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Schedules as sequences: a new method to analyze the use of time based on collective rhythm with an application to the work arrangements of French dual-earner couples

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Abstract

This paper sets out a new method to analyze schedules with an application to the analysis of synchronization within dual-earner couples. The flaws of the traditional time-budget approach are brought to light: time is not a constant flux and disregarding the social dimension of time and the significance of scheduling dismantles a great part of the phenomenon analyzed. The method proposed is inspired by Optimal Matching techniques but also informed by sociological theory: it relies on information about the collective rhythm. This method is further applied to French dual-earner couples in 1985 and 1998 (enquêtes Emploi du Temps, Insee, France, N=2574): twelve work arrangements are uncovered. Six of them refer to double full time schedules days, and two to feminine partially worked days. A significant proportion (20%) of the spouses who both worked a full time schedule experiences a high degree of desynchronization (greater than 50%). A few of them are even found to be completely desynchronized. Women who worked partially the day observed are also concerned by off-scheduling: though the probability of being desynchronized is reduced, a significant number of women work while their spouses are not working. Desynchronization dramatically increased between 1985 and 1998: more spouses work more desynchronized days but desynchronization also expands in most of the days. The increase observed is particularly prominent for couples where women work partial schedules.

JEL-Codes: C61, J20, J22

Keywords: method, sequence, optimal matching analysis, collective rhythm, dual-earner couples, synchronization

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Introduction: the social nature of time and its consequences for the analysis of the use of time

The use of time has been mainly analyzed through time-budgets, *i.e.* in a way by identifying time with money[30]. The introduction of a recent document broaching methodological aspects of time-use analysis provides a fine example of this process (National Research Council 2000): "Although much is known about how American budget their financial resources, very little is known about how Americans budget their time resources". The implicit hypothesis of such a rationale is that time is money that time can be accounted for in the same manner than money: that we can add up time like we would do with any currency. But is this true? It would if time were the homogeneous flux used by physicists, mathematicians, or economists. But the flow of the day is not a succession of identical moments filled in by activities. This representation, conveyed by an analysis of the use of time focused on time-budgets, helped and is still helping to detect empirically macro social changes, like for instance those underlined by Jonathan Gershuny (2000). However, when individual behavior is at stake, the use of time cannot be restricted to the budget of time (Wilson, 1998).

Indeed, adding up hours is legitimate when a temporal accounting system is aimed at. An accounting system gives a very synthetic picture of the assets and liabilities of firms but does not explain how these firms managed to reach these particular balanced budgets. It is the same with time-budgets. Trying to get back to the individual decisions which have led to the observed budget is a most perilous task, much more than that performed by a financial analyst whose job is made easy by the availability of additional information such as the firm's biography, whereas for the time-budget analyst, this information is not only missing but would be in fact useless, given the size of the sample required by statistical procedures. Moreover, using time-budget data to grasp individual behavior is quite puzzling knowing that these data come from time-use surveys which provide a wealth of details. It amounts to simplify the data and try to recover this subsequent loss of detail by using complex statistical methods. It would be simpler and safer not to lose information in the first place. And in that case, the information is the decomposition of time-budgets into different parts of the day, the scheduling of activities, which is far from being random.

In this regard, sociologists have long evidenced the social nature of time. It does not only mean that time is socially structured but also that people do and when they do it depends on their expectations about what others do or are supposed to do. Durations amalgamate these crucial subtleties and are to be avoided if individual behavior is to be grasped. Instead of muddling incomparable moments, comparable moments should be gathered and separated from different moments, *i.e.* only a typology can address this issue with some relevance[31]. This article introduces a new method to measure the similarity of schedules, a method based on collective rhythm. This method is illustrated with an application to the analysis of the work arrangements of dual-earner couples. But first, in view of its prominence in the study of schedules, the collective dimension of time is briefly emphasized.

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[30] Money is used here because of the connotation of the word "budget", but the issue at stake is much more general: statistically speaking, how far can we legitimately compute and use averages of dissimilar objects?

[31] A typology also ensures that averages computed within each type have some consistency.

The social nature of time

As Émile Durkheim noticed (1925, p. 16), time is a social construction that reflects the rhythm of the collective life but also contributes in return to structure this collective rhythm by producing a stable environment. This quite simple statement conveys two essential ideas for the analysis of schedules. First and foremost, it means that scheduling is a crucial dimension of activities since time reflects the collective rhythm or in other words *time is socially differentiated* so that adding up hours may dismantle a great part of the social dimension of the phenomenon studied: time is not a constant flux, each hour, day, week, etc. is different from one another. But it also means that the collective rhythm is liable to influence the scheduling of activities: time's multiple embodiment into calendars and clocks helps individuals to orient and schedule their activities by fostering a stable environment propitious to anticipation and planning (every parent knows that by the end of the afternoon they should pick up kids from school).

First, the link between time and collective rhythm is to be demonstrated. Secondly, the most prominent institution in the collective rhythm, work, is reviewed.

Calendars and clocks: the social regulation of cosmic phenomenon

If calendars and most calendar divisions derive ultimately from cosmic recurrent events, their present regularity are the most tangible evidence of the long work to stabilize them. Indeed, if the day is determined by the Earth's rotation on its axis, if the month is approximately linked with the phases of the moon, and if the year is connected with the Earth's revolution around the sun, these correspondences are actually quite loose in comparison with the accuracy of our calendar system (Elias, 1992). It was not so easy to work out a solution to the problem of the varying number of days in a year and this solution, the leap year, is now used with no understanding either of its signification or of its origin despite the total predictability it promotes. But this regularization is not the only social regulation of cosmic phenomenon.

In this light, the week represents one of the most achieved parts of this social regulation (Sorokin and Merton 1943, Zerubavel 1985). Indeed, the week is not rooted in natural recurrent events like the other calendar elements but, on the contrary, is a pure social construction to improve the coordination and the synchronization of collective activities (Sorokin and Merton 1943). Indeed, there is no natural phenomenon between the month and the day to break the continuous flow of days. Hence the necessity of a repetitive short sequence of days to organize daily life, to make daily social coordination easier: the week makes the month discrete hence manageable.

Furthermore, the week is structured by the recurrence of two days, the weekend days, during which the majority of people do not engage in supervised professional activities. But the difference between weekdays and weekends is not limited to work: the week is a cycle completing the other natural cycles; this system creates a regularity which enables expectations and transfers of activities according to these expectations. Thus, the week strengthens the stability of daily life and as a result helps people to organize their life.

Consequently, clocks and calendars are direct evidence of the link between time and the collective rhythm. They are the historical product of the gradual efforts of individuals to coordinate their activities. But it also means that individual schedules observed on a particular day incorporate individuals' expectations about what was to happen that day and the days following. The expectations concerned are not only those of the individuals but also the expectations of those who interact with them.

Therefore, now that the connection between time and the collective rhythm has been highlighted, let us clarify what encompass the concept of collective rhythm. The collective rhythm is actually made up of various clocks, each reflecting a certain aspect of the collective life, embodied into institutions (Sorokin and Merton 1937): the opening hours of administrations, shops, restaurants, as well as labor legislation, familial policies, etc., foster continuously a societal temporal space. By enabling social synchronization, these societal clocks, in turn, constitute the foundations of social interactions. Work is the most important clock and, since it is linked with the issue of synchronicity within dual-earners couples, is now reviewed.

The work clock

If time have its origin in religion, through the alternation of the sacred and the profane (Durkheim 1925), the division of work progressively increased the complexity of the interdependences between individuals hence required still more accurate and homogeneous means of coordination. For instance, Eviatar Zerubavel (1982) showed how railroad development in the US introduced the necessity of a time-zone system in order to improve social coordination. This case evidences how economic growth is able to directly mold the time system. But the economy also effects temporality on more daily and local grounds through firms' business hours. In this regard, the traditional day/night alternation functioning as the consumption/work metronome is now even challenged by the 24-hour economy. Indeed, this phenomenon seems quite developed in the US since 20% of men and 12% of women who work and live in a couple have non-standard work schedules (Presser 1987). This phenomenon is much more limited in France on account of the more restrictive labor legislation. Night shifts are highly penalized and were still forbidden in certain industries to women only a few years ago.

