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Extracting More Knowledge from Time Diaries?

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Abstract Time-use diary data convey information about the activities an individual was engaged in, when and for how long, and the order of these activities throughout the day. The data are usually analyzed by summarizing the time used per activity category. The aggregates are then used to determine the mean time use of a mean individual on an average day. However, this approach discards information about the duration of activities, the order in which they are undertaken, and the time of day each activity is carried out. This paper outlines an alternative approach grounded in the time-geographic theoretical framework, which takes the duration, order, and timing of activities into consideration and thus yields new knowledge. The two approaches to analyzing diary data are compared using a simple empirical example of gender differences in time use for paid work. The focus is on the effects of methodological differences rather than on the empirical outcomes. The argument is made that using an approach that takes the sequence of activities into account deepens our understanding of how people organize their daily activities in the context of a whole day at an aggregate level.

Keywords Time-geography · Time-use · Methodology · Daily life · Sequence analysis

1 Introduction

All individuals fill each day of their lives with various activities, such as work, sleep, socializing with friends and family, and taking care of children. The time spent on each activity can be recorded using time-use diaries. Time-use diaries have a long history, but modern usage can be traced to the multinational time use study directed by Alexander

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Szalai (1972). Szalai's team introduced an activity coding scheme and propositions for a variety of analytical approaches, some of which are still used in contemporary studies.

Szalai (1972) notes various possible levels of analysis. In the chapter on the analysis of time-budget data, Philip J. Stone (1972) describes three levels of analysis (Szalai 1972, pp. 96–97) that can be used to classify analytical approaches.

Level I, as described by Stone, are analytical approaches that use aggregated durations or frequencies of activities and compare these with various demographic variables. At this level of analysis, diary data are analyzed by totaling the time spent on an activity during a day and calculating the means. The aggregated mean time use per individual per activity then forms the basis for searching for differences between, or dependencies on, background variables.

Level II are analytical approaches using the average durations or frequencies of combinations of activities, identities of parties with whom activities were carried out, and location information. This second level expands on the first by adding more independent variables to the analysis, essentially moving from bivariate methods such as *t*-tests to multivariate tests such as regression.

Contemporary analyses using aggregated durations or frequencies use mainly a level II approach, and fewer analyses are based on level I. An example of a level I study is Millward and Spinney's (2011) exploration of how the degree of "active living" varies along the rural–urban continuum. An example of a level II study is the comparison of writing patterns by Cohen et al. (2011), who analyzed gender, race/ethnicity, educational attainment, age, and working status using a multilevel model of the mean time spent writing.

Level III analyses are based on the notion that the first two levels ignore the sequence of activities. I claim that taking into account the *sequence* of activities and how they together constitute the pattern of time use permits a deeper understanding of time use.

An argument for using this third level of analysis is that daily life is not simply about the total times used for various activities during a day. Instead, daily life is about how people distribute time for activities that they want or need to engage into live a decent life and to interact with other individuals. Activities such as raising children, working, socializing with family and friends, taking care of the home, sleeping, and eating are all essential to daily life and are usually performed now and then during the day. Trying to fit all these activities into the limited time frame of a day requires that individuals make choices about what activities to carry out and when to carry them out in relation to other activities and other people during the day.

It will be argued here that the various approaches based on level I, II, and III analyses yield different results as well as different views of time. This paper seeks to integrate time-geography and a sequence analysis method for analyzing time-use data; this integration takes into account the daily pattern of a group of individuals performing an activity, i.e., when, for how long, and in what order during a day. Time-geographic concepts, introduced by Torsten Hägerstrand in the 1960s, fit well with the level III analysis of time use.

From the time-geographic perspective, individual efforts to fit daily activities into the hours of the day are referred to as a packing problem (Hägerstrand 1970a, b, 1989). This packing also depends on other individuals' activities and on the arrangements of various organizations, such as the workplace and service providers. In the individual problem of how to "pack the day," the duration, order, and sequence of activities are essential components.

