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Examining large-scale time-use files through graphic representation

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Abstract

The objective of this paper is to demonstrate the utility of graphic means to add to the comprehension of time-use analysis. The paper traces the development of several graphic approaches, from the logic of plotting a single case in multidimensional space to several ways of examining time-use dynamics graphically without limitations on sample size. It draws on pilot studies from the FAMITEL research project on telecommuting and extends to Statistics Canada's General Social Survey in 1998 with time-use data (GSS12). The examples of graphic development focus on aspects of the daily lives of teleworkers, to illustrate in this context how graphic representation can illuminate much-discussed differences between the complex pattern of daily life characterizing of these workers in comparison to conventional workers, regardless of the size of samples and subsamples. The graphic techniques discussed advance understanding of these phenomena by presenting visual evidence of differential patterns reflecting the interrelations between the several components of time-use as well as reflecting the different times in the day in which phenomena occur, within and between analytic subgroups. As in many other analyses, gender can be literally seen in the graphics as an important differentiating factor, even within occupational situations.

JELCodes: C10, D10, D30, J20

Keywords: telework; home-based work; graphic analysis; tempogram; composite tempogram.

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Background and objectives

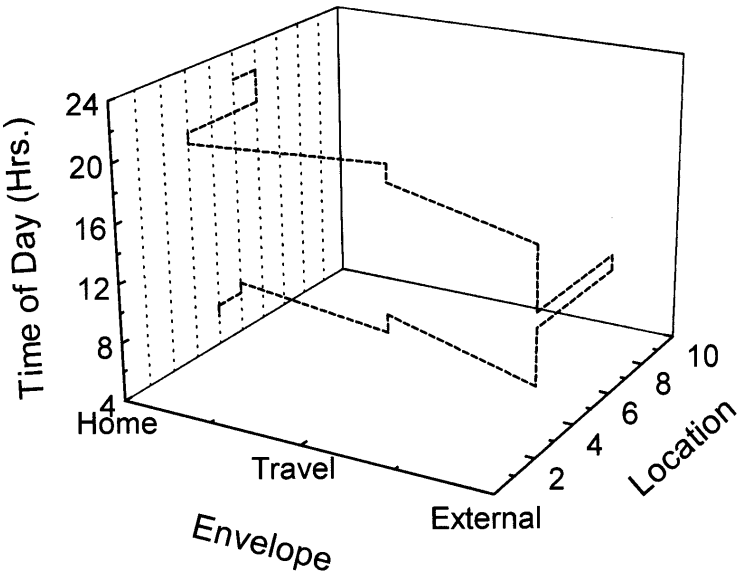
Time-use is inherently composed of multiple dimensions (time, duration, activity, places, persons, and sometimes perceived subjective outcomes), with numerous categories and values associated with each. Tabulation and statistical examination of this complex matrix may lead to diverse and interesting results, but these are not always easily discerned. Graphic presentation of results adds to the comprehension of these results (Michelson, Crouse & Stalker 2001; Michelson & Crouse 2002). It offers a unique ability to make the *pattern* of a person's daily use of time explicit. It also offers a means of pointing out the interaction between the several dimensions of time-use throughout a person's day. And it can plot the differences between subgroups in these patterns, such that they can be readily compared; these subgroups can represent aggregates whose comparisons are of theoretical and/or analytic interest or indeed changes over time with respect to the same aggregate. In the subfield of Geography called Time-Geography, the literature has shown over many years a necessity to use graphic means to explicate the dynamics of time and space pursued (e.g. Hägerstrand 1970; Parkes and Thrift 1980; Friberg 1993). This legacy has been largely conceptual until 2001, with simultaneous empirical operationalization by the present authors and by Kajsa Ellegård (2001).

Ellegård's approach captures elegantly for individuals and families the three dimensional components of daily activity developed in the time-geography tradition. But, to this point, her graphic approach to the daily activities of *larger* groups lacks parsimony and clarity. Progress in graphic representation is coming surely, but in bits and pieces from many sources (c.f. Research Centre on Portuguese Economy 2002).

The initial Canadian approach detailed here commenced in connection with a pilot study of teleworkers and their partners in Canada, coordinated with similar efforts in Europe within the umbrella of a research group called FAMITEL (families and telework). That first pilot involved only six families, chosen to fulfill certain requirements and variations but not particularly representative of any universe. Part of pilot work is intended to observe whether the implementation of the research design and methods is feasible. Beyond that, it is important to assess the extent that the data are sufficiently pertinent to justify extending data gathering to a larger scale. A sample of six teleworkers and six partners provides a time-use data matrix entirely too small and diffuse for tabulation and statistical analysis. Therefore, the assessment of data proceeded through the creation and analysis of graphic patterns. Even with only six respondent pairs, it was thereby possible to examine logical differences between teleworkers and their non-teleworking spouses in the pattern of the weekday time-use patterns.