Consequently, each type of industry, service or even each firm is liable to produce its own clock. Nonetheless, according to their occupation and their social position, work schedules are likely to vary to a large extent: work schedules space is likely to be connected with the position of workers in the social space.

In particular, Alain Chenu (2002) evidenced that the probability of working at each moment of the day depends on the position of the individuals on the social ladder. It means that the amount of cultural and economical capital owned determine to a certain extent the kind of daily life people have. Although the industry is also likely to introduce some distortion into this system, the occupation is nonetheless likely to be the main determinant of the possible sets of schedules. Indeed, if we consider a railroad company then a night shift is not uncommon among conductors but is pretty much inconceivable among secretaries, and to a lesser extent among executives, although employed in the same company. Pierre Bourdieu (1979, p. 535) underlined the temporal dimension inherent to the social space.

Each position in the social space corresponds to a certain set of work schedules probabilities. This issue has been recently addressed by Jonathan Gershuny (2000). His main idea can be summarized by the motto "leisure is work": extending Becker's famous theory of the allocation of time (1965), Gershuny points to an obvious fact rich in consequences, namely that consuming is time consuming. Even if Gershuny is drawing conclusions in terms of education policy and social stratification, a corollary of service consumption becoming more and more prominent in economic growth is that economic growth requires more and more desynchronization between certain social classes.

But the bottom line remains that individuals' daily schedules do not only give an account of individual lives but also of their lives as members of a particular family and society with a particular set of cultural and economical capitals. Consequently, the analysis of daily activities people engage in must be temporally grounded. For instance, two individuals can work the same amount of time, but one can work night shifts and the other daily fixed schedules. If these situations are mixed up then it is no wonder that it is so difficult to get good R^2 from regression analysis using time-use data. Adding-up hours dismantles the phenomenon studied: it amounts to neutralize all these differences to obtain a mean result that in fact means nothing (Halbwachs 1923, p 301). This is not to say that the analysis of daily schedules is vain but that new methods are required to extract all the relevant information contained in time-use diaries. But this is not the only issue at stake in studying the work arrangements of dual-earner couples given that the phenomenon studied is two-dimensional.

Synchronicity within dual-earner couples

Families are at the junction of the different component of the collective rhythm: each family member imposes on the family the various clocks he depends upon. This is not only valid for adults but also for children who bring into their family the temporality of schools and other extracurricular institutions.

But one of the most important change of the last fifty years is the transition from single to double breadwinners: the access of women to the labor market transforms drastically the nature of the daily family life since it complicates the temporal equation of families by doubling the economic and social classes clock constraints and engendering the issue of work synchronicity.

The issue of synchronicity

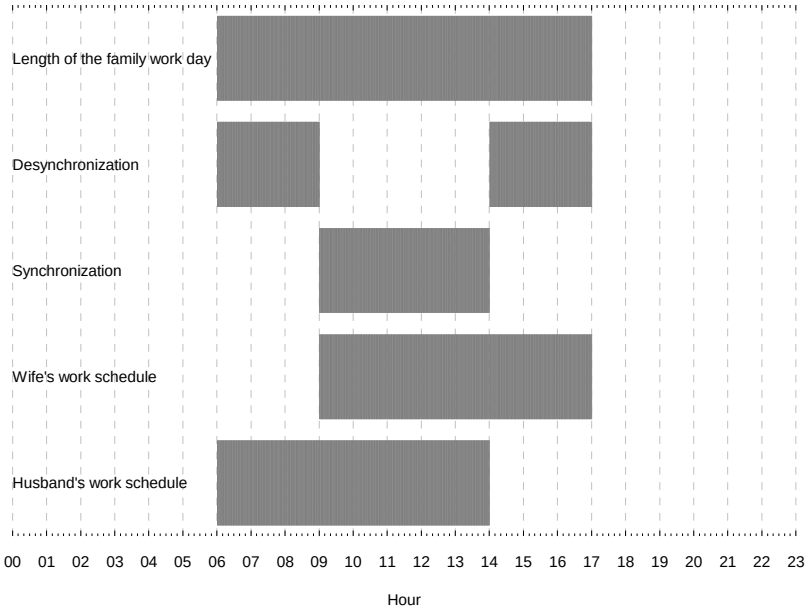
Indeed, when one spouse is engaged in paid work, family is facing only her economic and socio-professional constraints, the other spouse having the ability to adjust her schedule to her spouse's. Within dual-earner families, work constraints are doubled and work schedules might not match: desynchronization or off-scheduling, *i.e.* non-overlapped work schedules, is likely to appear.

For instance, if a husband works from 6 AM to 2 PM and his wife from 9 AM to 5 PM, then the two spouses have an eleven hours long family workday among which five hours of work are in common (synchronised work), hence desynchronized work amount to six hours (see figure 1). Here desynchronization is equally shared by spouses, each one works three hours not worked by the other, a rare case occurring when both spouses have the same work time (8 hours in the example). Synchronization and desynchronization can be expressed in relative terms, using the length of family workday as the unit of reference: relative synchronization amounts to 45% (5 hours out of 11) and the relative desynchronization due to the husband (only the husband works, or man relative desynchronization) as well as the one due to the wife (only the wife works or woman relative desynchronization) both reach 27%.

If spouses have different work time, for instance if an husband works from 8 AM to 8 PM, a 12 hour work day, and his wife works from 10 AM to 6 PM, then the length of their family work day coincide with the work day of the husband and reaches 12 hours (see figure 2) and the synchronized work overlaps exactly the work day of the wife. Desynchronization, which amounts to 4 hours, is here purely structural: although desynchronization is real, it echoes differences in the work time of spouses but not differences in the scheduling. If we use the midpoint of a work schedule as an indicator of its center of gravity, then we see that the midpoint of both spouses'

work schedule coincide (2 PM). Translated in relative terms, synchronization reaches 67%, relative desynchronization due to the husband 32% and relative synchronization due to the wife 0%. Hence, when spouses have different work time and that this difference explains a part of the desynchronization then non-structural desynchronization can be measured by the desynchronization due to the spouse whose work time is the lowest.

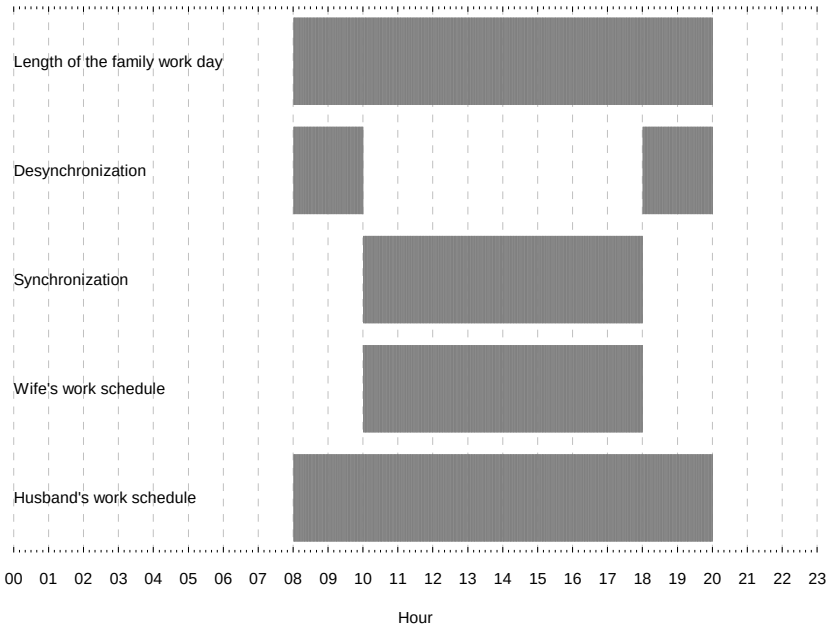
Figure 1 Example 1 of desynchronized work schedules



Both spouses have the same work time but different schedules: desynchronization is equally shared by spouses (each spouse works three hours not worked by the other).

