis: ACT-méthode STATIS-DUALE -inter-structure analysis

In Figure 7 it is possible to verify the countries similar and dissimilar and their deviation from the mean represented by the compromise matrix V : countries similar are Finland and Belgium, United Kingdom and Norway and on the opposite side of the factorial plane under the mean, Estonia and Slovenia. Further examining the reciprocal position of the six countries we

tion coefficients (R) according to the 'a posteriori codings' chosen for the three-indices matrix. In the application the coding of second type (see par.4.2) requests distances between correlation coefficients (RV).

note that Norway, Finland and Belgium are very near (similar), more distant from them the United Kingdom, all four countries over the mean (V). Estonia and Slovenia are not very similar but under the mean.

Figure 7
Simultaneous representation of the 6 time use tables on the plot of the first factorial plane (explaining 93.15 % of the total variance)



Source: own elaboration on sub-file extracted from the EUROSTAT.
Three-way analysis: ACT-méthode STATIS-DUALE – inter-structure analysis.
Notes: V is the mean (compromise) matrix and V=0 because data is standardized (mean 0 and standard deviation 1)

4.4 The intra-structure analysis: the compromise individuals and variables

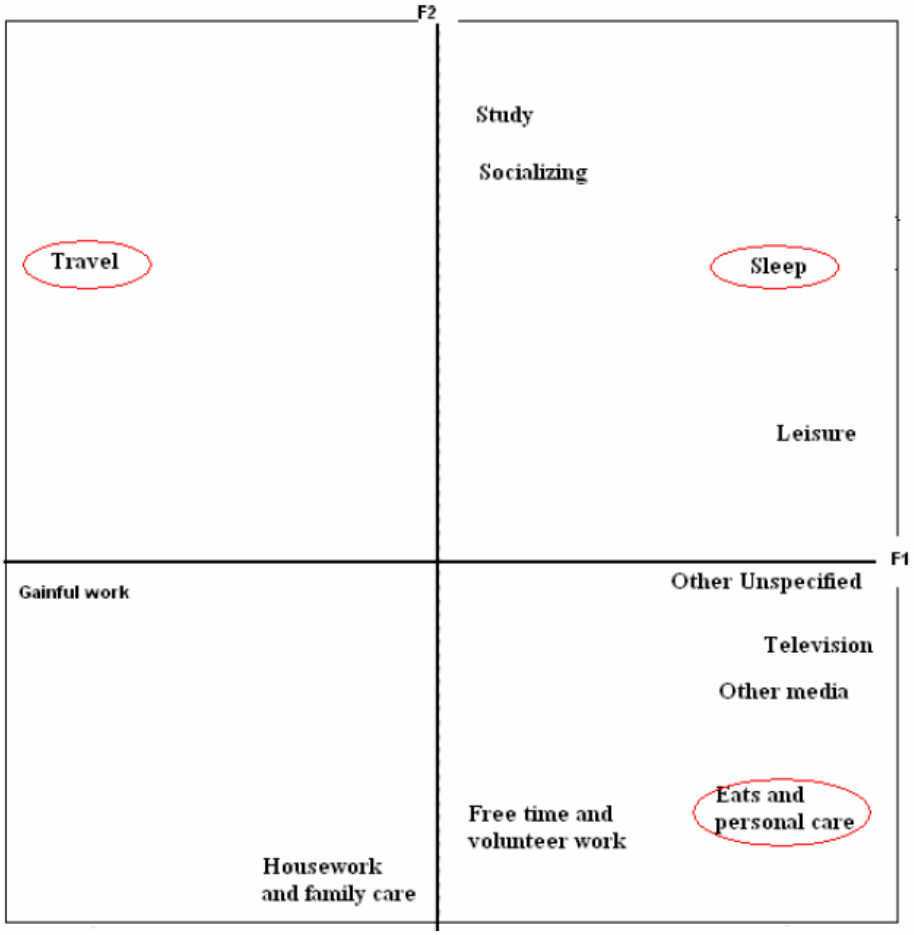
The compromise or intra-structure analysis has the goal to summarize the six studies. In particular it analyse the individuals (i.e. 14 categories of population) and variables (i.e. 12 activity groups) in view to identify the mean (or compromise)-individuals (mean-category of population: i.e. men, women in the application) and the mean (or compromise) variables (meanactivities: i.e. mean-time-budget) across the six occasions (countries).

