STATISTICAL METHODS FOR EXPLORATORY MULTIDIMENSIONAL DATA ANALYSIS ON TIME USE

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1. EXPLORATORY AND CONFIRMATORY DATA ANALYSIS: TWO DIFFERENT APPROACHES FOR COMPLEX PHENOMENA

Until the 1950s, statistics' principal meaning lay in direct and inverse inference. In the history of the two meanings of data analysis, confirmatory and exploratory, we can deduce that until the '50s data analysis leant heavily in favour of confirmative analysis. Starting from the '60s it was John W. Tukey (1962) with his writings and teaching who gave a decisive push in the opposite direction, by a series of important articles on the philosophical foundations of explorative analysis, and also putting forward ingenious methods that were widely welcomed and changed statistical activity. In his writings and teaching he found it useful to define what was meant by statistical data analysis, that is, the procedures for analysing data, the techniques for interpreting their results, the planning of methods for data collection and any computing and mathematical-statistical procedure that might be applied to data analysis. Statistics in the sense of drawing an inference from a sample and applying it to a population is therefore only a part of data analysis and not all of it (Morghenthaler, 2009).

Complexity is a cultural aspect of our knowledge: phenomena are what they are. In particular, in the empirical study of social phenomena it is important to underline that from the same phenomenon (e.g.. health, intelligence, quality of life, behaviour, opinions, but also employed and unemployed, GDP, etc.) it is possible to give different definitions from an operative point of view (that implies different measures and results of the measurement) because empirical language is not independent or, rather, it is 'entangled' with theory. There is a 'gap' between empirical concepts and measures that cannot be filled with single rules (Fraire, 1989). In this context, the exploratory approach of data analysis, in particular of exploratory multidimensional data analysis (henceforth EMDA) adapts very well to such complexity because, although the operative definition of phenomena in empirical observation is 'relative' to the observer-researcher, in the EMDA approach it is necessary to render explicit the conceptual definition and formalise the problem to be analysed. In the matrices of the sets N of the statistical units

and K of the statistical characters, what has to be formed is a description that is pertinent (with regard to the problem to be analysed), satisfactory (complete, comprehensive) and homogeneous (in the unit of measurement in which the variables are expressed) thus allowing anyone to check the operative definitions adopted, the used/useable procedures as well as to clarify the interpretation of the results. (Lebart L. *et al.*, 1997)

Although the two terms *multivariate* and *multidimensional* are often used as synonyms, there is a methodologically important distinction to be made between them that, all things considered, refers to the above-mentioned distinction between *confirmatory analysis (verificative-predictive)* and *exploratory analysis (descriptive-reductive).*

Multivariate analysis regards the study of the relationships in a circumscribed group of statistical variables, generally less than 10-15, studying their correlations and interactions generally of an order superior to two (e.g. analysis of regression, causal analysis, path analysis, structural equation models, etc.; log-linear models; ANOVA and MANOVA). (Corbetta, 1992). The principal aims of multivariate analyses are confirmative in the sense of validating hypotheses formulated *a priori,* or after an explorative analysis, on the set multivariate data, based on probabilistic models and statistical tests.

Multidimensional analysis of data includes three very numerous groups of statistical methods: classificatory (cluster analyses); factorial for two-way tables (principal component analysis, simple and multiple correspondence analysis, multidimensional scaling etc.); analysis for multiple tables (three-way and multi-way data analyses). These are all analyses with a strong computational basis and therefore only possible with computers and the appropriate advanced software. Currently, the increased possibility of dealing with great masses of data through rapid complex calculations using hardware and software accessible to all and increasingly 'friendly' in their use has created the conditions for the wider diffusion and application of EMDA methods in the most diverse fields of research.

From a methodological and applicative point of view, beyond the specific EMDA methods that can be applied, it is useful to consider the exploratory analysis of data as a *system* composed of a number of equally important and interdependent *phases*. In each phase, choices have to be made that do not always have fixed rules or single criteria of choice and each having *statistical* and *computerised* aspects. It is possible to hypothesise 7 principal phases in which an EMDA is used, shown in the conceptual map in Figure 1 with special emphasis on the first four phases that make up the 'preliminary phases', the 'crucial points' of the entire process of data analysis (Fraire, 1994, 2006).

In Figure 1 the phases relate to the following aspects:

*1st phase: initial statistical documentation***:** this is concerned with raw data, the definition of the object and the aim of the research, the plan for the material collection and gathering of data that can assume any form, whether paper (for example, compiled questionnaires) or in an IT format such as data files (in the form of databases, worksheets, warehouses, etc.) or directly via web.
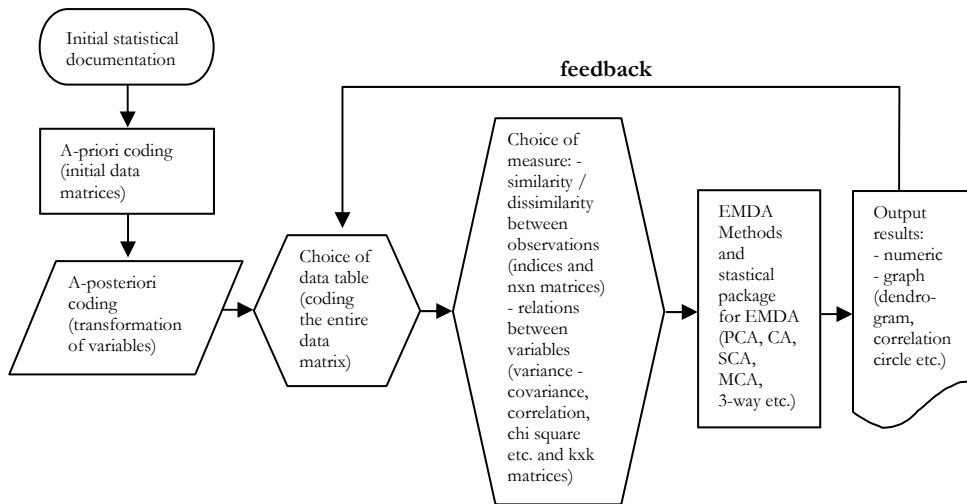
Figure 1 – Seven phases of EMDA.

2nd phase: regards *a priori coding* or the creation of the matrix of initial data, that is, the transposition of all the raw data gathered in the 1st phase in the form of a matrix of 'initial' data. There are very many types of data matrices depending on the research situations and each has a given algebraic *structure*, a non-algebraic structure, or no structure (Fraire, 1995).

3rd phase: regards the *a posteriori coding* of the original data matrix as transformations of variables (categorical or cardinal) for different aims: for example, division into classes of the variables, transformations by ranks, transformations in dummy variables, fuzzy coding, arithmetic, algebraic and functional transformations, treatment of the missing values etc. This phase also contains the statistics (means, variability, correlations, asymmetry etc.) and graphs, especially IT, particularly adapted to the explorative analysis of the data (*box plot*, *steam and leaf, Chernoff faces,* etc.), for a first description of the data matrices.

4th phase: regards the *choice of data table,* on which to apply one (or more) methods of data analysis and requesting the coding of the entire data matrix selected (i.e. generalised contingency table, complete disjunctive table, Burt table etc.) or obtained as feedback from preceding data analyses carried out on the initial data matrix (e.g. the matrix factorial scoring in PCA, the 'compromise' matrix in 3-way analysis, etc.). In the *multi-way* analysis considered here this phase regards the choice (section 3.4) of one of the three possible research situations to which correspond three different types of coding as well as data tables (compromise matrix, trajectory matrix) obtained as '*feedback*' from the execution of the three characterising aspects of the 3-way data analysis employed here (sections 3.5, 3.6, 3.7).

The 3 successive phases regard:

5th phase: regards the *choice of the measure*: that is, the choice of a measure of similarity/dissimilarity between units (ultrametric distances, distances, indices of dis-

tance, indices of similarity) or of a measure of relationship between characters (deviance-codeviance, variances-covariances, correlations, connections) adapted to the type of data table and to the chosen method of data analysis.

6th phase: regards the choice of the EMDA method and software.