Desynchronization is a quite recent issue, addressed so far only by a few analysts. Harriet B. Presser evidenced that desynchronization improved men's participation to childcare and household chores (1986, 1988, 1989, 1994). Steven L. Nock and Paul W. Kingston addressed this issue in an article dedicated to the problem of measuring dual-earners work day (Nock and Kingston 1984): using three measures (length of the family work day, total family work time and off-scheduling), they evidenced the variety of the dual-earner work day. In another paper (Kingston and Nock 1985), they illustrate the consequences of the family workday on the quality of family life and marital adjustment. They further evidenced that off-scheduling reduces significantly spouses' time together (Kingston and Nock 1987) but increases fathers' time with children (Nock and Kingston 1988). Daniel S. Hamermesh (2002) tested the significance of couples' synchronicity by comparing synchronicity resulting from independent work schedules with the actual synchronicity. The significance of the result is further interpreted as evidence supporting his hypothesis of spouses' search for being together. In the same vein, Alain Chenu and John P. Robinson (2002) proposed an index of desynchronization measuring the difference between an abstract situation of independent schedules and the actual schedules.

Figure 2 Example 2 of desynchronized work schedules



Spouses have different work time but otherwise quite synchronized schedules: desynchronization is structural.

Reintegrating synchronization into its daily substrate

Except Presser (1987) who did not measure off-scheduling but rather used an indicator of discordant work schedules[32], all these authors have used a single number to summarize desynchronization. At best, structural off-scheduling[33] is noticed, but on account of the reduction of this phenomenon to indexes, it remains quite impossible to disentangle it from pure off-scheduling. Chenu and Robinson (2002) tried to decompose their index into a gross and a net index using a measure of structural dissimilarity between work schedules. But this structural dissimilarity index only measures the duration of incompressible off-scheduling given that the rest of the spouses work schedules are perfectly synchronized. From the moment that this condition is not fulfilled, this measure becomes useless because it arbitrarily reduces the desynchronization observed for couples that are not perfectly synchronized anyway. For instance, for a couple where the husband worked a night shift of nine hours and the wife worked in an office during the day for seven hours the real structural desynchronization is nil but the Chenu and Robinson's (2002) structural desynchronization index adds up to two hours, the difference between the spouses work durations. Consequently, the off-scheduling issue needs to be put back in its daily context and in relation to spouses work commitment if it is to be understood.

Off-scheduling appears to be a major implication of a double work commitment and as a result is to be considered in this analysis. But a single index is unable to catch all the relevant dimensions of synchronization. The accounting approach of the use of time must be given up in favor of a

[32] She opposed day shifts to non-day fixed or non-fixed shifts.

[33] When the lack of synchronicity between two schedules is imputed to the difference of work time (when the two work sequences do not have the same length), the schedules being in other respects synchronized, then off-scheduling is purely structural, indicating a difference of work time not a difference of scheduling.

process one: *schedules must be apprehended as sequences, processes* and not as time-budgets. Consequently, the schematic description of the family work day must integrate in the most synthetic way and for each time slot what combination of work is observed. The most basic set of combinations is fourfold:

No spouse is working;

Only the husband is working;

Only the wife is working;

Both spouses are working.

It amounts to represent a dual-earner couple workday as a one-dimensional temporal process evolving in a four-state discrete space. Although this synthetic representation is focused on synchronicity it does not solve the issue of the temporal contextualization. Nonetheless, the necessity of taking into account the timing of activities is once more underlined and appears crucial both from a theoretical and a practical points of view and pleas for a tailor-made method.

Method and data

What we need is a method that respects both the order of the events and the particularity of every point in time they appear: schedules must be conceptualized as sequences. In addition, we know that every moment of daily life is liable to incorporate expectations about the future: the present does not only depend on the past but depends also on the future. This is a crucial point because this is a direct violation of a fundamental hypothesis of event-history models. Thus, the classical statistical methods to analyze stochastic processes cannot be used.

Andrew Abbott imported into sociology a new class of methods from biology called Optimal Matching Analysis (1986, 1990, 1995, 2000). This method can be used to compare sequences as a whole and, since it does not rely on statistical hypotheses, seems particularly interesting for the analysis of schedules as sequences. Actually, Optimal Matching algorithms are just a way to transform sequences into distances between individuals which can be clustered in order to uncover patterns: therefore, the end product of OMA is merely descriptive. OMA has been adopted by geography and transportation students and adapted in order to suit the dynamic and multidimensional requirements of urban and transport analyses (see for instance Joh et al. 2001a, 2001b). This burgeoning method is further briefly introduced and improved[34] upon to suit the theoretical requirements of this study.

Comparing schedules and preserving temporality

Optimal Matching Analysis comes from molecular biology and was aimed at the decryption of DNA (Sankoff and Kruskal 1983, Durbin et al. 1998). This technique was introduced into sociology by Andrew Abbott (1986). This method is basically an algorithm that produces a distance matrix out of a set of sequences. Thus, OMA is just a particular way to work out dissimilarities between individuals. This means that other procedures, like clustering or multidimensional scaling, are not only required to complementing the analysis, but also to access and assess the distances. Furthermore, it calls for attention to the relevance of the method to the

[34] This is not exactly an improvement since a new algorithm is introduced; however, it can be seen as an adaptation of OMA to the analysis of the use of time.

problem studied. Consequently, after a brief presentation, the meaning of OMA for the comparison of schedules is investigated and its specificities evidenced.

OMA in a nutshell

OMA is a way to measure the degree of dissimilarity between two sequences, i.e. two sets of ordered events. In OMA, the dissimilarity is the cost required to make identical the two sequences with the help of three basic operations: *in*sertion, *del*etion (*indel* operations) and substitution. Each operation is associated with a cost and the dissimilarity produced by OMA is the minimum total cost required to match the two sequences[35]. Consequently, choosing the cost parameters represents the crucial point of this technique.

For example, let us consider two sequences, X and Y, of a space with only two states, A and B (see Table 1).

Table 1 Two simple sequences

X:	A	A	A	A	B
Y:	A	B	B	B	

These sequences may have different lengths, even though in the case of the spouses' work schedules, all the sequences have equal length. To transform the sequence X into the sequence Y, it is possible to delete the first three As and to add two Bs, operations represented by the empty set operator (Ø). When an empty set is on the first line then it means that the element on the second line is inserted and when an empty set is on the second line, it means that the element in the first line is deleted (see Table 2).

Table 2 Transformation of the sequence X into Y with the help of three deletions and two insertions

X:	A	A	A	A	B	Ø	Ø
Y:	Ø	Ø	Ø	A	B	B	B

Obviously, this is not the only solution to match the two sequences. This can be done with three substitutions and one deletion (see Table 3).

Table 3 Transformation of the sequence Y into X with three substitutions and one insertion

X:	A	B	B	B	B
Y:	A	B	B	B	Ø

If a cost is associated with each operation then it is possible to determine the cost of each matching as the sum of the weighted costs. Eventually, the dissimilarity is the minimum cost to achieve sequence matching.

Traditionally, each indel operation costs one unit. The choice of the substitution cost depends on the interpretation of replacing a state by another one. If the transitions do not have a meaning, the substitution cost is usually set to two units (Abbott 2000). A data-based substitution cost system can also be derived from the frequencies of the transitions between all states which are used as measures of proximity between these states: thus, substitutions between two close states would cost less than between two states which are far away in terms of frequencies. This solution

[35] This distance is actually the Levenshtein distance cite, see Sankoff and Kruskal, *op. cit*.

amounts to use the diachronic closeness between states to build a synchronic proximity matrix between states and to use it to assess the diachronic proximity of individuals (Abbott 1990). In conclusion, the costs system is to be carefully chosen and adapted to the issue analyzed.

OMA and time-use analysis

To choose the best cost system, we must keep in mind that the dates of the events are of paramount importance in the study of schedules. The cost system must be able to discriminate between two sequences which are quite similar from the point of view of the ordering of states but moved forward or put back one hour, because this kind of shift is crucial in this analysis. The indel operations tend to separate events from their date of occurrence since each indel operation has all the earmarks of inserting or deleting time, thereby warping the temporal structure. Consequently, these operations should be rarely, if at all, used, especially when an accurate view of activity scheduling is aimed at. But if the substitution costs are too high then this kind of operation is never to be used, that is why Abbott (1990) suggests choosing an indel cost at least equal to the highest substitution cost increased by the difference between the two highest substitution costs. This is an indirect way to penalize the use of the insertion-deletion operations. For example, let us consider two sequences of identical length, X and Y, of a three-state space whose main differences lie in their temporal shift (see Table 4).