It is possible to draw simultaneously from different dimensions of time-use at the level of the individual episode (i.e. an activity at one point in time) from a spreadsheet type of matrix, so as to create graphs with a continuous line through a three-dimensional box denoting in serial order through the day whether people are at home, in transit, or are in a generalized category of external location (called an *envelope),* as well as the precise nature of location in an envelope (room in the home, mode if in travel, and type of land-use if external). Figure 1 is a hypothetical and hugely simplified

Figure 1 Hypothetical day of one person



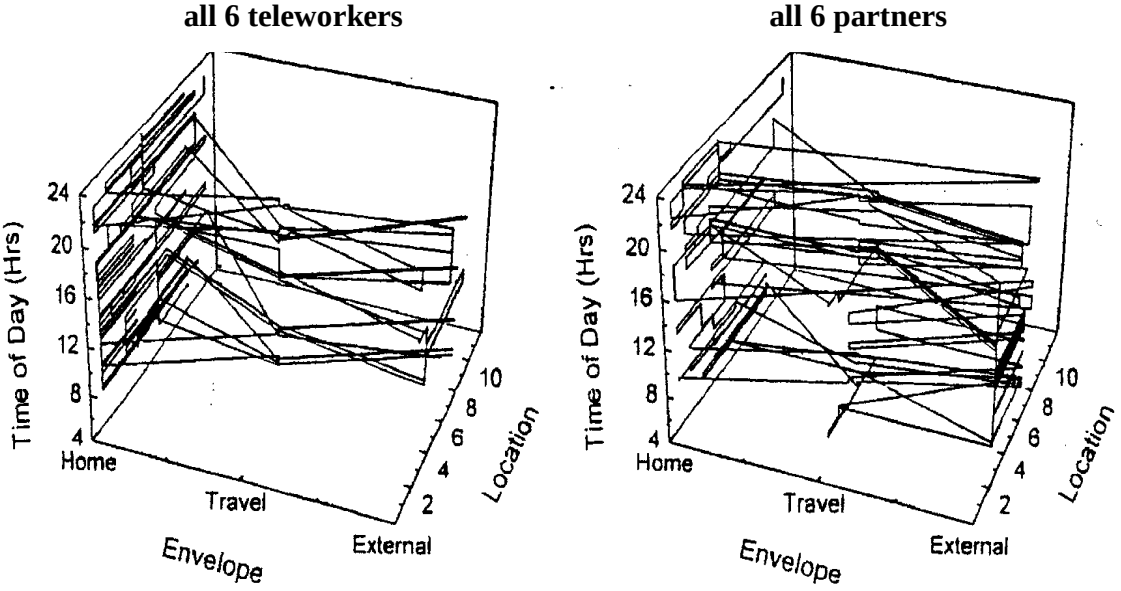
Source: not applicable (illustrative example).

representation of one person's day, starting from two rooms at home, going to work and staying there a while, stepping next door for lunch and then back to work, and returning home, in which several rooms are then used before retiring. This kind of figure is not restricted to just these dimensions of time-use. Type of activity, persons present, and self-reports of stress may be plotted alternatively.

Six teleworkers are compared to their partners in Figure 2a & b. This is done by plotting a line for each respondent on the graph and observing what the totality of lines says about the day for each of the two subgroups. The graph makes it easy to spot a pattern of life that goes well beyond the obvious facts that teleworkers are at home more and take fewer trips than their non-teleworking partners. The teleworkers are visibly seen to divide the day into a greater number of shorter episodes and to use a great number of different rooms in their homes through the day, not simply a room set up as an office.

Nonetheless, although this graphic technique relying on lines for all respondents is relatively clear for six cases, it becomes confusing and muddy when the sample increases – such as when including the results from additional research partners in the multinational project.