This paper compares the outcomes of different levels of analysis using the same time-use data, one using aggregated mean times (levels I and II) and the other using sequence analysis (level III) and clustering. Attention is paid to methodological differences and to how the two analysis yield different results due to their different views of time use in everyday life. The intent is to explore the two outcomes in terms of their handling and analysis of time diary data, their underlying assumptions, and the different methodologies that structure their results. Time-use survey methods will also be briefly presented: What do such surveys measure, how are the data collected, and what impact does this have on the analysis? The final step is to compare the outcomes of the different outcomes and their implications for the analysis of time-use data and, consequently, for the knowledge produced.

A study of gender differences in time spent on paid work will be used to illuminate the differences between the methods. This is a well-explored area, so the empirical data and results should not distract us from the effects of methodological differences.

2 A Time-Geographic View of Time Use

Time is a resource that differs dramatically from other resources: it cannot be stored for later use, it cannot be transferred between humans, and it is not possible *not* to use it. During a day, an individual will be doing something for 24 h and, due to the limited number of hours, the individual will have to make choices on what activities to fill the day with.

Some hours of the day must be used to carry out activities for sustenance and sleep, whereas other activities, such as paid work, are required by society. Some activities are directed by the desires and wishes of the individual alone and others by the social norms and values of his or her social context. The time used for activities is subject to *constraints* and requires that the individual *prioritize* activities.

In "What about people in regional science," Hägerstrand (1970b) presented the concept of constraints, which affect the activities an individual can carry out. He presents a categorization consisting of three types of constraints: capacity, coupling, and authority constraints. *Capacity* constraints are biological functions, such as the need for sleep and nutrition, but also include the technologies available to the individual for transportation and communication. *Coupling constraints* are demands for coordination with individuals, objects, or places. *Authority constraints* are constraints related to power and the control of individuals in the form of rules and regulations.

Ås (1978) proposed four kinds of time in descending order of priority: necessary time, contracted time, committed time, and free time. *Necessary time* refers to the time needed to satisfy basic physiological needs. Sleep, meals, and personal health and hygiene activities are typical activities that must be carried out in order to function. *Contracted time* is time when the individual is obliged to carry out specific activities. The examples cited by Ås are paid work and attending school, including the time used for commuting and waiting. These periods are typically fairly long and greatly influence the day's structure. *Committed time* is time used for household activities, such as unpaid work, childcare, housework, and shopping. *Free time* is the time that remains when the individual has carried out the activities that are necessary, contracted, or committed.

Taken together, what an individual can do during a day is restricted by the constraints experienced and the priorities of the activities engaged in.

2.1 Projects

From a time-geographic perspective, the activities performed by individuals in everyday life emanate from their various *projects*. Projects are collections of activities that together aim toward a goal (Hägerstrand 1973, 1974). Projects can consist of a few or many activities; for example, for most individuals, the project of "earning an income" requires not only the activity "paid work" but also the activity "commute."

Projects can also depend on supplementary activities to be performed by the individual or by other individuals. One such project, as presented by Ellegård (1994), is "maintaining dental health," which includes visits to the dentist. To carry out this activity, an individual must be at the specific geographical location of the dentist and be there at the specific time of day the dentist has allocated to him or her. To do this, the individual must arrange other activities to permit the "dentist visit" activity.

These activities include transportation to the location of the dentist. If the individual depends on public transportation, the transportation schedules serve as authority constraints due to the individual's lack of transportation (a capacity constraint).

If the individual is a parent, there may be a need to arrange childcare before the dental visit and to transport the child to and from the childcare provider. This is an example of a coupling constraint, meaning that individuals must co-arrange activities with another individual or individuals to be able to achieve the goal of a project, which is visiting the dentist.

The "dentist visit" itself might require only 30 min, but including transportation and childcare arrangements may inflate the required time to an hour or more. The aim of this project, of which visiting the dentist is part, is to maintain dental health, but various supplementary activities need to be carried out to fulfill the project. Accordingly, the individual needs to structure and prioritize various projects and their constituent activities in order to maintain dental health.