7th phase: regards the *output* of the synthesis of the results: both numerical (eigenvalues, factorial weights, factorial scoring, trajectories etc.) and graphic (*plots* of factorial planes, circles of correlations, dendrograms, etc.).

In this work the use of EMDA will be proposed adapted to the data analysis on time use obtainable from the time-budget diaries of and surveys on time use, characterised by their large size, multipurpose nature and complex structure (section 2).

In particular two applications will be dealt with:

1) *Analysis of the multiple tables using multi-way*, in particular here 3-way data analysis, to analyse simultaneously a number of two-index data matrices on time use.

2) *Global empirical models of time use*. These analyses require the calculation of particular tables and graphs based on cumulated frequencies, selected (intervals) time points, and categories of population engaged in all their daily activities. Such analyses are part of the sequential analyses on time use and time use for time points.

In describing the applications we will also refer to the conceptual map in Figure 1.

Finally, it should be observed that the nature of data on time use often does not allow the respecting of the requirements imposed by the used/useable models in multivariate analysis. For example with reference to models of regression:

– the assumption of *normality of the residuals*: despite the robustness of the model of linear regression, even using tobit regression the problem arises that the same set of independent variables can explain on the same plane the probability of the frequency of those who carry out the activity (doers) with the specific mean duration of the activity itself. Deviations from the norm are found more often in daily diaries rather than in weekly diaries;

– the *homoschedasticity* of the residuals: many daily activities have a differentiated variability depending on the social groups under consideration, e.g. the variability in wages that depends greatly on age;

– the *independence* of the independent variables (incollinearity) and the independence of the residuals are often violated when a respondent has filled in more than one diary (e.g. for working days and holidays) or if there is more than one interviewee in the same family (K. Fisher, 2009).

2. THE SOCIAL NATURE OF TIME: TIME BUDGETS AND STUDIES INTO THE USE OF HUMAN TIME

From the point of view of statistics, time budget can be defined as follows: time budget is a *continuous and analytical* instrument of *statistical observation* (for populations or social groups), over limited periods of time (generally based on the

human circadian rhythm of 24 hours and the social relevance of said period: working day, holiday, day off etc.) of the way of using time on the part of a given collective. The '*continuity*' of the observation requires special questionnaires (time-use diaries) that allow the recording of all the activities (under the form of a sequence of 'events') carried out by the respondent during the period of observation. The *analyticity* regards the following modalities of carrying out the activities of the collective under examination: the *duration* of each activity, the *sequence* in which it was effectively carried out on the day of the survey, its eventual *contemporaneity* with other activities, the *place* where it occurred, the *persons* present and/or participating, as well as *other* eventual *characteristics* foreseen by the study (socio-demographic characteristics of the interviewee, characteristics of the day of the survey, enjoyment, satisfaction-dissatisfaction with the activities carried out and so on) (Fraire, 1986, 2004).

The dataset of time-budget studies are a complex structure. The methodological-statistical problems have to do with the difficulty of time-budget studies compared to the usual sociological studies that emerge from the consideration of time as a base unit of measurement both in the gathering as well as the elaboration of data. We will mention only some of the problems and point readers to more detailed expositions of these arguments in literature specific to the topic (Szalai, 1972; Istat, 1987; Fraire, 2004; Istat 2008). In the data *survey phase*: apposite questionnaires should be provided with special *reticulates* (diaries) for the survey of times, the interviewees have to *self-survey* as regards the times taken for the activities, the choice of the *nomenclature of the daily activity* often presents notable difficulties, and so on. In the data *elaboration phase* and if we wish to exploit *all* the temporal modalities (cf. the definition of time budget) surveyable through time budgets (duration, frequency, sequence, contemporaneity, place, persons, subjective-perceptive aspects of the use of time) it is necessary to provide special *codings* both '*a priori*' (1st phase of the EMDA), the creation of the matrix of the initial data: *Time-Budget Data File,* as well as '*a posteriori*' (3rd and 4th phase) that are necessary for the automatic treatment of time-budget data because these have *particular* problems and solutions compared to traditional studies using questionnaires. We could mention, for example, in the *coding of time-budget data* the necessity for the '*rectangularisation*' of the matrix of the initial data: the *data files* of the traditional studies of a social character are made up of rectangular matrices in the sense that each individual (line, *record*) has a fixed number of variables (columns, fields) and the content of each column is the same for all the interviewees. On the other hand, the time budget data file is made up of a matrix in which each subject (line, *record*) has a different length due to the fact that each subject's record has a variable number of events (events: frequency of an activity) carried out in the 24 hours; the recording of the events occurs in the different orders in which they were carried out for each individual. Table 1 shows an example of the coding pattern at the level of the individual of time-budget data in which every record is therefore a *string of events*, $E_1 ... E_j ... E_k$ (each with 7 modality codes) rather than a *string of activities.*

TABLE 1

Time-Use Data File: coding at the level of persons

events \ persons	background characteristics				E₁ (1-st event)							...	E_j (j-th event)	...	E_k (k-th event)
	Q_1	Q_2	...	Q_k	1	2	3	4	5	6	7				
1															
2															
.															
.															
.															
N															

It is relevant to note that in the grid of time budget *diaries* (the special questionnaire employed in the TUS) it is possible to fix the minimum length of each event (i.e. 10 minutes in the grid of ISTAT – Time-Use Survey) or leaving the respondent free: this choice will affect the computation of the temporal sequences of daily events also named '*time-points data file'* from which come the 'sequence time use' tables and distributions.

One possible solution is therefore the 'rectangularisation of the matrix of the initial data' (3rd phase EMDA) through the coding for events instead of at the level of persons such as showed in a previous work of ours (Fraire, 1993).

At present in the industrially advanced countries new technologies in communications and IT are accelerating the convergence of different ways of life (WoL) of different countries (being informed, working, caring for children, studying, looking after one's health, shopping, social relationships and so on).

In this context, many countries reveal time-budget data that become increasingly relevant for several aims such as monitoring the similarities and differences and changes in the ways of life (WoL) of populations or given social groups, studying practical problems relating to social planning, e.g. linked to the use of the urban environment or relating to health (section 4).

Interest in the development of *international comparative data* on time use emerged at the end of 1980 with the *Multinational Time Use Study (MTUS)* whose scope was to gather the *datasets* from time use studies carried out in various nations and render them comparable at international level. The '*Multinational File'* that was called *World 1* in its first version is now (2009) up to the release of World 5.5 Version.[1]

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[1] The idea was to create a cross-nationally harmonized set of time-use surveys composed of identically recoded variables. Harmonized version of the dataset is available for free downloading at the website: http://www.timeuse.org/mtus after registration. Dataset concerns 34 surveys for total population of N = 321.390 diarists and $X_{k=100}$ variables: X_{1-11} variables concerning country, day of collecting data, type of diary (daily, weekly etc.) that follow X_{12-37} 26 variables concerning background characteristics of the diarist and finally the activities performed (only primary activities) in two classifications: 41 activities and a more restricted set of 22 activities to cover surveys that have a more restricted set of activity codes.

In Italy, ISTAT in the field of the Multiscope Family Survey carried out the following studies on Time Use on probabilistic samples: 1986-87 (n = 38,110 individuals in 13,729 families); in 1996, a preparatory pilot study for the successive study on a few cases; 2002-03 (n = 55,773 individuals in 21,075 families) and 2009 ongoing (Romano, 2004). From a methodological point of view it is important we distinguish different but complementary aspects in time budget data analysis:

1) *Transversal analysis on time budget*: based on the duration of the activities *(what)* and on the frequency of those who carried out the activity on the day being surveyed. [2]Such durations can be M_g = generic mean durations referred to the total of the population or social group under survey, irrespective of whether or not they carried out the activity on the day of the survey or $M_{s =}$ *mean specific* duration referring only to carrying out the activity with an indication of the frequency of those who carried out the activity. The mean specific durations can also be referred to the *primary* or *connected* activities with the frequency of the couplings.

2) *Sequential analysis of time use*: the daily rhythm of the activities *(when)* based on the frequency of the population carrying out a *given activity* by time points (episodes, intervals into which the 24 hours are subdivided); frequency of the population carrying out *all* the daily activities by time points (tables and *cumulative graphs of time use*)[3].