Figures 2a and b Envelope and location by time of day



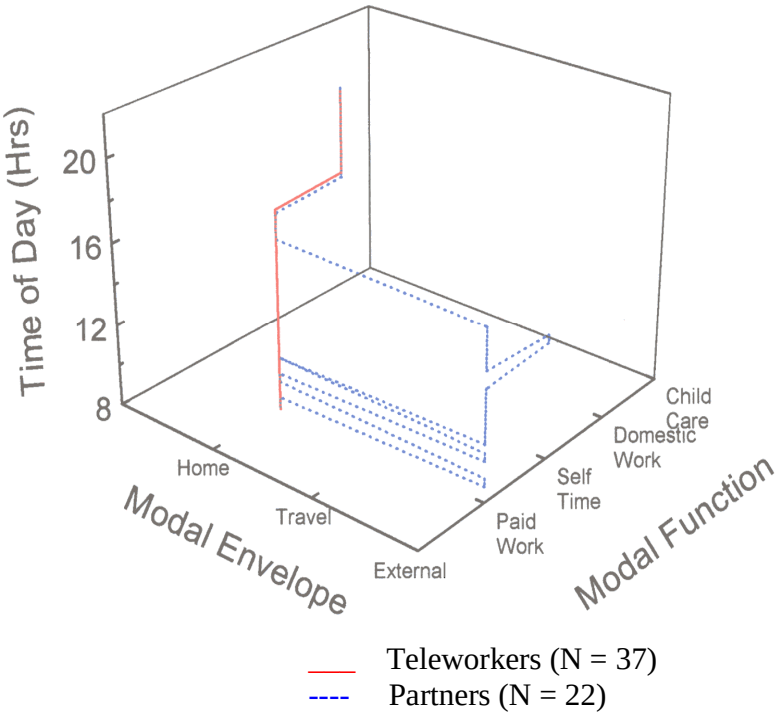
Source: Computed from Canadian pilot data for FAMITEL project, 2001.

Addressing larger samples

A modification is therefore necessary that can be applied with clarity to samples of large size, such as the national samples increasingly producing such valuable information. The key here is the creation of a single line through the day for each analytically pertinent subgroup, made possible through data reduction and simplification. This requires several fundamental changes in the organization and presentation of time-use data. Plotting of time must be away from sequences of episodic activity throughout the day representing individuals and to what was typical for the subgroup during fixed periods of the day. The logical extension on this is to plot typical activity components for each of the 1440 minutes of the day. Expressing what is typical of the group each minute (or other grouping) requires considerable reduction of the values of time-use variables and simplification of the data. Depending on the dimension of time use involved, this becomes the modal activity, place, or person present Hence, Figure 3 compares the 37 teleworkers and 22 partners from the multinational Famitel pilot data, regarding the interactions between place envelopes and main activities (called functions, as reduced to paid work, self time (a combination of personal care and free time), domestic work, and child care).

Figure 3 shows clearly[55] the modal pattern of teleworkers to be at home working until after 4 p.m., with the rest of the day predominantly devoted to self time. This contrasts to the pattern of their partners, the bulk of whose days center on their workplaces, other than going out around noon for personal purposes (which the teleworkers in this sample do not do). At no time during the day is travel a modal envelope for either subgroup, nor are domestic work or child care ever modal activities within these aggregations.

Figure 3 Modal envelope and function



Source: Computed from multinational data from the FAMITEL project, 2001.

The major purpose of this paper is to examine the feasibility, usefulness, limitations, adaptations, and results that occur when making the major leap to an application of graphic techniques on the 1998 General Social Survey #12 by Statistics Canada (referred to as *GSS12*), with a total sample of 10,749 respondents, pursuing in more detail the substantive themes developed in the work just described.

[55] In the development of more multidimensional plots from larger samples, the plotting of matrix lines varied marginally in successive stages in an attempt to increase an ability to see these plots in three dimensions. But then the three dimensional perspective becomes important to locate the position of a given line. The software (KyPlot) makes it possible to rotate the graphs to observe the dimensions from different viewpoints. But such rotation is not included here on behalf of parsimony.

Feasibility and usefulness

Figure 4, for example, parallels Figure 3, but it is based on 395 home-based and 3469 conventional workers (all of whom were shown to perform principal employment activities on a weekday for which time-use data were collected). The results are quite similar, even though the Statistics Canada GSS12 time-use matrix extends from 4 a.m. to the same time the next day, compared to the graphing in Figure 3 of data from 8 a.m. to 8 p.m. The home-based workers show a modal day which is the same except for a short period in the early afternoon, when the modal home-based worker goes for a short time to an external location for purposes of work. The modal conventional worker, does some work at home (for 4 minutes) before going to an external location for work. He or she takes the aforementioned noon break, which remains at an external location and is not related to work. When returning home, the modal conventional worker does not take up work upon arrival, but spends the rest of the day in self-time activities.

Figure 4 Modal envelope and function by time of day from a large sample

N = 3864; conventional workers = 3469; home-based workers = 395.

Source: Computed from General Social Survey 12, Statistics Canada, 1998.

Figure 5 compares the same two subgroups from the Statistics Canada 1998 data (GSS12), but substitutes persons present in the three-dimensional graph for functions. In this case, the graph shows quite clearly that the modal home-based worker spends the day until shortly after 4 p.m. alone; even when he or she goes out in the early afternoon, this does not change. In contrast, the modal conventional worker is shown explicitly and certainly not surprisingly in the company of

work colleagues through all the workday except at the very beginning and end, and for during a very short time during the lunch break. However, once home, the modal conventional worker is shown to spend a greater and continuous period with kin than does the modal home-based worker. The latter goes back and forth between being alone and in the company of kin, before turning to a solitary situation at an earlier hour than the conventional worker does.