Table 4 Two shifted sequences

X:	A	A	A	A	B	B	B	B
Y:	C	C	A	A	A	A	B	B

With a traditional cost system, the optimal matching (two insertions of C and two deletions of B) is associated with a cost of four units. If only substitution operations are used then the total cost is $2 \times 4 = 8$. Therefore indel costs smaller than substitution costs leads to the vanishing of the temporal shifts between sequences.

Consequently, Andrew Abbott's recommendation is to minimize the use of indel operations in favor of substitutions. As a matter of fact, when the main goal is not to detect patterns of consecutive events then the indel operations are useless. But if only substitution operations are used[36] then this is no more an optimal matching method but simply a matching procedure or a sequence comparison.

Using collective rhythm to compare individual schedules

Therefore, the comparison of the daily activities requires a new algorithm to work out distances from sequences. The algorithm proposed here is informed both by OMA and theory. Sociological theory tells us that calendar and other time concepts both reveal the rhythm of collective activity and ensure its regularity (Durkheim 1925, p. 16): it means that the different moments of the day are different because of the social activity, because what people do varies with time owing to their expectations on what other people do. In the example of the French dual-earners couple work day, it is the economic or the couple work rhythm, which is at stake and which, is to be uncovered. A collective rhythm can be compared with an ocean with different streams: uncovering a collective rhythm means revealing all its streams. In the case of the family work

[36] It is actually equivalent to use systematically the upper bound of the Levenstein distance which corresponds to the case where the best transformation is only composed of substitution operations with sequences of identical length (increased by as many insertions when one sequence is longer).

day, streams link the four different states with one another. If, for every point in time, the relative strength of the different streams is gauged, then it becomes possible to determine whether two couples are drifting together or apart, are close or not. In statistical terms, we need to derive substitution costs from the observed transitions between states. But the usual solution, which relies on a single transition matrix, is not enough since these general transitions hide temporal variations that are the substance of time. Consequently, as many transition matrices as time slots[37] will be used to compute the proximity between states at every point in time.

This solution is not only appealing from a theoretical point of view; it also gives an endogenous answer to the problem of the distance between activities at certain points in time. Indeed, even if we know that night-shifts are quite uncommon in France it is rather impossible to determine the distance between working or not for each moment of the night, and it is definitely impossible to derive distance matrices from theory when it is the couple and not an individual work schedule that is at stake. Thus substitution costs vary with the time and the degree of scarcity of the transition between the states for the particular time considered.

In mathematical terms, the substitution cost between the states *i* and *j* at time *t*, $d_t(i, j)$[38], is thus defined as:

If $t \notin \{1, T\}$, then :

$$d_t(i, j) = \begin{cases} 4 - \left[p_{t,t+1}(i, j) + p_{t,t+1}(j, i) + p_{t-1,t}(i, j) + p_{t-1,t}(j, i)\right] & \text{if } i \neq j \\ 0 & \text{otherwise} \end{cases}$$

If $t = 1$, then :

$$d_1(i, j) = \begin{cases} 4 - 2\left[p_{1,2}(i, j) + p_{1,2}(j, i)\right] & \text{if } i \neq j \\ 0 & \text{otherwise} \end{cases}$$

If $t = T$, then :

$$d_T(i, j) = \begin{cases} 4 - 2\left[p_{T-1,T}(i, j) + p_{T-1,T}(j, i)\right] & \text{if } i \neq j \\ 0 & \text{otherwise} \end{cases}$$

With $p_{t,t+1}(i, j)$ as the empirical probability[39] to reach the state *j* at time *t+1* given that the previous state was *i*.

Therefore, the rarer the transition shifts between two states (the weaker the stream) in a single time slot, both before and after, the higher the distance between these states at that time. For instance, since the transition between the states "no spouse works" and "only the husband work" at 1 AM is uncommon, the distance between a couple with a night shift and a couple with a day shift will be high. But since such a transition is quite common around 9 AM, couples with standard work schedules will be quite close. To put it in a nutshell, if we want to estimate the

[37] If there are *n* time slots then only *n–1* transitions matrices between two adjacent dates exist.

[38] This measure of dissimilarity fulfills only one of the three axioms required to be a distance hence cannot be legitimately called distance.

[39] The empirical probabilities $p_{t,t+1}(i, j)$ and $p_{t,t+1}(j, i)$ are hence not equal in theory.

proximity between two individuals at a certain time, we look at the proportion of the sample which has transited between the two states considered between[40] *t–1* and *t* and between *t* and *t+1*: if this proportion is high then it means that a lot of people "hesitate" between the two states thus that those states are close. As a consequence, the distance at every moment between two individuals depends on what the entire population has done at the last stage and is about to do in the next one, which is a way to have both a dynamic and a relative definition of which behavior is common and uncommon.

Although the sequence comparison algorithm proposed here is inspired by Optimal Matching techniques, it avoids some of its pitfalls by removing the indel cost issue, and, since it is no longer an optimization procedure, the result is not anymore the product of hidden trade-offs. Nonetheless, for all that method is theoretically appealing, it should also be assessed on the ground of its results. After a brief presentation of the French time-use surveys, this comparison method is applied to the 1985-86 and 1998-99 investigations.

The French time-use surveys

France has a quite long tradition of investigating the use of time after its participation to the seminal international study by Alexander Szalai (1972). The two last French time-use surveys carried out in 1985-86 and 1998-99 by the French institute of statistics (Insee) are used to investigate the dual-earner couples work schedules.

The number of persons who responded to all the questions is 16,155 in 1985-86 and 15,441 in 1998-99. Both surveys used leave-behind diaries but with different time slots. The 1985-86 survey has 5 minutes slots while the 1998-99 investigation records activities every 10 minutes. People living in collective accommodations such as rest houses, hospitals, barracks, etc., are excluded from the sample since only personal housing is sampled. People on vacations are equally not interviewed. Since this study is about dual-earner couples, these biases are not serious.

Given the scarcity of homosexual couples[41], only heterosexual dual-earner couples who worked[42] at least 10 minutes the day they filled in the diary will be considered, whatever the actual work duration or the day of the week.

[40] Rather than choosing the (t–1,t) transition matrix more than the (t,t+1), it seemed more interesting to use both in order to lightly smooth the trends.

[41] There are no homosexual couples in the 1985-86 survey and approximately 20 in 1998-99.

[42] The definition of work used here encompasses having a meal with colleagues at work or work-related travels. The aim is not to measure accurately working time but the amount of time dedicated to work in general: when you have a meal with colleagues, you are not available to do something else.

Table 5 Subsamples size

Subsample	1985-86	1998-99
Childless dual-earner couples	425	330
Dual-earner parents	1,038	781
Total	1,463	1,111
Grand total	2,574	

Source: French time use surveys, Insee, 1985-86 and 1998-99.

Comparability issue

The difference of the sample sizes (see Table 5) is due to the sampling procedure. Once a sample of accommodations is constituted, some of their occupants are interviewed. In 1985, one occupants among those older than 15 was selected in random order using the Kish method; if this person was living maritally, her spouse was also interviewed. In 1998, every occupant older than 15 was systematically interviewed.

But the differences between the two surveys exceed the sample sizes since the time slot of the diary has doubled in 1998 to reach 10 minutes. The consequences of this methodological difference are quite hard to grasp but are likely to sway only small duration's activities. Given that work is generally unlikely to be classified in that category, this methodological difference seems harmless for this study.

Calculation details

The sequence comparison algorithm proposed in the previous section is applied to the pooled 1985 and 1998 French surveys. Given the relative small size of each sample, pooling is appealing: it is likely to distort slightly the distances between couples[43] but in return, it enables insightful temporal comparisons.

The graphical comparison of the difference of the distance between states at every point in time does not indicate drastic changes between 1985 and 1998 consequently the analysis will be performed on the two pooled samples.

The distance between couples produced by the sequence comparison algorithm[44] is then used as input for a clustering algorithm. The algorithm used is the flexible-beta method proposed by Lance and Williams (1967) and reviewed by Milligan (1989). This clustering algorithm is not only very flexible owing to its smoothing parameter but is also able to produce clusters of unequal size.