In the following paragraphs these two aspects, transversal and sequential, will be considered, applying two different statistical methods of exploratory multidimensional data analysis (EMDA).

3. TRANSVERSAL ANALYSIS OF TIME USE: MULTI-WAY DATA ANALYSIS

3.1 *Multi-way data analysis: methods and software*

Multi-way data analysis concerns the analysis of multiple tables. There are different techniques of multi-way data analysis depending on the different study situations: *Procrustean Analysis*, *Multidimensional Scaling metric and non-metric*, *Multiple Factorial Analysis*, *Act-Méthode Statis and Act-Méthode Statis-Duale*, *Generalised Canonical Analysis*. In the field of multidimensional explorative and *asymmetric* data analysis*,* multi-way data analysis, and in particular three-way data analysis which will be employed here, constitutes a group of methods of great interest for the explorative, comparative and synthetic analysis of the *multiple tables*, that is, analysis in following different possible points of view of numbers of two-index matrices globally and contemporarily through a third 'criterion', 'occasions', chosen a priori. The occasions can be times, places or any other criterion (qualitative or quantitative). The aim of three-way analysis is that of comparing a number of studies,

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[2] It should be noted that with time-budget data it is also possible to analyse using the same time-use indices: *the places (where)* in which one is found in the 24 hours *irrespective* of the activities carried out, *and the persons (with whom)* present and/or participating still *irrespective* of the activities carried out.

[3] In this type of analysis too rather than activities we can also refer to the places or persons present and/or participating irrespective of the activities carried out on the survey day.

research and inquiries when each of these has many variables observed in many statistical units.

In particular, in the following applications *three-way* data analysis will be considered referring to quantitative data and, in particular, the *Act-Méthode Statis* and *Analyse Factorielle Multiple* methods, employed using ACT-Statis and SPAD-*Analyse des Tableaux Multiples*: *Statis* and *Analyse Factorielle Multiple* software[4].

3.2 *Initial statistical documentation (1ˢᵗ phase EMDA): sources of data, sample, macro-units and activity-variables*

Source of data: the source of the data employed for the applications is represented by a sub-file extracted from the dataset of the Time-Use Study 1988-89[5] of ISTAT. The time-use dataset employed had a dimension of 2437 bytes for every interviewee characterised by 173 variables of which: 23 variables on the socio-demographic characteristics of the interviewee and of the day of the survey, 150 variables relating to the activities (events): 3×50 (3 variables for every event) and considering a maximum of 50 daily events per person.

Sample : concerning $N = 327$ couples (99% married and 1% cohabiting) equivalent to 654 partners in work days and $N = 361$ couples (722 partners) on Sunday in mononuclear families living in major urban conurbations (11 Italian cities: Turin, Milan, Venice, Genoa, Bologna, Florence, Rome, Naples, Bari, Palermo, Catania.)

N=22 statistical units in the applications are represented by *macro-units*, categories of population, in particular here '*categories of partner*s' obtained through crossing the modalities of the following variables of analysis and variables relating to life cycle (classification variables) recorded in table 2.

TABLE 2

Analysis Variables and Life Cycle Variables for the set N = 22 macro-cases

ANALYSIS VARIABLES	*Value label*
1. DAY	*Day of Interview::* Sunday ; Workdays (from monday to friday)
2. SEX	*Sex:* Man; Female
3. PARTNER AGE	*Age Class:* 15-24; 25-44; 45-64; 65-74; 75-84;85+
4. AVERAGE AGE IN THE COUPLE	*Average Age Class:* 20-35 ; 36-50 ; >50
5. EDUCATION	*Education level:* High ;Middle; Low
6. EMPSTAT IN THE COUPLE (married/cohabiting)	*Employment Status in the couple:* Both employed; One only employed; None employed
LIFE CYCLE VARIABLES	*Life cycle*
7. CHILD <18 YEARS LIVING IN THE COUPLE	Without children less 18 years living in the couple ; with children less 18 years living in the couple;
8. AGE OF YOUNGEST CHILD LIVING IN THE COUPLE	*Youngest Age*: Adult living with at least one child aged < 5 ; Adult living with at least one child aged 6-11; Adult living with at least one child aged 12-18 .

Source: M. Fraire, E. Koch-Weser Ammassari (1995, 1997)

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[4] The acronyms have the following meanings: ACT is for *Analyses Conjointes des Tableaux*; STATIS indicates *Structuration des Tableaux A Trois Indices de la Statistique*; SPAD *Système Portable pour l'Analyse des Données*. The two types of *software* mentioned are respectively from the Unité de Biométrie (IN-RA-ENSA) of Montpellier, France and the CISIA, Centre International de Statististques et d'Informatique Appliquée, Montreuil Cedex, France.

[5] In the following analyses there will also be a comparison with the data from ISTAT Time-Use Study 2002-03 (section 4).

The 22 categories of partner were therefore the following (indicated with their labels): 1. Females; 2. FemaleNotEmployed; 3. Femployed; 4. FlowEducLev; 5. FhighEducLev; 6. FWithChild<18 years; 7. FWithouthChild<18years; 8. FMiddleEducLev; 9. FWithYoungestChild<05years; 10. FwithYoungestChild; 11. FWithYoungestChild 12-18 years. The same for the 11 cases of male partners.

X_k (k = 1, 2, ..., 9) = 9 variables here are made up of 9 daily activity groups that include all the activities carried and possessing the following characteristics: they are primary activities, that is, principal activities not carried out contemporarily with others or, in that case, considered primary anyway, the order of the activities is conventional, and only for the data analysis of the following times (section 4) by convention the (primary) activities are ordered from non-obligatory activities (free time) to those that are more obligatory (working, eating, sleeping); it should be noted that the choice of the classification of the activities with different possible levels of analyticity (digits) is carried out by the researcher on the basis of the study's aims – here the 9 primary activity groups considered with the activities are the following: 1. TV (TVand video); 2. OMED (Other mass media (radio, music, reading); 3. FREE (Free time: leisure time (sports, outdoor activities, hobbies and games unspecified); volunteer work and informal help to other households; 4. SOCI (Socializing (participatory activities, social life and entertainment and culture).; 5. TRAV (Travel including travel for work); 6. H&FA (Home and family care); 7. WORK (gainful work, study); 8. EATS (Meals); 9. SLEEP.

3.3 *Two- and three-index matrices (3rd phase of EMDA: a posteriori coding)*

If *P* is the statistical or collective population defined by:

$$P\begin{cases} i \in N(i=1,2,...,n) \\ x_j \in X(j=1,2,...,k) \end{cases} \tag{1}$$

in which *i* is the *individual or statistical unit (s.u.)* belonging to the total N: $i \in N$ (i = 1, 2, ..., n); the total *N* is the total of all the *n* s.u. and is generally supposed to be *finite and numerable* (in socio-demographic types of study; *N* is, on the other hand, infinite in theoretical populations or in particular experimental studies), X_j is *the statistical or variable character* (table 3) of matrices of intensity or quantitative data, it is a variable belonging to the total X of the *k* statistical characters: $X_j \in X$ (j = 1, 2, ..., k); the total *X* is defined "*a priori*". The statistical datum x_{ij} (i = 1, 2, ..., *N*; j = 1, 2,..., k) represents real numbers that can be:
– *intensity* (generic or specific mean durations of the time taken for each activity under consideration)
– *relative frequencies* (percentage of the member of the macro-unit considered that carried out the activity in the day under consideration); rational positive numbers in a *contingency matrix* that in the case of 3-way analysis has to be *normalised*[6].

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[6] Obtained examining the absolute frequencies in line with the numerousness N of the statistical units (units of analysis) considered on each 'occasion' to bear in mind the diverse numerousness of the populations on each of the occasions considered.