Prioritizing activities relating to various projects in everyday life can be described as an attempt to hit a moving target, as the opportunities to reach the intended goals are in constant flux. The individual must constantly plan and re-plan, prioritize and reprioritize, all while considering the restrictions set by society or other formal organizations with regard to carrying out the required activities (contracted time structured by authority constraints), coordinating one's own activities with others (committed time and coupling constraints), and adjusting to one's own abilities (capacity constraints) in order to reach the goal of the project.

From this perspective, analyzing time use ought to take into consideration not only how long an activity is carried out, but also when and in the context of what other activities it occurs. Using the presented categorization of activities, this would entail applying a level III analysis.

3 Time-Use Data Collection

The time-geographic framework builds on the obvious notion that a day is filled with many activities, performed in a sequence, all of which are parts of various projects that the individual attempts to carry out because they are in some way meaningful to him or her. To analyze the activities performed during a day, from this perspective, the data must capture the whole day of the studied individuals. Not all ways of collecting time-use data generate the type of data required for an approach that takes the sequence of activities into account.

Time-use data collection aims to record individuals' actual use of time, not their perceived use of time (the latter will not be discussed here). Time-use studies in various forms have been carried out in over 90 countries since the very earliest one in 1857, more than 50 such studies having been carried out since the year 2000 (Fisher et al. 2009).

Data on time use have been used for research purposes in areas such as employment and labor (Boone et al. 2009; Claessens et al. 2010; Krueger and Mueller 2010), leisure time and “active living” (Beck and Arnold 2009; Millward and Spinney 2011; Spinney et al. 2011), gender studies (Dribe and Stanfors 2009; Motiram and Osberg 2009; Schneider 2011), mental health (Bejerholm and Eklund 2006; Yanos et al. 2010), family life (Bianchi and Robinson 1997; Brown et al. 2010), and job satisfaction under changing regimes (Bendixen and Ellegård 2013). Time-use data have also been used to model energy use (Widén and Wäckelgård 2010). If data collection is repeated, time-use data allow for studies of longitudinal changes (Sullivan and Gershuny 2001).

Time-use data are collected using time diaries, stylized time-use measurements, or experiential sampling (Juster et al. 2003). The data are collected to measure the time individuals use for the recorded activities and usually also indicate the order of the activities carried out over a predetermined period.

When stylized measurement methods are used, the respondent is asked to estimate, retroactively, the average time spent on various activities via questions such as “How many hours on average do you work in a week?” This stylized method tends to be biased, over- or underestimating the actual time used for activities (Bonke 2005; Kan 2008; Kan and Pudney 2008; Otterbach and Sousa-Poza 2010; Ricci et al. 1995; Robinson et al. 2011). Data collected using stylized methods tend to focus only on activities of interest for the specific study and rarely take into account when an activity was carried out or in what context. Stylized methods generally yield the estimated average time spent on an activity or set of activities, meaning that the timing and order of the activities and the relationships between them are not recorded.

In experiential sampling methods, respondents report on their activities and answer supplemental questions at randomized times, usually indicated using an electronic pager. Experiential sampling methods offer less bias and more exact discrete snapshot data than do stylized methods. Experiential sampling methods yield data about what an individual is doing at randomized times and typically do not collect data about what happens between those times. The method thus overlooks the flow of activities throughout the day.

Time-use diaries are usually compiled in one of two ways: either in interviews in which the respondent is asked to reconstruct a prior day, or by using a time diary in which the respondent is asked to record what activities are carried out, when, with whom, and where, as the day goes on.

These different approaches to data collection have different strengths and weaknesses (Bonke 2005; Juster et al. 2003; Otterbach and Sousa-Poza 2010), though of the three methods, only time-use diaries yield a record of a full day of activities, in order, *for each individual*. To perform a level III analysis, the data collected must capture the sequence of activities and their positions in the day; therefore, the focus will be on time-use diaries.