[43] Given that distances are directly related to the transition matrices, it is equivalent to ask if we can add the weighted transition matrices time slot by time slot and compare work schedules of couples as if they were coming from the same sample. If we omit the differences in the sampling techniques used, pooling seems acceptable if the transition matrices are roughly equivalent time slot by time slot. But if this is not the case, then pooling will distort the distances which are based on the degree of scarcity of transitions: distances will artificially increase for one sample and decrease for the other. For instance, if night shifts or non standard schedules are differently represented in the two samples then it will affect systematically the distances. In brief, such a comparison is legitimate only if the structure of the transitions between states is roughly the same at every point in time for both samples.

[44] The algorithm has been implemented in the SAS software as a macro using the IML module. The code is available upon request; see the address of the author.

Joel H. Levine (2000) recently criticized OMA applications in the social science field for the lack of evaluation of their validity. Levine is right, but the lack of evaluation seems a rather more general issue in the social sciences where statistical methods are too often used as black boxes. The difficulty to assess the quality of OMA-like methods stems from the nature of the output obtained: after all, OM methods are just a rule to compute distances between individual in terms of a particular set of variables. Since another method is required to access and assess the output, the question has no answer. But the quality of the clusters will be here investigated, mainly with the help of graphical tools.

Results

The relevance of the work days of the French dual-earner couples uncovered is part of the assessment of the quality of the method proposed to compare schedules. Of course, given the limited number of states considered in the analysis of the family work day, uncovered patterns are likely to be quite familiar. But this familiarity would be a guarantee of quality. Moreover, besides the issue of originality, this is the first time that desynchronization is really adequately measured among dual-earner couples, as well as its temporal evolution. Finally, the quality issue is addressed using box-plots on the underlying dimensions of the family work day.

The twelve work days of the French families

Twelve configurations of family work day are uncovered: it means that if we pick at random one work day of any French dual-earner couples, it should be one of these days. The visual inspection[45] of these days reveals their high degree of homogeneity (see figure 4 below).

Table 6 Taxonomy of the French families work days

Type of family work day	Days	Main characteristic	Main difference
Double full-time schedules	1-6	Both spouses worked a full-time schedule	From almost totally synchronized to almost totally desynchronized
Single full-time schedule	7-8	Only husbands worked a full-time schedule	Morning vs. afternoon feminine part-time schedule
Atypical workers schedules	9-12	Low work time with nonstandard schedules	Distributions of work

Source: French time use surveys, Insee, 1985-86 and 1998-99.

Three types of days can be brought to light (see Table 6). Days 1 to 6 are double full-time schedules days, days 7 and 8 are partially worked by the wife, and the other days gather low work duration for at least one spouse, sometimes combined with non-standard work schedules.

Days 1 to 6 are not systematically associated with double full-time couples as well as days 7 and 8 are not systematically combined with part-time wives. Of course, the chances to work a full-time shift are higher (4.7 in 1985 and 2.5 in 1998) when women hold a full-time job, but 71% of women who held a part-time job worked a full-time schedule in 1998, and 14% of the full-time employed women in 1998 worked a part-time schedule (see Table 7) the day observed.

[45] The best visual representation of this kind of cluster is a graphic representing for each time slot the percentage of couples belonging to the four different states.

Consequently, the expression "full-time schedule" seems more precise than "full-time", emphasizing that what is observed is a schedule of a particular day and not the work time specified in the labor contract.

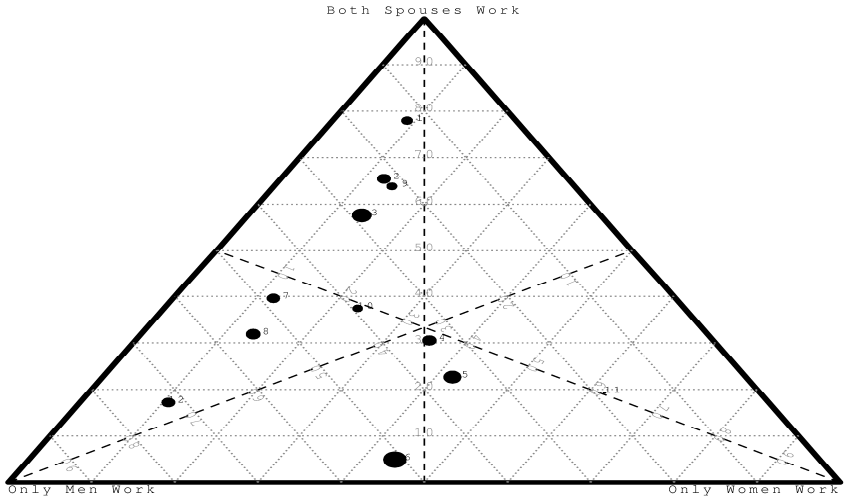
Table 7 Labor contract and schedule observed for women living in dual-earner couples

Women's labor contract		Full-time schedule (days 1-6)	Part-time schedule (days 7 and 8)	Total
1985	Full-time job	89%	11%	100%
	Part-time job	64%	36%	100%
1998	Full-time job	86%	14%	100%
	Part-time job	71%	29%	100%

Source: French time use surveys, Insee, 1985-86 and 1998-99.

The first main result is that 70% of the days worked by dual-earner couples are double full-time schedules, 13% are partially worked by the wife and 17% belong to another work pattern. Besides differences in the beginnings and endings of work, the dissimilarities of the days within those types lie in the degree of synchronicity of work schedules and the source of the desynchronization observed, *i.e.* whether the desynchronization is equally shared by spouses or also reflects asymmetrical work duration. These three main differences, related to the length of the family workday can be represented in a ternary plot (see Figure 3). The vertical line coming from the top of the triangle materializes the different degrees of synchronization (the higher the couples are located on this line, the more synchronized they are) as well as the equality of the contribution of spouses to the desynchronization observed (hence the difference of their work time).