The *2-way*[7] *and two-indices matrix* $X_{N,K}$ at *n* lines at *k* columns is reported in table 3:

TABLE 3

Two-indices quantitative matrix

$$X_{N,K} \equiv \begin{matrix} x_{11} & x_{12} & ... & x_{1j} & ... & x_{1k} \\ x_{21} & x_{22} & ... & x_{2j} & ... & x_{2k} \\ ... & ... & ... & ... & ... & ... \\ x_{i1} & x_{i2} & ... & x_{ij} & ... & x_{ik} \\ ... & ... & ... & ... & ... & ... \\ x_{N1} & x_{N2} & ... & x_{Nj} & ... & x_{Nk} \end{matrix} .$$

If we refer to the research situation considered here and to the transversal analyses of time use (section 2) what we are dealing with in particular is a *matrix intensity* or quantitative data insofar as the abovementioned matrix $X_{n,k}$ is composed of *statistical data x_{ij}* represented by *real numbers*,

– *each line* of the matrix can be seen as a numerical vector to *k* dimensions indicating the coordinates of a *point-individual* in a *space R^k of k-dimensions*, called *space of the statistical units*. In this application *i-th row* is the *whole* time-use *profile* (description) of *i-th* individuals or category of individuals (partners). If the *row-sum* is equal to 1440 minutes the row is *i-th* category's *time-budget* (because activity duration is referred to all persons of the population's category). Comparisons *among rows* (also transforming data in % of the 24 hours = 100) give the differences in time-budgets of the 22 categories of population (partners).

– *each column* of the matrix is represented by a numerical vector to *n* dimensions indicating the coordinates of a *point-individual* in a *space R^n of n-dimensions*, called *space of the variables*. The *j-th column* is the *distribution* of average durations of *j-th* activity among N = 22 categories of partners. Each column gives consistency (amount of time spent) and dispersion of *j-th* activity (primary activity group) among 22 categories considered.

– the *statistical datum x_{ij}* (*i* = 1, 2, ..., *N*; *j* = 1, 2, ..., *k*) = *statistical data* which can be alphanumeric codes or real numbers.

In this application the data considered is average duration in minutes (and decimals) of the *i-th* whole category of population (including persons who had not performed the activity) for *j-th* primary activity. The choice of referring the activity's average duration to the whole population or only to those who have performed the activity ('*doers*') is related to two different meanings and research interests: a) analysing the *incidence* of average duration of each activity in the 1440 minutes = 24 hours = 100 therefore focusing analysis on time-use 'budget'; b) analysing the real, 'typical' duration of each activity, focusing analysis on *time-use structure*.[8]

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[7] By *mode* what is intended is the type of information considered in the matrix under study; in this case, for example, the "individuals" mode and "variables" mode, but they could also be modes such as places, times, judges, etc. The *indices* indicate, on the other hand, the criterion for classification of the "statistical datum" x_{ij} where $i \in N$ (*i* = 1, 2, ..., *n*) are the individuals and $X_i \in X$ for *j* = 1, 2, ..., *k* are the statistical variables being considered.

[8] If data *x_{ij}* are frequencies of macro-cases performing the activities in the day, data matrix is a

As I note such matrices possess an *algebraic structure of Euclidean vectorial space*; this means that they can be subject to all the operations between matrices and the majority of the data analysis methods, whether predictive or explorative; furthermore, such matrices can be subject to different *metrics among s.u.* (ultrametric distances, Minkowski, Mahalanobis, etc.) or among variables (deviances and codeviances, variances and covariances, correlations, etc.).

Schematically, a 3-mode and 3-way matrix is indicated as follows: referring to the case under consideration, 3-mode and 3-way data analysis, that is, "cubic" data[9], could be represented in the following way $_O X_{N,K}$ in which O = *occasions*, N = *statistical units* or *cases*, K = *variables*.

Two different hypotheses of 'occasions' particularly interesting for the EMDA time-use data are: age classes and countries. In this article we will refer to 3-way data analysis with the ACT-STATIS method, adapted to matrices of quantitative data and in particular to the example in Figure 2 in which the third criterion is 'age classes' while we refer to a previous work of ours (Fraire, 2006) for 3-way analysis in the case in which the third criterion is represented by the nations.
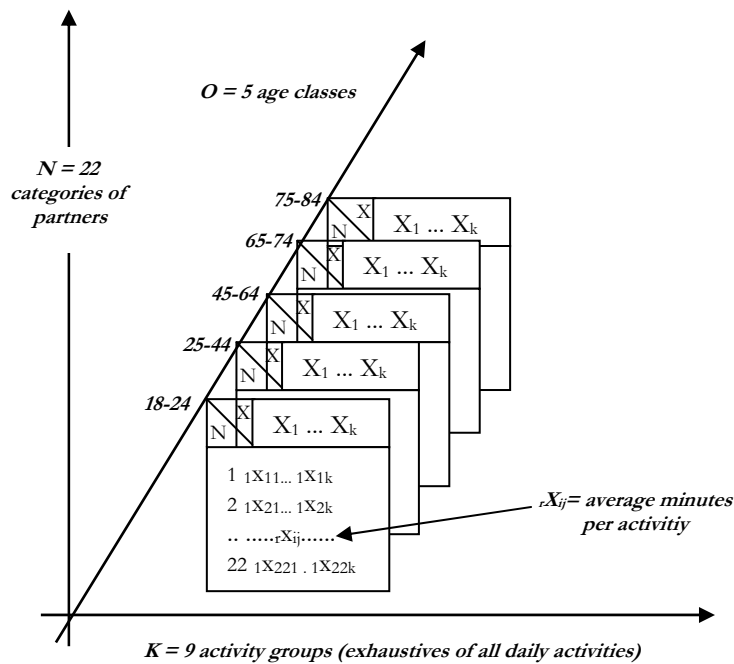
Figure 2 – Three-way time-use analysis when occasions are age classes.

contingency table. In 3-way analysis frequencies had to be normalized weighting the absolute frequency with N total population of each 'occasion'.

[9] *Cubic* data is structured as a *multidimensional hypercube* in which every side is a dimension; these allow even latent data to be analysed and modelled multidimensionally with an aim that is both predictive and classificatory for the identification of typologies, models and data structure.

3.4 *A posteriori coding of the 3-way data matrix: the choice of data table (4ᵗʰ phase of EMDA)*

It is important to distinguish the type of *3-way data table* that has to be constructed (a posteriori coding corresponding to the 4ᵗʰ phase of EMDA) depending on the research situations: 1) a matrix of dimension [N, ($K \times O$)] in which *the K variables* are considered *diverse* found on O successive occasions and *the N s.u equal.*; 2) a matrix of dimension [($N \times O$), K] in which *the K variables* are considered *equal* and *the N s.u. diverse found on O successive occasions*; 3) a matrix of dimension [($N \times K$), O] in which are considered *equal both the N s.u. and the K variables* found on O successive occasions.

In this work, the research situation considered is that described at *point (3)*, that is, the *K = 9 variables,* primary activities, can be considered equal as can the *N = 22* categories of partner *on O occasions* represented, in this case, by the 5 age classes. The 3-index data matrix under consideration can be indicated as:

$$O=5_{age-classes}.\, X^{(workday)}_{N=22\,partners,K=9\,activities} = X_{(N\times K),O} \tag{2}$$

defined by the following elements:

X_j (j = 1, 2, ..., k) = 9 primary activities (table 4);
N = 22 types of partners (table 2);
O_r (r = 1, 2, ..., 5) = partners' age classes: 18-24 years; 25-44 years; 45-64 years; 65-74 years; 75-84 years

$_r x_{ij}$ (r = 1, ..., 5; i = 1, ..22; j = 1, ..., 9) = average duration (in minutes and decimals) referred to *all persons* of *i-th* partner's category in *j-th* activity in *r-th* occasion. *I-th* row is the *time budget* of i-th partner. Figure 2 reports the time use three-way data of the application. Table 5 reports a synthetic example of *time use three-way matrix* coded in a suitable form for the situation research (application) under consideration and the software employed.[10]

In particular, table 4 reports the *data table* that constitutes the 3-way data matrix, considered for the *multi-way* analyses that follow and referring in particular to the form requested, the 'piling' of the 5 matrices, using the statistical software ACT-STATIS.

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[10] With SPAD-méthode STATIS software this table would be built, rather, placing the matrices of the occasions under consideration *consecutively*. All the analyses reported here of the inter-structure, intra-structure or compromised structures and trajectories were carried out using ACT-Méthode STATIS-CISIA software.