The mean matrix (compromise matrix) represents the synthesis of all matrices and is calculated in different way according to the a posteriori data coding[8]. In the intra-structure analysis the compromise matrix is diagonalized and it is possible to represent on the principal compromise planes (in this application explaining the 69.75% of the total variance) the meanindividuals points and the mean-variables points referred to all the six occasions. In the present application the meaning of mean-individuals-points is enough clear and correspond to the men and women of the six countries. Similarly for the mean-variable points they correspond to the mean time-budget across the 6 countries.

[8] In the application (different cases and same variables) the compromise matrix is obtained by the scalar product of the correlation matrices and their weighted arithmetic mean.

In the multiway analysis, act-statis-duale method, the intra-structure (compromise) analysis when the 'a posteriori coding' is that one concerning different cases and same variables it is possible to represent on the compromise factorial plane the mean-variable points which are reported in the Figure 8.

Figure 8
The underlying dimensions of the six European countries time-budgets.
Mean-variable points on the first factorial compromise plan
(explaining 69.75% of total variance).



Source: own elaboration on sub-file extracted from the EUROSTAT. Three-way analysis: ACT-méthode STATIS-DUALE – intra-structure analysis.

From Figure 8 it is possible to identify the mean-structure underlying the time budgets of the six countries. Two underlying dimensions (factors) characterize the time-budgets structures:

- the first compromise axis characterized by the activities of gainful work opposed to leisure-watching TV-other media;
- the second compromise axis characterised from the housework and family care-volunteerswork opposed to study and socializing.

Three activities groups are correlated with both axes and could be defined interstructural activity groups: sleep, eats and personal care, travel.

But it is now time to return back for the last analytical description of the time-budgets individuals, 14 categories of population at different stages of life in the six European countries by the last phase of the multiway analysis.

4.5 The trajectories analysis: comparing analytically activities and individuals across the countries

The aim of the trajectories analysis is to have a detailed exploration of differences between the studies comparing the 12 activities of the 14 categories of population across the 6 countries in view to identify the role of each variable in the time use differences, always referring to an average day of the week. It is possible to represent the trajectories in many different ways. In the application because the cases are different and the data are macro data (average durations of categories of population) the analysis of the trajectories obtained by the statisduale method do not add new important information with respect to the analysis above mentioned. On the contrary it is possible to obtain a more analytical description of the variables and individuals by the Multiple Factor Analysis (MFA)[9]. In Figure 9 we report the plot of the 84 individual-points[10] across the six countries on the first factorial plane (explaining the 72.39 % of the total variance).[11]

From the Figure 9 it is possible to identify, excluding the cluster of individual points near the origin of the axis corresponding to the mean-individual points in the six countries (corresponding to total men and total women in each country), four clusters of individual-points each-one including the categories of population at different stages of life similar with respect to their time-budget in a weekday:

- Cluster 1: Men and Women Employed, Men and Women living in Couple with Child 0-6 and 7-17 years old living with parents, for all the six countries. From Figure 9 it is possible to see and compare with the other clusters the size (number of points), the shape and the dispersion of the individual points of the cluster;
- Cluster 2: Men and Women 45-64 years old living in couple without children living with parents in all countries;
- Cluster 3: Men and Women more than 65 years old living in couple not having children less than 18 years living with parents in all countries;
- Cluster 4: Men and Women less than 25 years old Not having children less than 18 years old living with them in all countries.