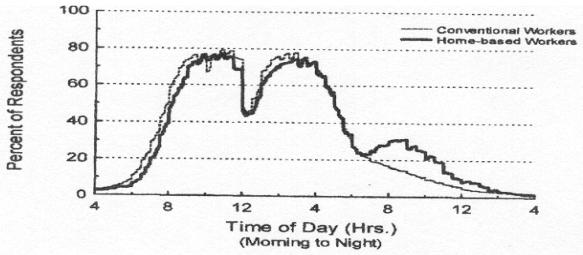
Figure 5 Modal envelope and persons present by time of day in a large sample

N = 3864; conventional workers = 3469; home-based workers = 395.

Source: Computed from General Social Survey 12, Statistics Canada, 1998.

The analytic utility of this approach needs to be examined more completely. Figures 4 and 5 do show that plotting the patterns of *typical* aspects of behavior made possible by time-use protocols produces patterns that are logical and consistent with other analyses, without any detriment from greatly increased sample size. A comparison of Figures 3 and 4 shows nearly identical results, despite the sampling deficiencies underlying Figure 3 and the greater hours in the day covered by Figure 4. In an earlier paper, with the smaller FAMITEL international sample, this approach, with a modified selection of variables, enabled insights into the precipitants of perceived stress in the context of the daily pattern. Stress among home-based workers visibly rises just before other family members return in the afternoon (Michelson & Crouse 2002).

Figure 6 Paid work by time of day: home-based vs. conventional workers



N=3864: conventional workers = 3469; home-based workers = 395

Source: Computed from General Social Survey 12, Statistics Canada, 1998

Limitations and adaptations: tempograms

Nonetheless, there are limitations that accompany the simplification of time-use data within analytic subgroups to typical values, whether modes, means, or medians. It excludes examination of alternative values, the distributions of which through the day can be of considerable interest. For example, domestic work and childcare are never modes within our two analytic subgroups, but this does not mean that they are non-existent or their distributions, uninteresting. Paid work is not modal in the evening, but it is important to examine the extent that it takes place and by whom.

Therefore, although Figures 4 and 5 show that graphing typical patterns with large-scale data sets is both feasible and, to some extent, profitable, graphic presentation of typical patterns by no means pre-empts other forms of data analysis and presentation. Creating graphic patterns on the basis of a continuous scan of the day, rather than by individual-based episodes, can include a greater range of values of time-use. The analyst may show the percentage of respondents (in their respective subgroups) evincing a given value of time-use each minute of the day in successive graphs. The percentage distributions through the day for the reduced four values of activity (or functions) are displayed in Figures 6 and 8 - 10. Given the resemblance of these figures to cardiograms, these graphs are called *tempograms* in this discussion.[56]

The tempogram in Figure 6 shows the percentage of home-based workers and conventional workers engaged in paid work by the minute throughout the day. The over all shape of the pattern is the same for both work situations. Nonetheless, there are some visible differences. With only momentary exceptions, the conventional workers are marginally more likely to be involved in their work until after 3 p.m. From 3 until a shade after 6 p.m., the percentages are indistinguishable. However, after 6 p.m. and until about 2 a.m. the home-based workers are much more likely to be involved in paid work. For example, at about 8:30 p.m., about 35 per cent of home-based workers are so engaged, twice the percentage of conventional workers. And the ratio remains at about 2:1 throughout the evening.