3.1 Time-Use Diaries

As noted earlier, time-use diaries permit one to record activities as they occur rather than recollecting them after the activities have transpired. Activities may be recorded throughout the day in various ways. One such way is to ask participants to use their own words to describe what they are doing. The written descriptions in the diary are later categorized by the researchers. Another way is to instruct the diarist to use predetermined categories of activities. The time used for activities and when they occur can be recorded using either variable time, in which the respondent notes the start time, and in some cases also the end time, of an activity, or using fixed time intervals, such as 10 min.

The American Time Use Survey (ATUS) conducted by the US Bureau of Labor Statistics uses telephone interviews in which the interviewee is asked to reconstruct the previous day (US Bureau of Labor Statistics 2012). The interviewee is asked what activities were carried out, in what order, and for how long. The Swedish Time Use Survey performed by Statistics Sweden in 2010 used paper time diaries with 10-minute intervals; respondents recorded their main activity in each time interval, either on the surveyed day or retroactively (Statistics Sweden 2013). Telephone interviews have the benefit of being more cost effective, but paper diaries have the potential to record minor activities that might “disappear” in the noise of everyday life.

A diary usually covers a specific period such as a day, or more rarely a week or a month. HETUS guidelines (Eurostat 2009) recommend 2 days, one weekday and one weekend day, justified mainly by fieldwork cost efficiencies (Gershuny 2011).

Time diaries record a sequence of activities, either in the form of a discrete sequence of time intervals or as ordered activities recorded using variable time. From this data, information about when and for how long an individual has carried out various activities can be extracted for analysis. At its core, a time diary has three features: it measures when during the day an activity takes place (timing), it indicates how long each activity lasts (duration), and records the number of times an activity occurs during the day. Information about with whom and where activities are performed is usually also included.

Background information on demographic factors and variables of interest to the researchers is generally collected. This information can be used to identify population groups for which aggregates can be calculated. Control questions are usually asked to ensure and strengthen the validity of the data.

4 Analysis of Diary Data on Time Use

The entries may begin with sleep and go on to record morning routines, breakfast, paid work, lunch with some time for other activities, resumed paid work, time for other activities, dinner, and finally some leisure time before going to bed when the day approaches its end (see Fig. 1, left). This is the principle of the sequence of activities used in the level III approach.

A distinction will be made between “activity,” used as a general denotation of what individuals do, and “occurrence of an activity,” used to specify each time an activity appears in the diary during the day. The left part of Fig. 1 shows the occurrences of the various activities performed.

4.1 Aggregated Analysis of Time-Use Diaries

The level II approach to analyzing time-use diary data entails aggregating all the time used for a specific activity, for example, paid work, leisure time, or childcare. This approach collapses the sequence of all occurrences of the studied activity into a sum of time used (see Fig. 1, right). One result is that the order of the activities is lost and the divisions between occurrences of the same activity are made invisible. The diarist’s day goes from being an ordered, continuously performed, but fractured (in terms of activities) sequence of occurrences of activities to sums of time spent on each activity performed during the day.

Aggregating the times of all occurrences of an activity decontextualizes each occurrence of the activity from surrounding activities that supplement it and enable it to be carried out. Also lost is information about when during the day activities are carried out.