---

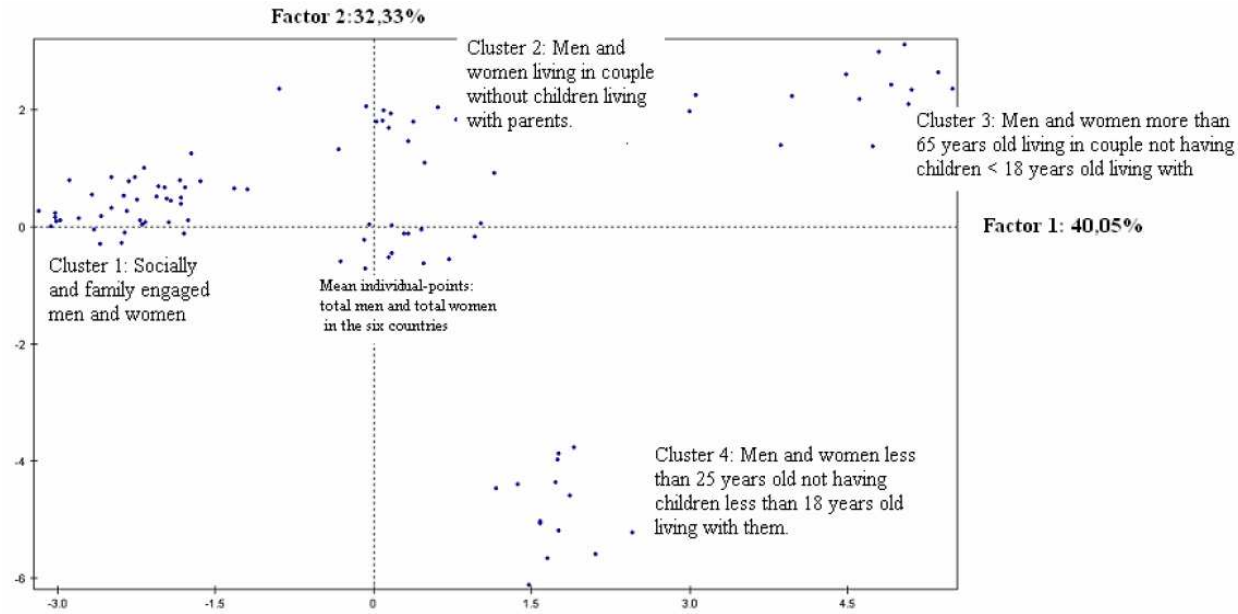
9 Among the multiway analysis the Multiple Factor Analysis is suitable to analyse different groups of individuals on which are observed the same or different quantitative or qualitative variables. MFA is based on repeated applications and synthesis of Principal Component Analysis (for quantitative variables) or Multiple Correspondence Analysis (for qualitative variables).

10 84= 14 categories of populations at different stages of life × 6 European countries.

11 It is to remark that the plot of the variable-point (circle of correlation) on the first factorial plane obtained with the Multiple Factor Analysis is the same obtained in the compromise Statis-Duale analysis reported in Figure 8.

It is important to remark that cluster 1 and cluster 3 are correlated with the first axis characterized in the compromise analysis (see par. 4.4) by the gainful work opposite to leisure and mass media and that cluster 2 and cluster 4 are correlated with the second compromise axis characterized by the housework and family care-volunteers work opposed to study and socializing.

Figure 9
Plot of the 84 categories of population at different stages of life across the six countries on the first factorial plane (explaining the 72.39 % of the total variance)
The size (number of points), shape and dispersion of the four clusters



Source: own elaborations on sub-file extracted from the EUROSTAT Multiple Factor Analysis method

5 Concluding remarks

In the above application the multiway data analysis has shown to fit well for exploring and comparing many time use tables simultaneously. At this purpose the application considered on cross-national comparisons in time-use at different stages of life in six European countries has given important results and could be applied to much more countries, cases and variables as well.

The inter-structure analysis has revealed a general similarity in the homologous points (time-budget of the same category of population across the six countries). Belgium and Finland resulted very similar United Kingdom-Finland and Norway-Finland too, Estonia results very dissimilar with respect to all other countries but particularly United Kingdom and Norway and similar to Slovenia. All the countries except Estonia and Lithuania are located over the mean line.

The intra-structure analysis has revealed two main dimensions underlying the time-budget structure of the 14 categories of population across the six countries: the first factor related to the activities of gainful work opposed to leisure-watching TV-other media; the second factor related to the activities of the housework and family care, volunteers work opposed to study and socializing. Interstructural activities resulted Travel, Sleep and Eats and Personal care.

Finally the trajectories analysis has identify four clusters of population with respect to their time use across all countries: cluster 1) Men and Women Employed, Men and Women living in Couple with Child 0-6 and 7-17 years old living with parents; cluster 2) Men and Women 45-64 years old living in couple without children living with parents; cluster 3) Men and Women more than 65 years old living in couple not having children less than 18 years living with parents; cluster 4) Men and Women less than 25 years old Not having children less than 18 years old living with them. The correlations of the four clusters of individuals with the two underlying factors (see par. 4.5) characterising the time-budget structure in the six countries allow us to identify four ways of life, patterns of spending the time use across the six European countries in a weekday: a) Cluster 1: Socially and Family engaged men and women; b) Cluster 2: Men and women living in couple without children; c) Cluster 3: Old (>65 years old) living in couple d) Cluster 4: Young men and women (<25 years old). It is possible to compute the typical time-budget characterizing the pattern of time use of each cluster by the average time-budget of the cluster cases.