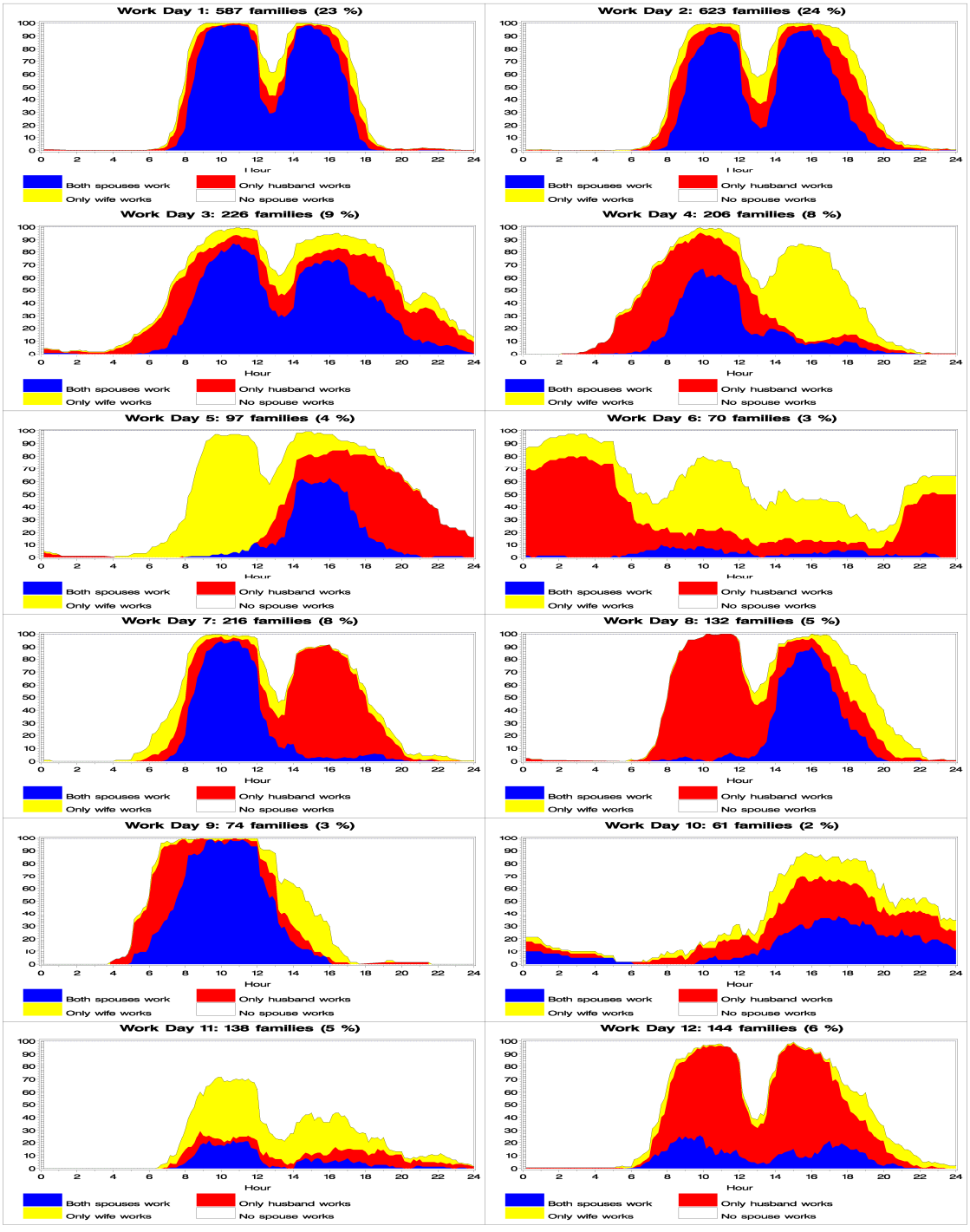
Figure 3 The French families work day



The French families work day according to their mean synchronization and desynchronization relative to the mean length of families work days (which length is proportional to the thickness of the dots). Population: 1985-86 and 1998-99 dual-earner couples who worked at least 10 minutes.

Source: French Time Use surveys, Insee, 1985-86 and 1998-99

Figure 4 The twelve work days of the French families



Population: 1985-86 and 1998-99 dual-earner couples who worked at least 10 minutes.

Source: French time use surveys, Insee, 1985-86 and 1998-99.

The first six days cluster around this axis: days one to three are characterized by a quite high degree of synchronicity, men contributing slightly more to desynchronization than women; days four to six exhibit more desynchronization than synchronization[46], men and women contributing quite equally to this phenomenon. Eventually, standard double full-time schedules days (i.e. days 1 to 3) account for 56% of the dual-earner work days and for 80% of the sole double full-time schedules. It means that almost half of the dual-earner couples experience a different work organization than a double standard work schedule and that even if only double full-time schedules couples are considered, the figure is still sizeable (20%). Consequently, disregarding the distribution of work over the day is likely to flaw the analysis of dual-earner couples' work. It is worth noting that the lower the relative synchronicity, the higher the length of the family work day, hence the higher the absolute desynchronization. This result is confirmed if we inspect the work days absolute desynchronization (see Table 8): one out of three double full-time schedules couples experience desynchronization greater than five hours, about 3% of them living completely desynchronized (mean desynchronization towers over 13 hours). Serious desynchronization is thus affecting a great part of the French dual-earner couples despite quite restrictive labor regulation.

Logically, work days with feminine part-time schedules clustered in the left part of the triangle, illustrating the difference between the work lengths of spouses. However, if we consider again the representation of these two days (see Figure 4 above), we can see that the desynchronization observed is not purely structural since a significant amount of those women work earlier (day 7) or later (day 8) than their spouses, which is expressed by not being stuck to the triangle's upper left side: a substantial amount of partial work involve non-standard schedules. Even when one spouse is not working a full-time schedule, a lack of synchronization is still perceptible: absolute desynchronization due to women adds up to more than one hour. The concept of structural desynchronization is definitely difficult to implement without a global perspective on the work schedules, even in the textbook case of part-time schedules.

Concerning the other types of family work day, the proximity between days 9 and 2 noteworthily evidences that even if the clusters obtained can be described using mean durations, they cannot be subsumed to these simple figures. If proximities had been based on these three dimensions, those days would have been merged despite their tremendous differences (see Figure 4): work starts between eight and nine AM and stops between six and eight PM in work day two characterized furthermore by a bimodality indicating a midday break; on the other hand, in work day 9, work starts between four and six AM and progressively ends from twelve to five PM with no midday break. But in any event, the crucial point remains that time is not the constant flux symbolized by the chronograph: the tool should not be confused with the process whose true nature is social (Elias, 1992). Days 10 and 11 exhibit both a low spousal work time and quite non-standard schedules with prominent night work: these groups are likely to capture the weekend work of executives or teachers for instance. Eventually, day twelve is largely characterized by the very low work time of women and could be labeled "false dual-earner workday".

[46] All the family work days located below the 50% horizontal line are characterized by relatively more desynchronization than synchronization. Subsequently, schedules which relative desynchronization lower than 50% will be called standard schedules.

Table 8 Work schedule overlapping of the twelve family work days[47]

Day	Size (%)	Only men work	Only women work	Total desynch.	Both spouses work
1	22.8	1:13	0:50	2:03	7:16
2	24.2	2:17	1:17	3:34	6:48
3	8.8	3:42	1:46	5:29	7:27
4	8.0	3:35	3:43	7:18	3:12
5	3.8	4:17	5:06	9:24	2:45
6	2.7	7:27	6:25	13:52	0:43
7	8.4	4:51	1:12	6:04	3:58
8	5.1	5:54	1:27	7:21	3:26
9	2.9	1:58	1:16	3:14	5:43
10	2.4	3:26	2:02	5:29	3:17
11	5.4	1:01	3:23	4:24	1:03
12	5.6	7:21	1:05	8:26	1:45
	100.0	3:07	1:49	4:58	5:14

Population: 1985-86 and 1998-99 dual-earner couples who worked at least 10 minutes

Source: French time use surveys, Insee, 1985-86 and 1998-99.

Temporal evolution

The assessment of the evolution of desynchronization between 1985 and 1998 is not an easy task. Instead of working out a number for the entire set of days, it seems more interesting to gauge the evolution of the double full-time schedules couples and of the partially worked ones separately[48]: the homogeneity of these days is great and thus ensures that such indicators have a meaning. The mean desynchronization for the double full-time couples is based on the total desynchronization observed in days 1 to 6 and weighted with their relative size (the reference is the number of double *and* single full-time couples). The mean desynchronization of part-time couples (days 7 and 8) is obtained by weighting the desynchronization imputable to women. The results are shown in table 9: desynchronization increased dramatically between 1985 and 1998, especially for single full-time schedules.

Table 9 Global evolution of desynchronization[49]

	1985	1998	Evolution	Structural part
Double full-time schedules	3:38	3:52	6.4%	73.7%
Single full-time schedules[50]	0:09	0:16	77.8%	46.2%

Population: couples who worked either a double or a single full-time schedule (days 1 to 8).

Source: French time use surveys, Insee, 1985-86 and 1998-99.

But these two figures hide two kinds of change:

Structural or inter-day change: the relative sizes of the workdays can vary with time;

[47] The averages computed here are based on relatively homogeneous collections of objects, as a result of the clustering algorithm.

[48] The desynchronization observed for the rest of the days is not typical and quite hard to interpret.

[49] Absolute figures are the weighted means of the desynchronization observed in each work day: the part-time figures underestimate the actual desynchronization observed in days 7 and 8 (see table 10) because of the weighting system which is based on days 1 to 8.

[50] Desynchronization for single full-time schedules is measured by the desynchronization due to women.

Global or intra-day change: the underlying dimensions of each workday can evolve with time.

The first source of change corresponds to change in the distribution of days, possibly owing to change in the structure of work opportunities, since, as in most developed countries, the service sector is growing in France, leading to more non-standard work schedules. The second source of changes would result from a societal movement towards more individualized schedules, perhaps affecting differently the family workdays. It seems that both changes are at work (see Table 10).