TABLE 4

The 'a posteriori' coded time-use three-indices matrix of the application

(partners of 18-24 years old)

	TV	OMEDIA	FREE&VOLUNT	SOCI	TRAV	HOME&FAMILY	WORK&STUDY	EATS	SLEEP&PCARE
1 M18-24	215.0	0.0	12.5	0.0	80.0	37.5	517.5	112.5	465.0
2 M18-24NotEmploy	.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 M18-24Employ	215.0	0.0	12.5	.0	80.0	37.5	517.5	112.5	465.0
....									
2 F18-24WithChild12-18	.0	0.0	0.0	0.0	.0	.0	.0	.0	.0

(partners of 25-44 years old)

	TV	OMEDIA	FREE&VOLUNT	SOCI	TRAV	HOME&FAMILY	WORK&STUDY	EATS	SLEEP&PCARE
1 M25-44	99.4	24.7	40.8	47.9	77.5	72.9	468.1	138.0	465.1
2 M25-44NotEmploy	110.6	12.9	80.0	66.9	82.1	181.9	262.9	142.1	475.0
3 M25-44Employ	98.9	25.2	39.2	47.1	77.4	68.5	475.4	137.8	464.7
....									
2 F25-44WithChild12-18	80.8	22.0	46.7	34.2	73.2	181.0	392.4	136.7	469.1

(partners of 45-64 years old)

	TV	OMEDIA	FREE&VOLUNT	SOCI	TRAV	HOME&FAMILY	WORK&STUDY	EATS	SLEEP&PCARE
1 M45-64	128.5	40.9	69.4	31.2	75.0	93.1	347.1	150.1	498.2
2 M45-64NoTEmploy	119.0	20.1	64.3	37.1	15.9	475.5	9.1	164.2	516.3
3 M45-64Employ	85.9	8.2	21.0	27.8	44.6	311.2	290.8	147.7	489.6
....									
F45-64WithChild12-18	55.0	90.0	.0	5.0	105.0	7.5	562.5	120.0	495.0

(partners of 65-74 years old)

	TV	OMEDIA	FREE&VOLUNT	SOCI	TRAV	HOME&FAMILY	WORK&STUDY	EATS	SLEEP&PCARE
1 M65-74	171.5	64.6	150.9	45.4	48.5	144.9	43.1	180.9	589.5
2 M65-74NotEmploy	131.4	37.1	86.6	32.8	16.4	410.4	.0	169.7	547.2
3 M65-74Employ	150.0	30.0	260.0	.0	130.0	135.0	.0	105.0	630.0
....									
2 F65-74WithChild12-18	.0	.0	.0	.0	.0	.0	.0	.0	.0

(partners of 75-84 years old)

	TV	OMEDIA	FREE&VOLUNT	SOCI	TRAV	HOME&FAMILY	WORK&STUDY	EATS	SLEEP&PCARE
1 M75-84	201.2	59.5	127.2	52.5	29.4	127.9	20.0	166.9	643.7
2 M75-84NotEmploy	167.7	9.5	80.5	40.9	10.0	379.0	.0	150.5	601.8
3 M75-84Employ	.0	.0	.0	.0	.0	.0	.0	.0	.0
....									
2 F75-84WithChild12-18	.0	.0	.0	.0	.0	.0	.0	.0	.0

In which:

– the line vectors x_i ($i = 1, 2, ..., 22$) are the time budgets (in minutes) expressed in generic mean durations for each category of partner for each of the daily activities (note that the total per line is equal to 1440 = 24 hour);

– the column vectors x_j ($j = 1, 2, ..., 9$) represent the distribution of mean times dedicated to each activity group by 22 types of partners;

– the x_{ij} data are the generic mean durations (section 2). The data refer to a working day.

Four different 3-way analyses have been carried out: on workdays and Sundays and on average durations referring both to all persons and to doers. We shall report here synthetically the results referring only to *workdays* and *average durations for all persons*.

It should be observed that the method of 3-way analysis is composed of three different aspects that are carried out in succession:

1) analysis of the inter-structure;

2) analysis of the intra-structure or compromised structure;

3) analysis of the trajectories.

In the following paragraphs the principal results of the three aspects will be examined.

3.5 *Analysis of the inter-structure (5th-6th-7th phase of EMDA)*

The analysis of the *inter-structure* concerns the analysis of the structure of the tables by means of *global* representation and the *distance* between them with the aim of comparing the five 'studies' (age classes) to verify which are similar (that have similar representations to the individuals) and which are different (Escoufier Y., 1980). In the case examined, what has to be evaluated is if the 22 types of partners in respect to the variables considered (9 activities; including all daily activities, their time budget) have through the 5 age classes under consideration a structure that is *similar, near.* This means verifying if and which are the partners who, in reality, for their class of age maintained *homologous* structures, that is, they did not undergo *structural* changes (of the homologous points) in their time budgets in a working day and in which there was a change.

The similarity or dissimilarity between the 5 data tables can be measured both by using a metric based on distances between statistical units (for example, Euclidean, Manhattan, and Mahalanobis distances, indices of distance such as χ^2 and so on) as well as by distances between variances-covariances (V), correlations (R) according to the type of 'a posteriori coding' chosen for the 3-way matrix. In the application under consideration, the considered coding (of the third type cf. par. 3.4) requires distances between the coefficients of correlation (Pearson, Escoufier RV etc.), in particular the coefficient of correlation RV of Escoufier having value 0 if there is the maximum dissimilarity and value 1 if there is the maximum similarity between couples in the tables. Table 5 shows the matrix of the RV coefficients and Figure 4 the global representation of the 5 tables of data of the first factorial level ($\lambda_1 + \lambda_2 = 39.44\% + 26,21\% = 65.65\%$ of total variance) obtained, similar to what happens in ACP, from the diagonalisation of the RV matrix of coefficients of Escoufier (1980). The data is standardised (*3rd phase EMDA*: *a posteriori coding*) because despite having the same unit of measurement, in minutes, both the statistical units and the variables had means and variability that were very different for each of the 9 daily activities considered) which means that on the first factorial plane reported in Figure 4 the origin of the axes (*== 0) and the mean matrix WD coincide.

TABLE 5

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

	18-24	25-44	45-64	65-74	75-84
18-24	1.000				
25-44	0.357	1.000			
45-64	0.150	0.378	1.000		
65-74	0.057	0.091	0.332	1.000	
75-84	0.084	0.112	0.169	0.626	1.000

Some main points about table 5:
– *most similar* pairs of time use tables are: 65-74 / 75-84 age classes (RV = 0.626); 45-64 / 25-44 age classes but with RV coefficient = 0.378;
– *most dissimilar* pairs of time use tables: 18-24 / 65-74 age classes (RV = 0.057; 18-24 / 75-84 age classes (RV = 0.084).

From the plot of the five time-use tables on the first principal plane in Figure 3 it is possible to see that the time-use table referring to partners of the 45-64 age class is near the mean (WD) and is dissimilar to the other time-use tables and the age classes over and under the mean matrix (WD).
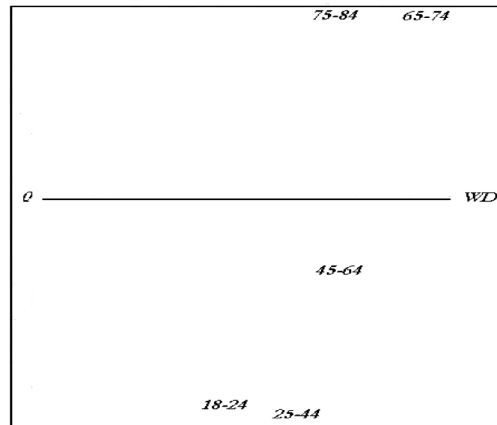

Figure 3 – Plot of the five time-use tables on first factorial plane (65,65% of total variance).
Notes: WD is the mean (compromise) matrix and WD = 0 because data are standardised (mean = 0 and standard deviation = 1).

3.6 *Inter-structure or compromise (mean) analysis (5th, 6th, 7th steps of EMDA)*

In the conceptual map of the 7 phases of EMDA (cf. Fig. 1) this analysis corresponds to the 1st *feedback*: from the *7th phase* of EMDA= output= mean matrix (compromise, WD) that becomes the data table (4th phase of EMDA) for the analysis of the intra-structure.