Finally notwithstanding their geographical and cultural differences the six European countries reveal the same large differences in the gender division of gainful work and domestic work and gender differences in the free time available.

References

AA.VV. (1987), Methods for multidimensional data analysis, Advanced Statistics, Università di Napoli, Dip.to I Matematica e Statistica, Napoli.

ACT-STATIS (1989), Analyse conjointe de tableaux quantitatifs, Méthode STATIS, Saint Mandé, CISIA.

Bolasco, S. (1999), Analisi multidimenislnale dei dati, Roma Carocci Ed.

Benzécri, J.P. (1973), L'Analyse des Données, tome I: Taxinomie, tome II: Analyse des Correspondaneces, Paris, Dunod.

Bertier, P. and J.M. Bouroche (1975), Analyse des données Multidimensionneelles, France, Ed. P.U.F.

Caillez, F. and J.P. Pages (1976), Introduction à l'Analyse des Données, Paris, S.M.A.S.H.

Escofier, B. and J. Pagès (1984), L'analyse factorielle multiple, in: Cahiers du Bureau Univ. Recherche Operat., Série Recherche 423.

Escoufier, Y. (1980), L'analyse conjointe de plusieurs matrices, in: Jolivet et al. (eds.), Biométrie et Temps, Société Francaise de Biométrie.

Fraire, M.(1993) Coding approaches, tables and graphs on time budget data – Towards identifying temporal sequences of daily events', ISTAT, Time Use Methodology: Towards Consensus, Note e Relazioni, n.3.

ID. (1994), Metodi di Analisi Multidimensionale dei Dati, Aspetti statistici e applicazioni informatiche., Roma.

ID.(1995), Multidimensional data analysis ans its preliminary phases: statistical aspects, in: Rizzi A. (ed.), Some Relations Between Matrices and Structures of Multidimensional Data Analysis, Applied Mathematics Monographs, n.8, Pisa, Giardini Editori e Stampatori.

ID. (2000), Analisi dei Dati a Tre-Vie delle Risposte a Domande Aperte e Indicatori Empirici, in: Atti della 5 Journées internationales d'Analyse statistique des Données Textuelles, EPFL, M.Rajman & J.-C, Chappelier editeurs.

ID. (2004) I Bilanci del Tempo e le indagini sull'uso del tempo. Time-Budget Studies(TBS) and Time-Use Surveys.

Metodologie di rilevazione e analisi statistica dei dati sull'uso del tempo umano giornaliero, Roma, CISU.

Fraire M. (1995), Multidimensional data analysis and its preliminary phases: statistical aspects, in: Rizzi A. (ed.), Some Relations Between Matrices and Structures of Multidimensional Data Analysis, Applied Mathematics Monographs, n.8, Pisa, Giardini Editori e Stampatori.

Fraire M. and E. Koch-Weser (1997), Lo sport nel contesto e nei ritmi della vita quotidiana, in: 'Statistica e Sport' a cura di A. Mussino, Roma, Società Stampa Sportiva.

Gershuny, J. (2000), Changing times, Oxford:Oxford Univeristy Press.

Harvey, A.S. (1993), Objective and subjective approaches to the measurement of work, ISTAT, Time Use Methodology: Towards Consensus, Note e Relazioni, n.3.

ISTAT (1987-91), L'Uso del Tempo in Italia. Indagine Multiscopo sulle famiglie, Roma, vol.4.

Koch-Weser Ammassari, E.,(1993), On the sociological relevance of Time Budgets in general household surveys, ISTAT, Time Use Methodology: Towards Consensus, Note e Relazioni, n.3.

Koch-Weser Ammassari E. and M. Fraire (1995) Televisione e tempi familiari, Sociologia del lavoro, n.58.

Lebart, L., A. Morineau and M. Piron (1997), Statistique Exploratoire Multidimensionnelle, Paris.

Musatti T. (1992), La giornata del mio bambino, Bologna.

Rizzi, A. (1989), Analisi dei Dati. Applicazioni dell'informatica alla Statistica, Roma.

Romano, M.C. (2004) Le indagini multiscopo dell'ISTAT sull'Uso del Tempo, in: Fraire M., I Bilanci del Tempo e le indagini sull'uso del tempo. Time-Budget Studies(TBS) and Time-Use Surveys.

Szalai, A. (1972), The Use of Time, Paris, Mouton.

SPAD (1999), Manuel de prise en main, vers.4, Montreuil.