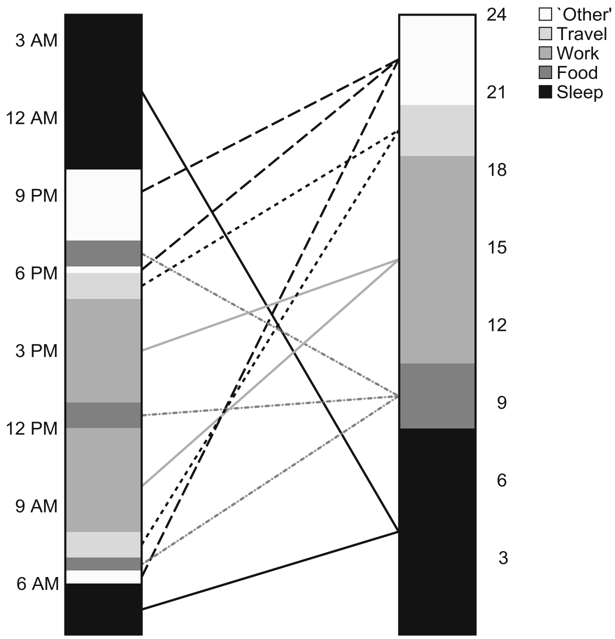


Fig. 1 Sequence of activities in the course of a day (*left*) and the same activities collapsed into 24-h aggregates (*right*)

There is arguably a difference between an individual who performs household work for an hour with no breaks and an individual who does household work for a total of an hour but does so in intermittent several-minute stretches while switching between other activities. This splitting of the activity is lost by collapsing the data into an aggregated sum.

When it comes to analyzing time use, Bolger et al. (2003) distinguish two approaches. The first one is aggregation over time, in which the time spent on an activity is summed over an individual's day and then compared with that of other individuals. A simple way to do this is to compare the mean time use of groupings of individuals, for example, the mean time spent on paid work by men and women.

The second approach is modeling, which is used to determine variations both between and within people. One way to model variations between people is to use regression analysis. Regression allows the analysis to include multiple predictor variables, such as background variables. An example of this would be comparing time spent on employment not only by men and women but also by level of education, age, and type of work. This approach attempts to take multiple variables into account to explore the time spent on paid work. Within-person models are models that explore developments over time for individuals. Such modeling can be used to analyze individual changes in the time used for a specific activity over time and how these changes compare with those of other studied participants. These approaches depend on a priori decisions regarding what to study, what groups to compare, and what predictors to use.

Modeling approaches have proven successful and applicable in various areas and usually use regression analyses (e.g., general and generalized linear models) as well as more descriptive statistics, means, proportions, and frequencies.

For example, Schneider (2011) tested gender performance theories and Baxter (2011) analyzed how flexible work and other work factors relate to parental time by using ordinary least squares (OLS) regression. Krueger and Mueller (2010) used Tobit and OLS regression to investigate the connection between meaningful time use and unemployment.

Regression models, however, are not without problems when dealing with time-use diary data. The data usually have a positive bias in which the number of individuals spending a shorter time on an activity is much greater than the number of individuals spending a longer time on it. Another problem occurs when there are individuals in the sample who have not undertaken the studied activity, for example, those who are unemployed or in part-time employment when analyzing paid work. The analysis will suffer because a large number of individuals did not use any time for the specific activity (Gershuny 2012).

There are ways of reducing errors, such as analyzing those who use no time for an activity separately from those who do use time for the activity. Another option is to use methods that do not violate the assumptions of the model. The assumption of normality, that is, that the distribution of values follows a Gaussian distribution, is often violated with time-use data due to the aforementioned positive bias. Brown and Dunn (2011) suggest using a generalized linear model (GLM) utilizing a Poisson-gamma distribution to avoid the assumption of normality made by OLS and Tobit models.

Regression models are limited to working with the length of time used for the activity, although the number of occurrences of activities during a day, or their order when analyzing multiple occurrences, can be used as covariate or predictor variables. This does not, however, maintain the connection between the time used and the *sequence* of activities.

Survival analysis[1] is a related approach examining the extent to which factors such as background variables contribute to the transition between states. For the purposes of this paper, survival analysis is considered an aggregated analysis because it uses probabilities based on aggregating the transitions between states.

Survival analysis is limited by how it treats the individual transitions between activities based on aggregated probabilities. The individual sequence of activities is analyzed based on probabilities derived from the sample. This disconnects the transitions between activities during the day from the individual. Survival analysis generally assumes that transitions depend on external factors rather than recognizing that the path an individual takes through a day depends on the individual's prior activities, prioritization of activities, and the goals.