The scope of the analysis of the *intra-structure* is that of identifying the *mean-individual-points* (compromise) and the *mean-variable points* through the 5 occasions. In other words, which categories of partner have most greatly contributed to variability, through the age classes, on the time budgets of a working day. With this aim we have to identify the 'type of mean-partner' and the corresponding 'mean profile of time budget' (in substance the 'barycentre' of time used for the age classes under consideration and the types of partners) and to what extent and which are the classes of partner that move furthest away.

The 'mean' matrix (WD) is called 'compromise matrix'; this represents the synthesis of all the matrices and is given by the *weighted* arithmetic mean of the matrices of similarity or distance $N \times N$ among individuals, in the case under consideration, for example, they are:

$$_{18-24}S_{22,22} ; {}_{25-44}S_{22,22} ; {}_{45-64}S_{22,22} ; {}_{65-74}S_{22,22} ; {}_{75-84}S_{22,22} \tag{3}$$

corresponding to the original matrices expressed in deviations from the mean, weighted with the corresponding eigenvectors to the *first* greatest eigenvector of the matrix

$$C \equiv C_{ij} \tag{4}$$

being

$$C_{ij} = tr(_i S_j S) \tag{5}$$

Based on the first eigenvector the compromised matrix WD is 'robust' insofar as it is not very influenced by the small variations in the matrices of similarity.(Rizzi,1989). It is important to verify that in these multi-way analyses the quantities selected 'make sense' in relation to the phenomenon under consideration: here the compromise matrix undoubtedly has a clear meaning of 'mean time budget', typical of the categories of partners considered, irrespective of their age. For the analysis of the intra-structure, the compromise WD matrix forms a diagonal which, in the case under consideration and limiting ourselves here to reporting only the first two factors (compromise axes), has the following eigenvectors:

$\lambda_1 + \lambda_2 = 39.44\% + 26,21\% = 65.65\%$

It is possible, therefore, to represent on the first factorial plain both the variables (*mean variable-points*) and the s.u. (*mean-individual-points*) in respect of the first two compromise axes. Figure 4 limits itself here to reporting the plot of the mean variable-points (activity) in respect of the first two compromise axes. It can be noted that three types of partner can be clearly identified in respect to both the age classes as well as to the activities carried out (Figure 4) and that each cluster
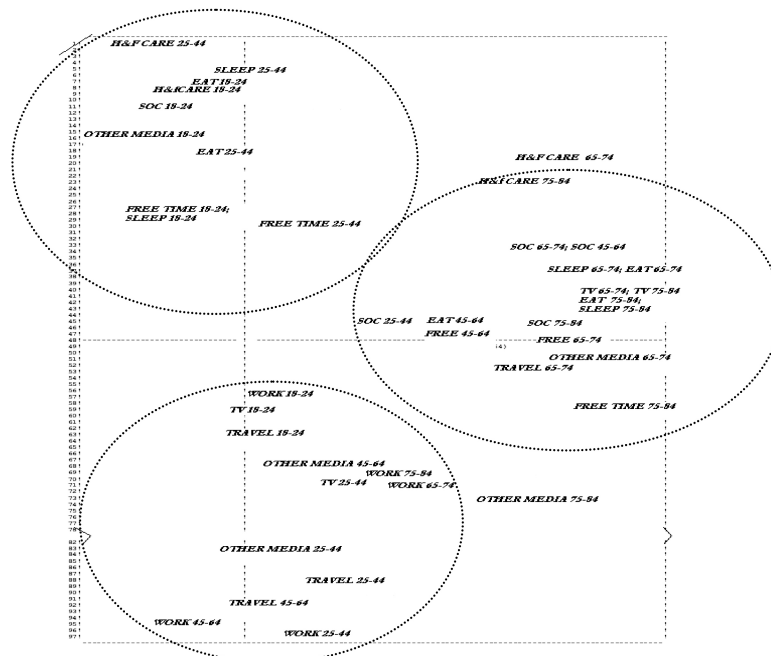

Figure 4 – Plot of mean-variables (activities) points across five age classes on the first compromise factorial plane.

presents a greater incidence of particular activities between the 9 groups of activity being considered. The clusters indicated schematically in Figure 5 are as follows: c*luster 1*: adult (18-24/25-44) at home: sleep; socialising; eating; other media; free time; *cluster 2*: old (65-74/75-84) relaxation-routine at home: eat, sleep, travel, TV; *cluster 3*: adult (18-24/25-44) out of home: travel; work; other , the day considered is a working day.

3.7 *Analysis of the trajectories: comparing the 22 categories of partner in respect of their time budgets through the five age classes*

In the analysis of the *trajectories* we wish to compare the 'trajectories' of the 22 partners with regard to their time budgets through the 5 age classes with a view to identifying the role of each category of partner with respect to the differences in the use of time in a working day. In particular the analysis of the trajectories permits the comparison *simultaneously* and *analytically* of the individuals (22 partners) and the variables (9 groups of primary activity including all daily activities) for the five age classes under consideration; that is *identifying* and *comparing* the 'paths' of each category of partner through the 5 age classes. To this end, it is possible to represent the trajectories in many ways: representing each s.u. with respect to the *factorial plains* obtained from the analysis of the intra-structure (par.3.6) or reporting the trajectories of the s.u. with respect to the single factorial axes. Here we have chosen this last mode with reference only to the first factorial axis explaining the 42.48% of the total variance. In table 6 the factorial scores are of the 22 types of partner through the 5 age classes. It is also possible to show the 22 trajectories indexed showing on the vertical axis *the factorial scores* referring to the first axis under consideration and on the horizontal the five age classes under consideration.

TABLE 6

Trajectories of the 22 categories of partners across the five age classes.
Factor scores on the first factorial axis (42,48% of the total variance)

Partners/Age classes	18-24	25-44	45-64	65-74	75-84
Male	0.0936	0.1546	0.1956	1.0745	1.1929
MNotEmploy	*	0.4975	0.4339	0.6389	0.8231
Memploy	0.0936	0.1405	-0.1607	0.7379	*
MLowEduc	*	0.2492	0.4106	1.0625	1.1494
MMiddleEduc	0.0936	0.0905	-0.0347	1.0919	1.3140
MHighEduc	*	0.1888	0.1256	1.1152	1.4180
MWithChild<18	0.0936	0.1561	-0.1527	*	*
MNoChild<18	0.1675	0.1485	0.501	*	*
MWithChild<05	0.0936	0.1429	-0.3478	*	*
MWithChild6-11	*	0.2146	0.0209	-1.2446	-0.8548
MWithChild12-18	*	0.0734	-0.1762	-1.2446	-0.8548
Female	-0.2325	-0.2025	0.2607	0.6421	0.8231
FNotEmploy	-0.2670	-0.1329	1.2403	0.9903	*
FEmploy	-0.1769	-0.0985	-0.8499	-1.2446	-0.8548
FLowEduc	*	-0.3785	0.2803	0.5953	0.8595
FMiddleEduc	-0.2967	-0.2232	0.1978	0.9494	0.6611
FHighEduc	-0.1825	-0.0961	0.3343	0.5866	-0.8548
FWithChild<18	-0.3480	-0.2597	-0.1268	*	*
FNoChild<18	-0.0455	0.1080	0.3860	0.6421	0.8231
FWithChild<05	-0.3480	-0.2991	-2.0525	*	*
FWithChild6-11	*	-0.1510	*	*	*
FWithChild12-18	*	-0.2072	*	*	*

Note: * = the phenomenon does not exist

Commenting briefly on the results of the trajectories obtained *Across five age classes*, it is possible to verify the change of position in time budgets of the same category of partners with respect to the others. The most remarkable differences in time-budget trajectories, on a working day, among 22 categories of partners *across 5 age classes* are the following: both male and female partners have similar (among the same gender) time-budgets in age class 25-44 years but in increasing the age classes, 45-64 and above all 65-74, large differences in time-budget among different categories of partners of the *same* gender become apparent. In particular it is possible to know the category of partner (table 6): for example male high educational level with respect to male with youngest child < 6-11 and 12-18 years old living at home devote less time to work, TV, travel. It is useful to remark that 3-way data analysis confirms the large differences of time use by gender in the couple *also when* the third criteria, chosen '*a priori*', is the partners' age classes.