Table 10 Inter- and intra-day temporal evolution between 1985 and 1998 of absolute desynchronization within the workdays of French dual-earner couples

	1985-1986				1998-1999			
Day	Size	Des. Men	Des. Women	Des. Total	Size	Des. Men	Des. Women	Des. Total
1	27%	1:09	0:45	1:55	18%	1:20	0:58	2:19
2	22%	2:18	1:13	3:32	26%	2:16	1:21	3:37
3	8%	3:47	1:34	5:22	10%	3:37	1:58	5:36
4	8%	3:24	3:38	7:03	8%	3:47	3:48	7:36
5	4%	4:38	4:56	9:34	4%	3:47	5:21	9:09
6	3%	7:27	6:28	13:56	3%	7:26	6:20	13:47
7	7%	4:52	1:03	5:56	10%	4:50	1:21	6:12
8	4%	5:48	1:15	7:04	6%	5:59	1:38	7:38
9	3%	1:51	1:15	3:06	3%	2:07	1:17	3:25
10	2%	3:18	1:48	5:07	3%	3:35	2:17	5:53
11	6%	0:47	3:23	4:11	4%	1:30	3:22	4:52
12	6%	7:40	1:03	8:43	5%	6:56	1:07	8:03
	100%	2:59	1:43	4:43	100%	3:18	1:57	5:15

Population: 1985-86 and 1998-99 dual-earner couples who worked at least 10 minutes

Source: French time use surveys, Insee, 1985-86 and 1998-99.

The structural component of this increase can be assessed by simulating a situation where intra-day synchronization would have not changed between 1985 and 1998.[51] We see in table 9 that structural changes account for most of the increase observed for double full-time schedules days but only for half in the case of single full-time schedule days. We now review these two sources of change.

More spouses work desynchronized days

The relative size of the work day 1 decreased dramatically between 1985 and 1998; days 2 and 3 benefit from this decrease: in the end, day 1 lost its title of most sizeable day between 1985 and 1998 to day 2, *i.e. desynchronization increases* (see Table 10). However, if the most extreme forms of desynchronized work schedules (days 6, 7 and 8) remained stable, the number of feminine partial workdays increased significantly as if partial work were chosen to avoid a degree of non-structural desynchronization too high[52]. Among the other type of family workdays, only the size of day 11 changed downward.

Hence, the increase of desynchronization observed for double full-time schedules couples stems from a decrease in the number of couples working the most synchronized and standard day.

[51] The desynchronization of 1998 is calculated using desynchronization of 1985 but with 1998 distribution of days.

[52] The percentage of feminine part-time jobs increased significantly between the 1980's and the 1990's in France, starting from 10% to reach 16%.

However, the relative size of the most desynchronized days remained unchanged: the number of double full-time schedules with desynchronization increased, but the desynchronized work days concerned by this increase are not the most desynchronized ones. Therefore, if the number of desynchronized workdays increased in France between 1985 and 1998, this increase remained however limited.

The increase of the number of feminine part-time schedules perhaps contributed to the relative stability of the relative size of the most desynchronized days, but accounts for less than half of the increase of the desynchronization observed for those couples. Therefore, the shape of the family workdays has also evolved, leading to more desynchronization.

Desynchronization expands in most of workdays

Besides the distribution of workdays between the different types, their essential dimensions have evolved between 1985 and 1998 towards more desynchronization. If the dimensions of the work days 2 and 3 remained approximately unchanged, desynchronization increased by half an hour in work day 1: the most synchronized work day is losing ground in terms of relative size (less couples are concerned by this type of work day), but also in terms of synchronization (desynchronization increases).

The desynchronization of workdays 5 and 6 remained stable. The exception is the workday 4, which desynchronization increases by half an hour: desynchronization increased only in one of the three highly desynchronized full-time schedule workdays.

With regard to single full-time schedules, desynchronization, measured by the contribution of women to desynchronization, expanded significantly between 1985 and 1998 (around 20 minutes for work days 7 and 8): the increase of part-time labor contract in the 1980's and 1990's among French women mechanically increased the number of single full-time family work days but also came with an increase in non standard work schedules translated at the level of the couple into desynchronization.

In the end, more couples with double full-time schedules experience desynchronized work days which are themselves more desynchronized; desynchronization also rose for couples where the wife partially worked: the individualization of work schedules gained ground between 1985 and 1998.

Quality

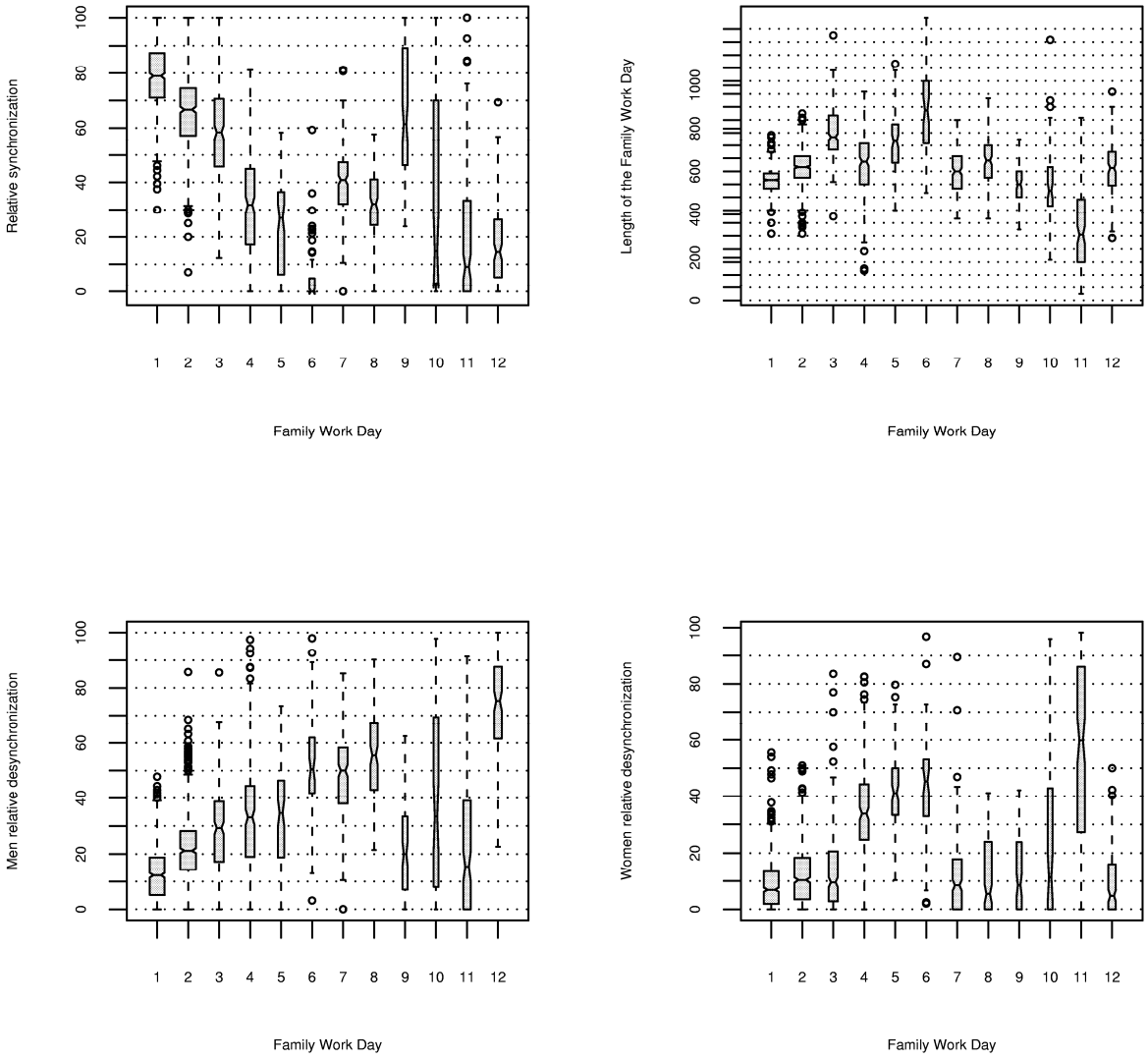
Given the lack of explicit variables used to cluster couples' work schedules, it is only possible to assess the quality of the classification by using a series of variables related to family work day: synchronization, men's and women's desynchronization, spouses work time, length of the family work day. A good classification is discriminatory, *i.e.* is characterized by a homogeneous population within each cluster and heterogeneous populations between clusters, in statistical words with low intra-class variance and high inter-class variance.