4.2 Analysis of Activity Sequences in Time Diaries

Taking a point of departure in the time-geographic perspective, the amount of time spent on an activity is regarded as only one of many aspects of an activity. The number of times an activity occurs in the course of the day is of importance, as is the order of various occurrences of activities. As noted earlier, regression modeling using the sums of aggregates cannot directly handle this.

Handling large numbers of individual sequences by themselves is not feasible; attempting to analyze a large number of sequences qualitatively quickly becomes overwhelming. Vrotsou (2010) offers a way of handling this by visualizing the data and using algorithmic sequence mining to explore patterns of activities.

The order of activities performed by an individual as the day progresses can be analyzed using the sequences as a basis (Abbott 1990, 1995; Abbott and Tsay 2000). The approach entails using the patterns of an activity or activities and relating these to the individual as

[1] Also known as event history analysis in sociology or duration modelling in economics.

the unit of study rather than aggregating specific activities one by one, or relying on probability distributions over time. Sequence analysis has been used in the biosciences, particularly in analyzing DNA. Time-use data differ from bioscientific data as time-use analysis requires taking into account not only the order of the states and the transitions in each state, but also the temporality and duration of states.

In diary data, all respondents have the same number of "steps" in the day; if 1-min periods are used, there are 1,440 steps in 1 day. There are never more or fewer[2] than the number of minutes in a day.

The sequence analysis method is not based on probability distributions but is a descriptive method. This is a weakness of the method compared with regression analysis, as noted by Abbott and Tsay (2000) and Wu (2011).

The argument for using descriptive methods is that they provide the option of not using similarities in predefined socioeconomic categories for analysis, but instead similarities in the sequences of activities. Regression trees (Studer et al. 2011) can be created using the similarities of activities as a basis and then using background variables to explore the dependency of these activities on the sequences. Another possibility is to cluster the sequences and then explore background variables within and between these clusters. This puts in the foreground individuals' activities rather than the socioeconomic groups to which they belong.

5 Empirical Exemplification

The problem that will be used to compare the results of traditional level II analysis with those of time-geographic level III analysis is the difference between men and women with regard to time spent on paid work. Since this is a well-explored area, previous research provides a solid foundation for comparing the two approaches to analyzing how time is used.

In this example, only two variables are used, gender and time spent on paid work during the diary day. Factors not taken into consideration are whether the individual is employed part- or full-time and the individual's form or type of employment.

5.1 Data Used

The data used in this example are exactly the same for both approaches. The dataset consists of time-use diaries collected in a pilot study conducted by Statistics Sweden in 1996. For this exemplification, the diaries for the weekday were used and data were extracted for 464 respondents (233 women, 231 men). From the dataset, those who were *not* retired, enrolled in education, or unemployed were used to form a subsample consisting of 117 men and 123 women. The gender distribution in the subsample is considered even, $\chi^2(1, N = 240) = 0.15$, $p = .699$. All analyses were performed with R, version 2.15.3 (R Core Team 2012).

5.2 Analysis of Aggregate Time Use

As mentioned earlier, Bolger et al. (2003) distinguish two approaches to analyzing time-use data, aside from an aggregated approach, i.e., the comparison of averages and the comparison of variances within and between regression models.

[2] Exceptions being the day an individual is born and the day the individual dies.

By comparing averages, gender differences in time use can be analyzed by aggregating the time used by individuals in paid work, accounting for the means, and then comparing them. In the example, the men's mean is 434.37 (SD = 202.66) minutes in paid work, whereas the women's mean is 327.16 (SD = 199.97).

To compare means, an independent samples *t* test can be used, though this is problematic in this case, since a Shapiro–Wilk test of normality indicates that the time used in paid work cannot be considered normally distributed ($W = 0.898$, $p > .001$). A non-parametric alternative such as Mann–Whitney is also problematic, as 39 individuals (13 men and 26 women) had zero employment minutes during the measured day (see Fig. 2).