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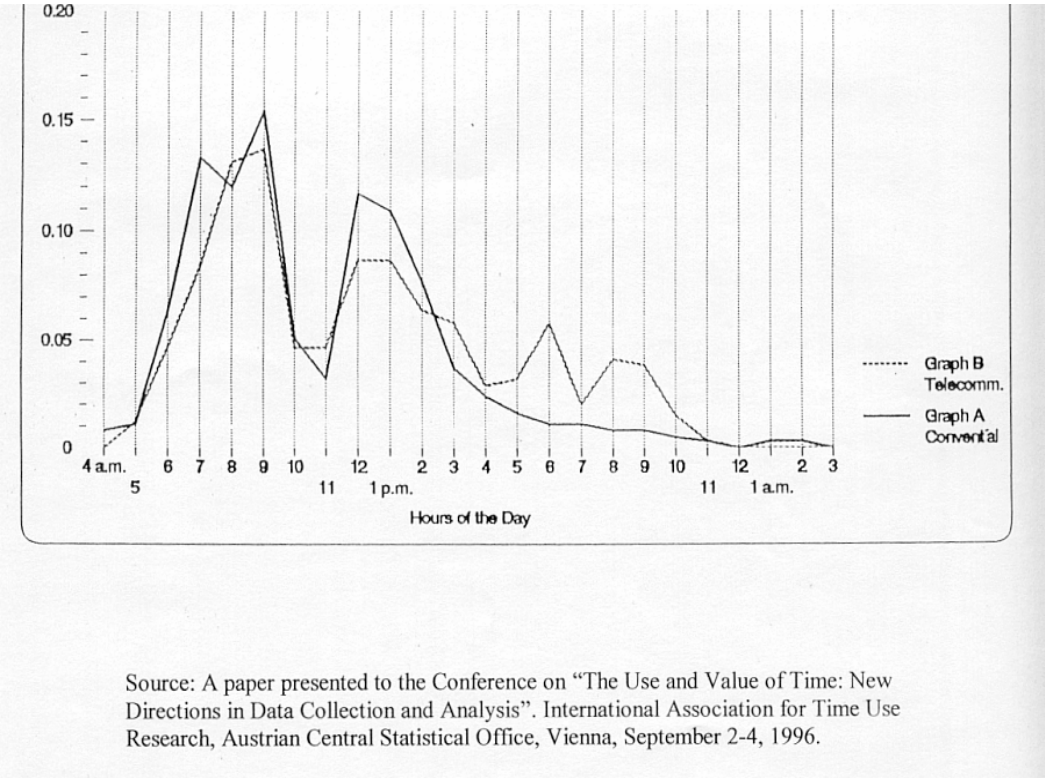
[56] The Multinational Time-Use Study (Szalai 1972) applied this technique to 15 minute periods during the day on such aspects as travel, time with children, and location. This approach appeared in their work to be most informative when the simple percentage of persons in an aspect of time use was used, in contrast to absolute numbers of people or the cumulative percentages of numerous activities. As might be expected, graphs based on 15 minute periods are less smooth and exact than tempograms reflecting each minute.

This general pattern and the differences between home-based and conventional workers parallels closely findings in a study of Swedish national time-use in 1991, gathered by the Swedish Central Statistical Bureau (Michelson 1996).See Figure 7. In that analysis, the graph represented the hourly percentage distribution of the starting time of episodes of paid work. Comparing the two graphs, it is evident that our current method, shown in Figure 6, shows more accurately the duration of times of the day during which paid work occurs. Plotting starting times leads to sharper peaks but not as good an indication of how long typical devotion to work lasts. This is particularly evident in the graphs' depiction of evening time-use, in which Figure 6 suggests a greater continuity of paid work through the evening than does Figure 7. The tempogram for home-based workers follows also the same pattern of 104 American home-based workers studied by Ahrentzen (1990), who plotted the percentage engaged in paid work at half-hour intervals.

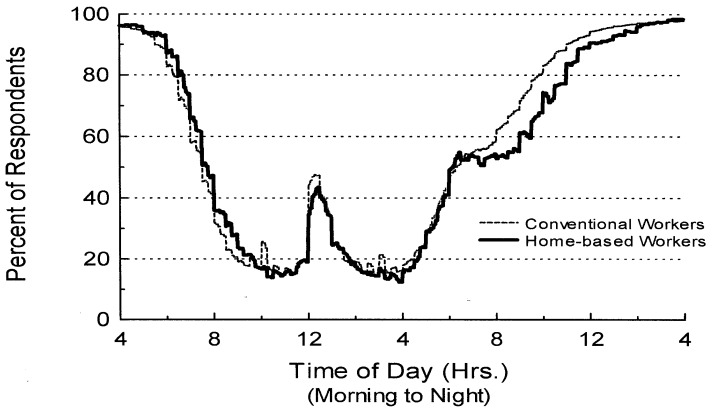
Figure 7 Hourly distribution of starts to regular work episodes: telecommuters vs. conventional workers (in percentage of daily trips by hour)



Source: A paper presented to the Conference on "The Use and Value of Time: New Directions in Data Collection and Analysis". International Association for Time Use Research, Austrian Central Statistical Office, Vienna, September 2-4, 1996.

Figure 8 shows the distribution of time through the day spent on what *self time*, a reduction and combination of activities frequently grouped as personal time and free time. The former includes sleep, personal hygiene, and eating, while the latter includes various active and passive pastimes. In general, this pattern varies inversely with the distribution of time for paid work. Differences between conventional and home-based workers in self time in the evenings are particularly noticeable, just as was the case for paid work in the evenings. Nonetheless, the tradeoffs are not completely identical.