To gauge the quality of this classification, box-plots of these variables are used (see Figures 3 and 5). The most striking result lies in the thickness of the boxes and the clear-cut median values, indicating a low intra-class variance and an excellent discrimination. In short, each workday uncovered is homogeneous and distinct from the others[53]. Of course, the higher intra-class

[53] The combination of the information of those box-plots leads to the previous interpretation.

variance observed for workdays 9 to 12 was expected given their visible heterogeneity (see figure 4).

Figure 5: Box-plots of the French families work days according to the underlying variables of the analysis (I)



Population: 1985-86 and 1998-99 dual-earner couples who worked at least 10 minutes

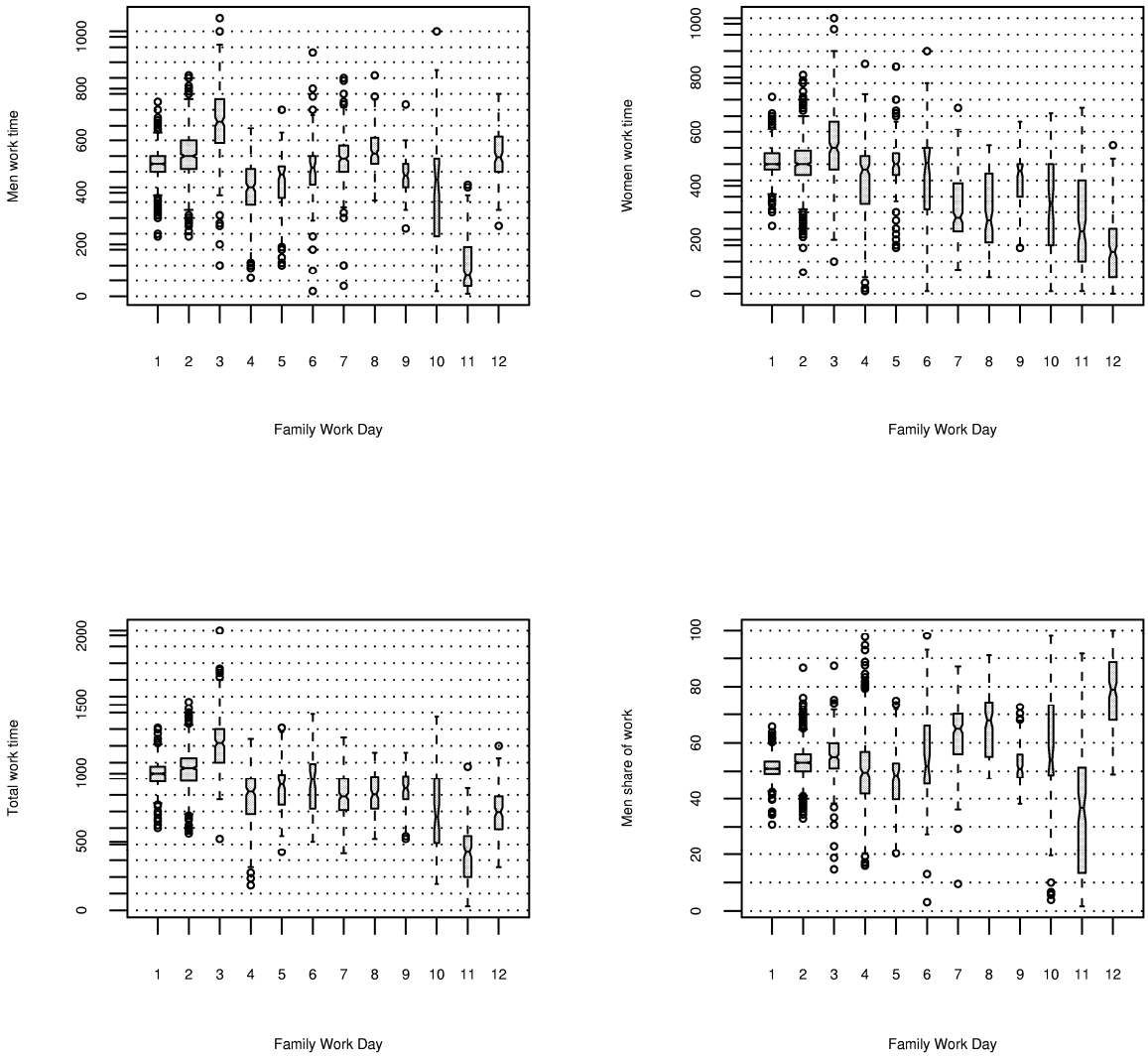
Source: French time use surveys, Insee, 1985-86 and 1998-99.

A substructed typology[54] can be drawn from the different family workdays (see table 6) based on obvious dimensions such as the time spouses worked, the scheduling of this work, and the shift between their schedules. Indeed, the days uncovered seem trivial so that the reader can wonder if the result is worth the effort. Why develop a new method if the empirical identification of clusters can be easily derived from a typology, *i.e.* a conceptual classification. However, it seems that the familiarity of the work days uncovered, far from being a problem, rather emphasizes the quality of the algorithm and furthermore enables us to identify theoretical cases which were by the way

[54] Creating a full typology out of a single type is a substruction operation (Lazarsfeld, 1937).

impossible to form given the continuous processes at stake. Eventually, this identification of theoretical cases of the substructed typology makes possible the uncovering of the explaining factors of the twelve family workdays.

Figure 6 Box-plots of the French families work days according to the underlying variables of the analysis (II)



Population: 1985-86 and 1998-99 dual-earner couples who worked at least 10 minutes

Source: French time use surveys, Insee, 1985-86 and 1998-99.

Conclusion and discussion

This study brought to the fore the absolute necessity to temporally ground the analysis of the use of time. Indeed, time is not a uniform process, a constant flux, but on the contrary a true social phenomenon. Time reveals the collective activity, the need for people to being synchronized, a need obviously linked to the social division of work. Calendars and clocks remind permanently individuals of their binds with society, with other people. Because clocks and calendars also help

individuals to orient and plan their activities, the scheduling of activities partakes of the use of time. Adding up hours dismantles a great part of the social phenomenon studied. But taking into consideration this dimension is not an easy task. It requires considering schedules as sequences, sequences of a particular kind since the present is liable to depend on anticipations, *i.e.* on the future. Consequently, usual statistical methods to analyze processes cannot be used. The only solution is to consider sequences, schedules as a whole, an issue addressed by Optimal Matching methods. But, as demonstrated, standard OM methods warp the temporal structure of schedules.

When taking into account the exact timing of activities is of paramount importance, OMA-like methods lead to inconsistent results because of this warping. Of course, when one tries to classify numerous activities combined with additional information for instance about with whom and where the activities were performed, then OMA methods have proved their efficiency, especially in geography and transportation studies. The warping of time, i.e. the extension or contraction of time, is even an advantage when the goal of the analysis is to identify different string of events. But when only a few states are studied and when the exact scheduling of activities is crucial then OMA is defective. To tackle this problem, a new method is proposed, based on what the entire population do at each moment of the period of time considered. Substitution costs are derived from those transition matrices and enable to work out distances between schedules. The keystone of this method lies in its sensitivity to small time differences, consequently, only a few states/activities can be handled adequately. Otherwise, this method is likely to rapidly lead to an unmanageable situation with too many clusters for instance. However, it is possible to adapt the method to such situations, for example by increasing the number of dates encompassed by the transition matrices, which is a way to reduce its time sensitivity.

This method is applied to the work arrangements of French Dual-earner couples in 1985 and 1998. Applying this method to this issue enabled us to visualize and measure accurately synchronicity. A substantial part (20%) of the French dual-earner who worked a double full-time schedule experiences a high degree of desynchronization (greater than 50%). Couples where women worked part-time schedule are also concerned by non-structural desynchronization. Desynchronization significantly increased between 1985 and 1998, for structural and more substantial reasons: the most synchronized day yielded ground to more desynchronized work arrangements, but also to more partially worked days; desynchronization also increases within the different family work days uncovered, especially within the part-time schedule ones. On the whole, work desynchronization expanded considerably: the non-overlapping of double full-time schedules increased by 6.4% between 1985 and 1998. Although the first application of the method proposed seems satisfactory from both interpretation and quality standpoints, more applications are required to validate definitely its relevance in the field of time-use studies.

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