The problems of normality and the fairly large number of individuals with 0 min of paid work (16 %) can be overcome by using regression modeling, meaning that rather than comparing averages, the variations are analyzed. To perform this analysis of the skewed data, a Poisson-gamma GLM was used, as suggested by Brown and Dunn (2011).

The Poisson-gamma GLM indicates that men and women differ in the time they spend in paid work ($p < .001$; see Table 1). For the GLM analysis, the R libraries tweedie (Dunn 2013) and statmod (Smyth 2013) were used to calculate the Poisson-gamma index P, yielding a value of 1.1 for the Poisson-gamma distribution.

This approach does not yield any information on *how* men and women differ in their time use; it states only that their aggregated times do differ. This analysis could be improved by adding the number of times the activity occurs during the day as a predictor or covariate. Another option would be to use survival analysis. However, neither of these options uses the *whole unbroken sequence* for analysis.

5.3 Analysis of Sequences

To account for the whole sequence, a method of analysis is required that uses whole sequences. There are several methods for measuring similarities and distances between sequences. The method used in this example is optimal matching from the R package TraMineR, developed by Gabadinho et al. (2011). Optimal matching uses insertions, deletions, or substitutions to "transform" one sequence into another. This use of insertions, deletions, and substitutions has costs that are algorithmically minimized and then summarized into a distance matrix. This distance matrix can then be used as a basis for clustering the sequences. The results of optimal matching are dependent on how the costs of insertion and deletion (indel) and of substitution are determined. Lesnard (2010) explores the effects of indel and substitution costs when using the optimal matching for temporal patterns and concludes that a choice must be made between focusing on when an activity occurs (timing) and whether the patterns (of time used and fragmentation) are similar. A simulation study conducted by Lindmark (2010) demonstrated that it was preferable to use transition rates computed from the sequence data for substitution costs; due to the very minor effects of varying the indel cost, an indel cost of 1 has been used here.

Unsurprisingly, the sequences of paid work indicate a heavy occurrence at midday (Fig. 3). In the figure, the respondents are on the *x*-axis and the minutes in the day on the *y*-axis. A vertical line represents the day of an individual, and the part of the day he or she spends in paid work is shown in black.

The results of the optimal matching were then used in clustering the sequences. For this purpose, Ward's method was used to extract three clusters, which can be found in Fig. 4. The third cluster has the pattern of a "common workday." The time spent on paid work is centered on midday, with a typical break for lunch. Compared with the third cluster, the

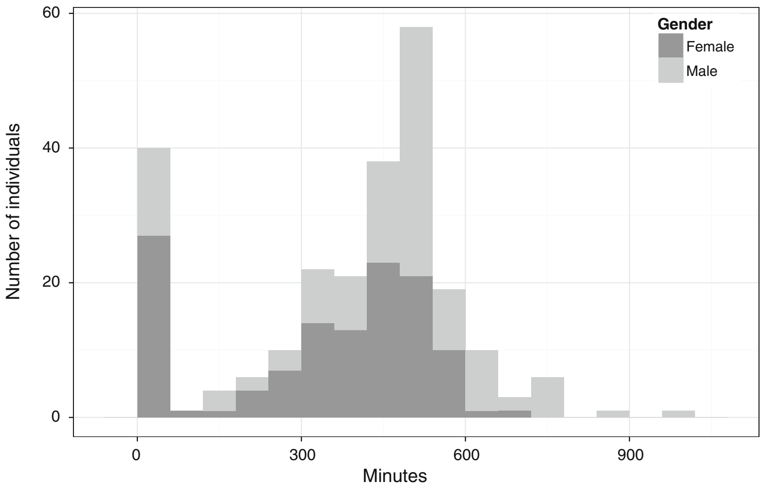


Fig. 2 Histogram of time used for paid work

Table 1 Poisson-gamma GLM of time in paid work and gender

	Estimate	SE	t	p
Intercept	5.79	0.052	112.058	$p < .001$
	0.28	0.069	4.072	$p < .001$

first cluster represents a more "scattered" day, suggesting that it captures those in employment who do not follow the common workday pattern. The second cluster is largely empty, and represents those who did not work on the diary day.