4. SEQUENTIAL ANALYSIS OF TIME USE

4.1 *Meaning and aim of sequential analyses of time use*

Having examined the transversal analysis of time use through 3-way analysis, we will now refer to the sequential analysis of time use.

Sequential analyses or analysis of the hourly sequences is based on frequencies, pre-arranged 'time points' (intervals, parts of hours, episodes) into which the 24 hours are subdivided (of a working day or a holiday) of those who carry out a given *activity* or who find themselves at those times in given *places irrespective of the activities being carried out,* or who are, at those times, *with given persons still irrespective of the activities being carried out*.

Sequential analyses allow us to know *the daily collective rhythm*, the frequency by time points of the carrying out of the activity/activities or the use of places or of the types of people present and have particular importance in the analysis of the use of time for various reasons.

Knowing the hourly sequence of the activities with respect to the mean duration of the activities allows us to know the diversity of the different social groups in the carrying out of the activities: even if a given activity has the same mean duration for two different collectives, for example, male professional work and female professional work, it does not mean that said activity will be carried out in the same way on the day of survey. The hours when an activity is carried out recount the lives of the individuals insofar as they are members of the society that has its own rules, calendars and daily habits. Time is a social construct that reflects the rhythm of collective life. (Sorokin and Berger, 1939; Elias, 1986; Durkheim, 1991).

In particular on the basis of sequential analysis it is possible to c*ompare, synthesise, and, construct empirical models* of behaviour in the use of time both *specifically* (referring to a single activity or homogeneous group of activities) and *global* (referring to *all* the daily activities).

Analyses by time points can provide cognitive elements that are useful for the resolution of practical problems such as those inherent *to the urban environment and the use of the city*; problems connected to *ecology* and *development of sustainable consumption* such as knowledge of 'rush hours' and habits linked to particular social consumptions (water, electricity, etc.), the rhythm of the carrying out of activities such as eating, sleeping, performing motor activities in relation to problems linked to *health* and *lifestyle* (insomnia, anorexia-bulimia, presence of chronic and degenerative illnesses, etc.).

For the sake of brevity and by way of an example, we will limit ourselves here only to analysing the *global* daily rhythm in the carrying out of *all the activities* of a working day, through the global empirical models on the use of time, leaving a complete vision of the different types of exploratory multidimensional analysis of sequential data to other publications (Fraire, 2007, 2008; ISTAT, 2007, 2008).

4.2 *Empirical global models of time use: cumulative tables and graph on time use*

All the daily activities carried out[11] will be analysed with the frequencies with which they are carried out, pre-established time intervals, e.g. 144 intervals of 10 minutes each for different categories of population both working days and not. The choice of intervals of 5 or 10 minutes (or even less than 5 minutes, as was carried out in the International Comparative Inquiry on time budget carried out by UNESCO in 1966) is dictated by two motives: a) to obtain the real frequency of the activities, including those of a shorter duration; b) to have the greatest possible analyticity of the intervals to provide continuity to the form of the distribution as empirical models on time use. In this sense we speak of *global* empirical models of time use rather than *specific* empirical models, that refer instead to the frequency distribution by time points (intervals, episodes) for single activities. Such analyses require the tables of the cumulated relative percentage frequencies for the 144 time points and activity groups considered and the *cumulative graphs of time use*.

Table 7 shows an example of a data table, a contingency matrix, $N_{144;16}$ used choosing 144 time points, intervals of 10 minutes each, closed on the left and open on the right, in the 24 hours, e.g. 04:10 for 04:10 ⊢ 04:20; 04:20 for 04:20 ⊢ 04:30; up to 03:50 for 04:50 ⊢ 04:10 of the next day, and 16 primary activities including all the daily activities.

In order to determine time intervals ("time-points" or episodes) into which to split the 24 hours, the maximum analyticity allowed by Istat data was selected (in diaries, the 'minimum' time unit was ten minutes): therefore, 144 time intervals of ten minutes, each one starting from the interval 4:00 ⊢ 4:10 , in table 7 indicated with the "time-point" 4:10, 4:10 ⊢ 4:20, 4:20 and so on up to the last time interval of 3:50 ⊢ 4:00 of the day after.

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[11] In this application activities have been classified in 16 subgroups including all the daily activities carried out.

TABLE 7

Percentage of total population (or social sub-groups) engaged in all daily activities collapsed in 16 subgroups at fixed time-points for the 24 hours (weekdays, Saturday, Sunday) being at given – Contingency matrix $N_{144;16}$

Time-points	Other private activities	Mass-media	Reading	Social relation	Sports activities	Games and sports activities	Other leisure time activities	Partecipation in the public life	Family-care	Household activities and shopping	Education and training	Professional work	Comunication	Travel for other reason	Eating (regular meals)	Sleeping and personal care	Total
04:10	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.4	0.0	0.1	0.0	99.0	100.0
04:20	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.4	0.0	0.1	0.0	99.0	100.0
04:30	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.3	0.0	99.0	100.0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12:10	0.2	4.2	1.7	2.9	2.7	1.8	0.2	1.8	0.7	23.2	11.9	28.1	0.3	8.9	6.6	5.0	100.0
12:20	0.2	4.1	1.8	3.5	2.4	1.5	0.4	1.5	0.7	25.1	11.8	27.9	0.3	6.5	7.6	4.7	100.0
12:30	0.3	4.3	2.0	3.0	2.3	1.4	0.4	1.3	0.8	24.0	11.1	27.2	0.3	6.5	11.2	4.0	100.0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
16:50	0.2	6.0	2.0	8.4	6.2	4.5	0.6	2.9	2.8	13.7	6.5	22.8	0.3	9.4	1.9	11.9	100.0
17:00	0.2	6.0	2.0	9.2	6.5	4.2	0.8	2.9	2.6	13.0	6.7	22.7	0.3	9.8	1.6	11.6	100.0
17:10	0.1	6.8	1.8	9.4	7.4	4.1	0.7	2.5	2.6	13.1	5.6	20.2	0.3	13.6	2.2	9.5	100.0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
21:50	0.2	49.9	2.1	4.7	1.9	2.1	1.0	0.7	1.6	6.7	0.7	1.5	0.6	2.3	9.8	14.1	100.0
22:00	0.2	49.3	2.3	4.7	2.0	2.3	1.0	0.6	1.2	5.8	0.7	1.5	0.6	2.5	7.9	17.2	100.0
22:10	0.2	42.7	3.2	4.5	1.6	2.2	1.5	0.7	1.6	4.3	0.6	1.4	0.5	2.9	5.7	26.6	100.0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
03:50	0.1	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.4	0.1	98.6	100.0
04:00	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.4	0.1	98.7	100.0

Note that the order of the activities is conventional: generally the activity of sleeping is placed last in order to have, as we will see in the graphs that follow, this activity as a background for the cumulative graph on time use.

Starting from that, it is possible to construct *cumulative graphs of time use* that permit an *extraordinary condensation* of the huge quantity of information contained in the abovementioned tables and the possibility of being able to easily carry out the comparison.

By means of such analyses it is possible in fact to 'contextualise' each activity: with regard to the hours when they are carried out and therefore to its daily rhythm and with regard to the timetables and rhythms of all the others. The graphs in particular have in fact a triple reading that is described in the section below.[12]

4.3 *The daily rhythm of partners' activities in 2002-03 compared with the data from 1988-89*

In particular, referring to a working day for married or cohabiting partners belonging to mononuclear families and living in large urban conurbations, a comparison will be carried out between the data from the Istat survey, Time Use in Italy carried out in 1988-89 (previously employed for the multi-way analyses described in par. 3) and in 2002-03. With this aim, a subfile of partners was created, analogous to that of 1988-89 (section 3.2), starting from the Istat 2002-03 data regarding mononuclear families with no isolated members; living in districts of

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[12] Cumulative graphs have been obtained from TABLE 8 (not cumulative percentages) by Excel –MS_Office selecting graph– Area 3D 100% and including sleeping activity.

large urban conurbations (the same as in '88-89) + the outskirts of the metropolitan area[13].