Figure 8 Self time by time of day: home-based vs. conventional workers



N=3864: conventional workers =3469; home-based workers= 395

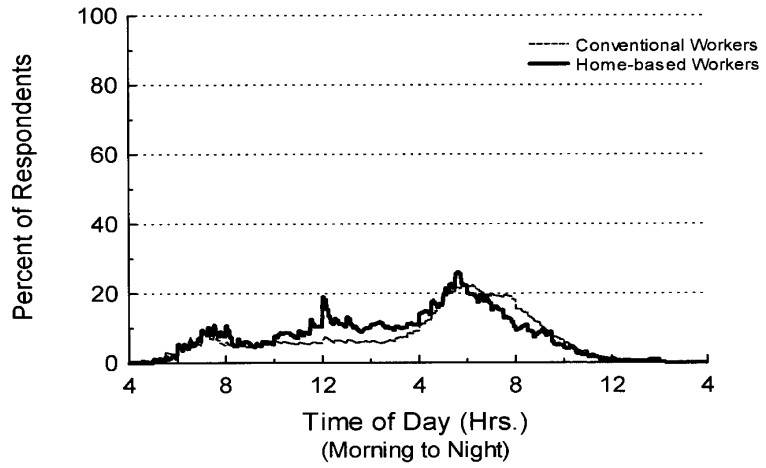
Source: Computed from General Social Survey 12, Statistics Canada, 1998.

Some greater understanding of the lack of a full tradeoff between paid work and self time among the home-based and conventional workers is gained by bringing in consideration of a minor function, at least in terms of participation percentage at any single time. Figure 9 shows that home-based workers exceed conventional workers in domestic work participation nearly every minute during the traditional work day. It is only after about 5 p.m., when the conventional workers arrive home and the home-based workers are more likely to hunker into paid work again (see Figure 6), that the conventional workers start to exceed home-based workers in percentage performance of domestic work.

As might be expected from the literature (c.f. Michelson 1998), Figure 10 shows both the absolute rate of participation and the differences between home-based and conventional workers are greater when analyzing female workers only. Home-based workers do mix paid and domestic work episodes during the workday (as in Figure 2), particularly among the women, even if this does not show up in patterns of modal behavior.

In aggregate, without considering the situation of parents alone, an even smaller percentage of working people is found to participate in child care at any given minute, always less than 10 per cent. The patterns of home-based and conventional workers are essentially similar except within about 7-9 a.m., when it is the home-based workers who are much more likely to be caring for whatever children are on hand. Once again, it is women who are much more likely to be performing child care. When women alone are observed, the home-based workers are much more likely to be participating in child care activities not only between 7 and 9 a.m., but until about 8 p.m. The tempograms clearly show not only the existence of gender role differences in behavior but also when in the day they occur. These graphic representations are shown in Figures 11 and 12.

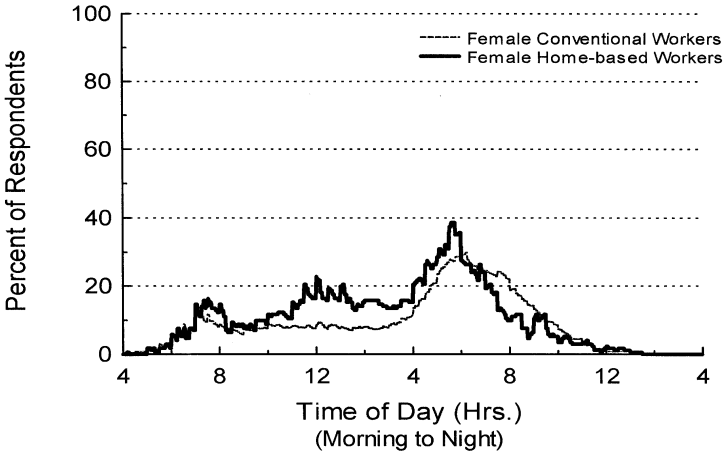
Figure 9 Domestic work by time of day: home-based vs. conventional workers



N=3864: conventional workers = 3469; home-based workers = 395

Source: Computed from General Social Survey 12, Statistics Canada, 1998.

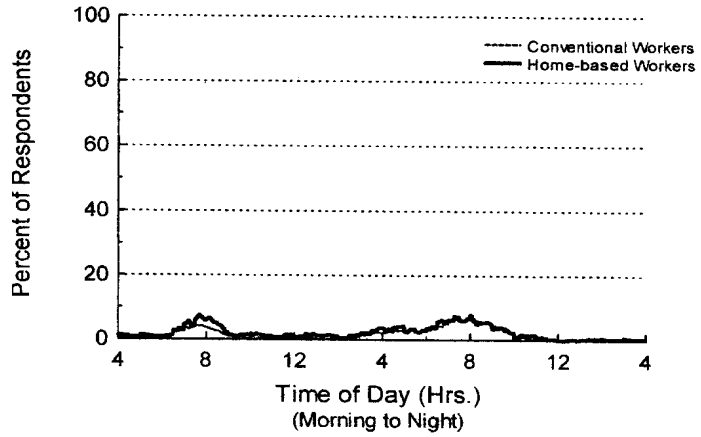
Figure 10 Domestic work by time of day: female home-based vs. conventional workers



N=1806: female conventional workers = 1635; female home-based workers = 171

Source: Computed from General Social Survey 12, Statistics Canada, 1998.

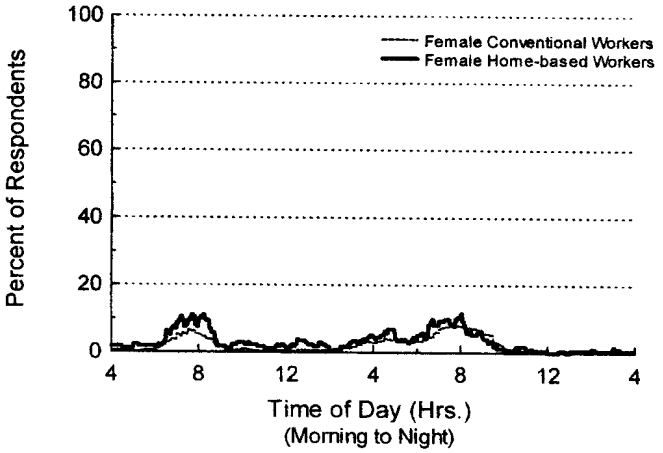
Figure 11 Child care by time of day: home-based vs. conventional workers



N=3864: conventional workers =3469; home-based workers =395

Source: Computed from General Social Survey 12, Statistics Canada, 1998.

Figure 12 Child care by time of day: female home-based vs. conventional workers



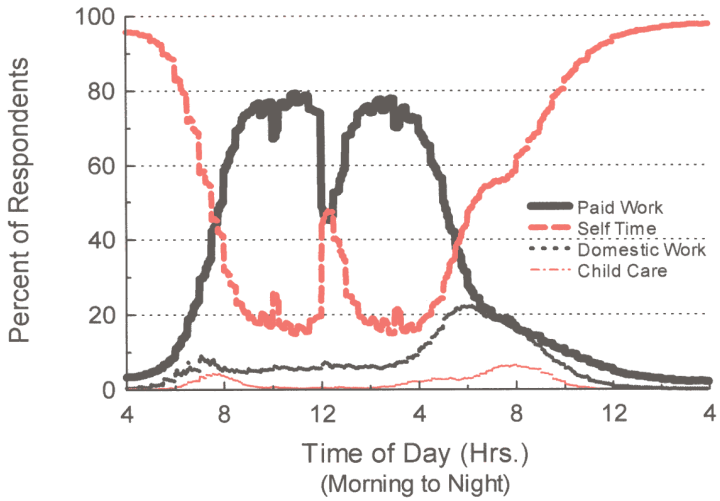
N=1808: female conventional workers =1635; female home-based workers =171

Source: Computed from General Social Survey 12, Statistics Canada, 1998.

In Figures 13 and 14 composite tempograms are presented for conventional and home-based workers, respectively. These composite tempograms enable more of a view of the dynamic relationships of behavioral functions throughout the day in the two analytic subgroups of workers – and more clearly than has been the case in graphs showing composite strata adding up to 100 per cent (c.f. Szalai 1972). The general reciprocity between paid work time and self time is clearly evident for both subgroups. However, the place of domestic work compared to paid work and self time is highly visible in this comparison. Among the conventional workers, the line reflecting participation in domestic work stays distinctly below that of free time throughout the day, but rises to meet the line representing paid work in the early evening. In contrast, among

home-based workers, domestic work encroaches on self-time at several points in the day, particularly in the late afternoon. And domestic time declines to a level well below that which the home-based workers devote in the evening to their paid work.

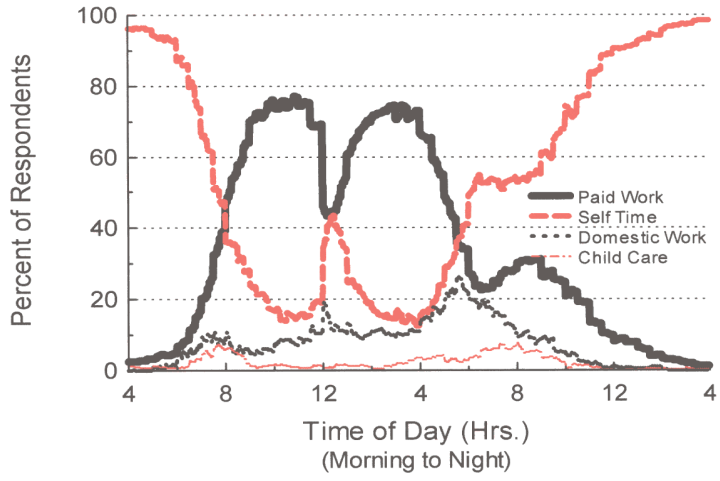
Figure 13 Four functions by time of day: conventional workers



N= 3469

Source: Computed from General Social Survey 12, Statistics Canada, 1998.