Figure 5 shows *the cumulative graphs of time use* referring for brevity only to the total of the male and female partners, in a working day, on the basis of the 1988-89 and 2002-03 data.[14] Before commenting briefly on the data, we refer to the possible triple reading of the graph but it is to remark that for the possibility of being able to easily identify the activities the graph should to be in colours and here is not possible. We will limit ourselves here only to show an indicative example of the cumulative graphs in Figure 5 in which the activity names are listed in the same order for male and female and begin from the bottom to the top.

The *background* of the graph is the activity of sleeping, and generally (v. Fig. 5) we can note how both in the early hours of the morning (04:10 and following) as in the night-time hours (3:00 and following) it is practically 100% the frequency of those who are carrying out the activity of sleeping and no or almost no frequencies are marked for other activities.

Furthermore, the graph can be read three ways:

— a *horizontal reading* that allows both the frequency given by the width or narrowness of the band (each band has a colour that indicates a given primary activity) as well as its progress in 24 hours (form of distribution, modal hours etc.) to identify the rhythm of the activity, the time sequence in which it takes place in the day under consideration and for the category of population under consideration. It can also be noted that it is possible to identify the sequences of *all* the activities carried out and examine them *comparatively* for each time interval in the 24 hour.

— a *vertical reading* that allows us to know "at a given time of the day how many people are carrying out which activities" (distribution of cumulated frequencies between all the activities in a given interval). Since the frequencies are cumulative it is possible to know (by means of the difference between the extreme bottom of the frequency of the successive band and the extreme top of the preceding band) which is the frequency of a given activity in a given time band.

— the contemporary *horizontal and vertical* reading that allows the examination of the interdependence between the activities (e.g. some activities 'occupy' or 'restrict' the space for others) and while this is not an analysis of causality it is still possible to know in which way the collective under consideration tends to organize and 'systemise' its daily time.

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[13] Tables and graphs have been developed by Dr Elio Ascoli Marchetti - Codres (Cooperativa Documentazione Ricerca Economica Sociale) in Rome.

[14] The variables considered for mononuclear families were the following: *Day of survey*: weekday; Sunday. *Gender*: M;F ; *Average age of the couple*: E2035; E3650; Eol50. *Level of education*: IstEl (university degree, second-class degree, high-school degree - 4-5 years); IstMd (high-school degree 2-3 years; grammar school); IstBa (elementary school, reading and writing, illiterate). w*orking condition*: EnOc (both work); UnOc (only one works); NsOc (neither of them work). *cohabiting children*: SenFg (without cohabiting children); ConFg (with minor cohabiting children). *Age of the younger child*: Fg05 (children aged between 0 and 5); Fg611 (children aged between 6 and 11); Fg1218 (children aged between 12 and 18). Overall, 30 types for weekdays and 30 for holidays, also considering total M and F.
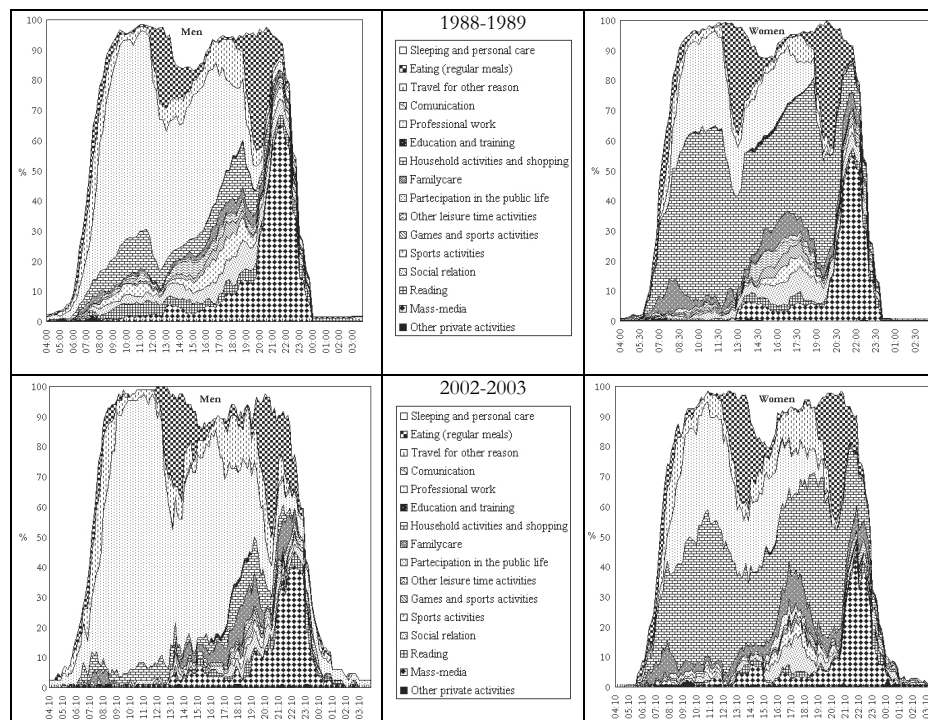
Figure 5 – Workdays of partners by gender. Years 1988-1989 2002-2003 (cumulated frequencies in percentage).

Commenting briefly on the results of the graphs the first thing to note is a general difference in the overall use of time between males and females, evident above all in the central part of the graph, which regards *professional* work and *domestic* activities: the latter, as we would expect, are performed much more by women than by men, while the opposite is true for professional work. The difference does not reduce in a consistent way from 1988 to 2002-03 (it can be seen that this is the same even considering the ulterior variables of specification of the partners described in the note, e.g. when both are professionally employed). Referring to the years '88-'89 and '02-'03 what has increased is *the 'complexity'* of the male and, above all, female day: in fact, for women the burden of domestic work and childcare does not decrease over the course of the 24 hours, but what increases in 2002-03 is the complexity of the working day, intended as the number of daily activities carried out; among these there are also those '*for oneself*' that belong in the realm of the personal. On the other hand we can note a generalised increase in nocturnal activity that in 1988-89 was limited only to male work, while in 2002-2003 they are varied and practised by the female population as well. The composition of these activities, though, is different between the two sexes. Another significant difference present for both sexes is the diminution, in 2002-2003, of the use of the mass media in the evening hours in favour of their gener-

alised use throughout the day, and this can be explained by a wider ownership of personal computers and internet access, extensively used today not only in the workplace for work purposes.

CONCLUDING OBSERVATIONS

The applications of the exploratory multidimensional data analysis examined show they adapt very well to the dimensions and complex structure of the data with a view to exploring, comparing and synthesising said data, of drawing from them, despite their mass and maintaining the wealth of the complexity of information they provide, typologies, structures, interesting relations, and of discovering facts from them using whatever procedure might serve the purpose. The only limits to such analyses are those imposed, other than by the statistical compatibility of each technique with the nature of the data, by the creativity of the researcher which is in turn linked to the knowledge of the phenomenon and the multidisciplinary approach that is indispensable for complex phenomena. In particular:

– from the *exploratory* point of view they allowed the selecting of categories of populations and variables with the aim of constructing typologies, highlighting diverse data structures, constructing empirical models of time use that will also be useful for any eventual successive confirmatory analysis;

– from the *comparative* point of view what is evident is the great capacity for analysing simultaneously numerous and complex cases (e.g., categories of population) and many variables (e.g.. in the analyses of time use, the number of activities examined can also be very high)

– from the point of view of the *synthesis* the heuristic characteristics of the interpretation of the results of the classifications and factorisations provided by EMDA, typologies and underlying dimensions adapt well to the fuzzy nature of human behaviour.

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SUMMARY

Statistical methods for exploratory multidimensional data analysis on time use

After a brief introduction on the different approaches between exploratory multidimensional data analysis (EMDA) and confirmatory multivariate data analysis (CMDA) the paper deals with EMDA and in particular multi-way methods suitable for comparing statistical studies when each of them has many variables observed on many cases as in time use data analysis. Then the paper focuses on the two main time-use analyses: transversal and sequential analysis using respectively 3-way data analysis and time-points cumulative frequencies tables and graphs. Application concerns differences in time use of categories of partners based on Istat – Time Use Surveys data 1988-89 and 2002-2003.