Figure 14 Four functions by time of day: home-based workers



N=395

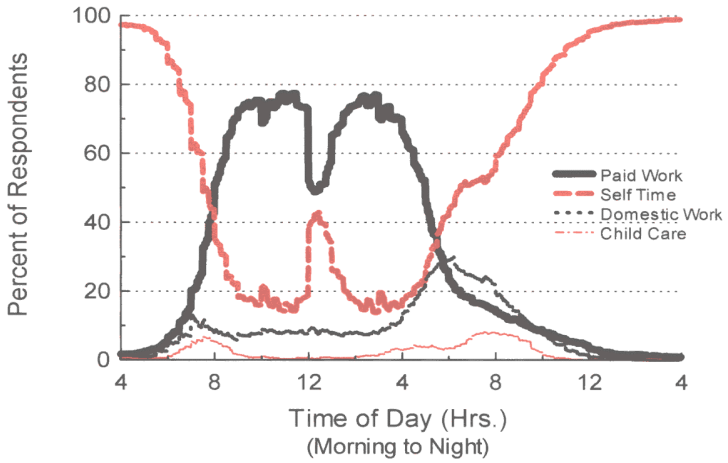
Source : Computed from General Social Survey 12, Statistics Canada, 1998.

The composite tempograms also bring out the special place of gender in explanation. Compare, for example, Figures 13 and 14 with Figures 15 and 16, which depict these phenomena for

women alone. Among female conventional workers, the line showing percentage of participation in domestic work lies closer to that for self-time than is the case for conventional workers as a whole, and it considerably exceeds participation in paid work from about 5 p.m. to 9:30 p.m., unlike the pattern in Figure 13. Among the female home-based workers, participation in domestic work approximates or exceeds self-time during most of the afternoon, as shown in Figure 16. Indeed, domestic work among the female home-based workers exceeds paid work from about 5 p.m. to 7:30 p.m., a pattern which is decidedly not the case in Figure 14, when men are factored in.

These composite tempograms help us understand the temporal meaning of the purely statistical results from a previous study showing that, among home-based workers spending great amounts of time doing their work at home, women, despite enjoying their work as much or more than men, spend less time at it and report more stress in their days (Michelson 1998). Particular parts of the day are cut out for domestic work and child care, regardless of the salience of work in their lives.

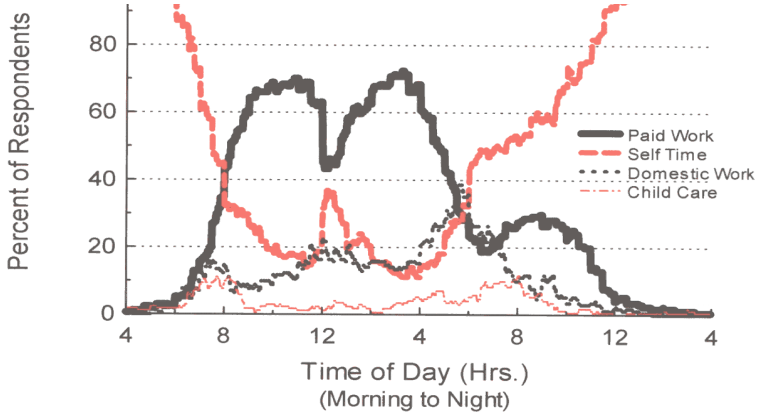
Figure 15 Four functions by time of day: female conventional workers



N= 1635

Source: Computed from General Social Survey 12, Statistics Canada, 1998.

Figure 16 Four functions by time of day: female home-based workers



N=171

Source: Computed from General Social Survey 12, Statistics Canada, 1998.

Concluding observations

The analyses and graphic representations in this paper confirm that adaptations to traditional episode-based approaches to analysis and data presentation, intended to display and communicate more easily patterns of time-use (and analytic comparisons), can be extended to large samples in ways that are concise and legible. Furthermore, the plotting of reduced and simplified data by minutes of the day can provide comparisons with enhanced analytic value, because they provide *visual* evidence of potentially differential *patterns* reflecting the interrelations between different components of time-use. However, the contribution to understanding may be brought to a greater degree of specificity if a focus on typical behavior (modes, means, medians) is extended into tempograms and composite tempograms dealing with percentage of participation in a limited number of activity functions minute by minute throughout the day. The tempograms enable a visible understanding not only of how much time is devoted to the dimensions of time but also differential patterns of time distribution throughout the day, within and between analytically pertinent groups. When calculated in terms of percentage participation by the minute, a more exact, complete, and useful picture of human activity is portrayed.

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