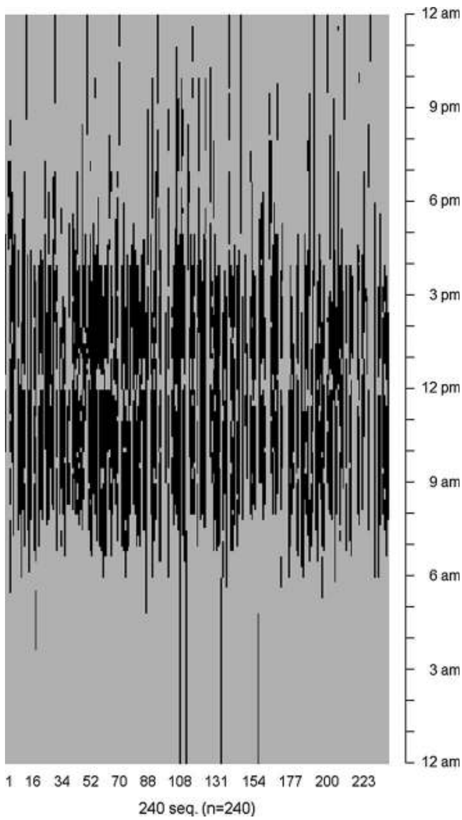
Table 2 shows the gender distribution across the clusters. A Pearson Chi square test of gender and cluster is significant, $\chi^2(2, N = 240) = 18.45$, $p < .001$.

Closer inspection of the standardized residuals (Agresti 2007) of the gender distribution (Table 2, in parentheses) reveals that the gender distribution is skewed in all clusters. The first two clusters are skewed toward women, whereas the third is skewed toward men.

The clusters can also be used in comparing the aggregated time used in each cluster. The third cluster, which captures those with a common workday, indicates the longest time spent on paid work (M = 519.69, SD = 101.55) followed by the first cluster (M = 333.74, SD = 101.55). The second, as evident in Fig. 4, indicates exceptionally little time spent on paid work (M = 1.51, SD = 94.79). The first and third clusters differ significantly with regard to time spent on paid work. An independent samples t-test, $t(197) = -13.52$, $p > .001$, indicates that those in the first cluster spent less time on paid work than did those in the third cluster.

For the first cluster, testing for gender differences in time spent on paid work using a Welch's t-test indicates no significant difference, $t(61.40) = -0.23$, $p = .817$. For the second cluster, only two out of 41 (5 %), both female, have any time value (13 and 26 min), so no test will be conducted. As the distribution in the third cluster is positively skewed and cannot be considered normally distributed ($W = 0.20$, $p > .001$), a Mann–

Fig. 3 Sequences of the activity of paid work from midnight to midnight; time used in paid work is indicated in *black* and other activities are in *gray*



Whitney test was used. The test is significant ($U = 1807.5$, $p = .03$), with men working longer (Md = 520) than women (Md = 500).

A conclusion that can be drawn from the analysis of the clusters is that men and women differ in the amount of time spent on paid work and also in how their work patterns are distributed over the course of the day. Women work more scattered hours than do men, and more of them were in the non-working cluster. This may be a consequence of women working more part-time hours than do men, and of their not having been at work on the measured day. No difference between the genders in time spent on paid work can be found in the two first clusters. Men are more frequently found in patterns that correspond to the common workday, with men in this cluster spending on average more hours in paid work.

6 What Difference Does a Method Make?

The two analytical approaches answered essentially the same basic question: Does the time spent on paid work differ between men and women? They both reached essentially the same conclusion, though they treated the data differently. The aggregated approach treats the time used for activities as the most important factor and disregards when activities are carried out or whether the activity appears in a scattered or collected pattern in the course of the day. The sequence analytical approach, on the other hand, takes into account when

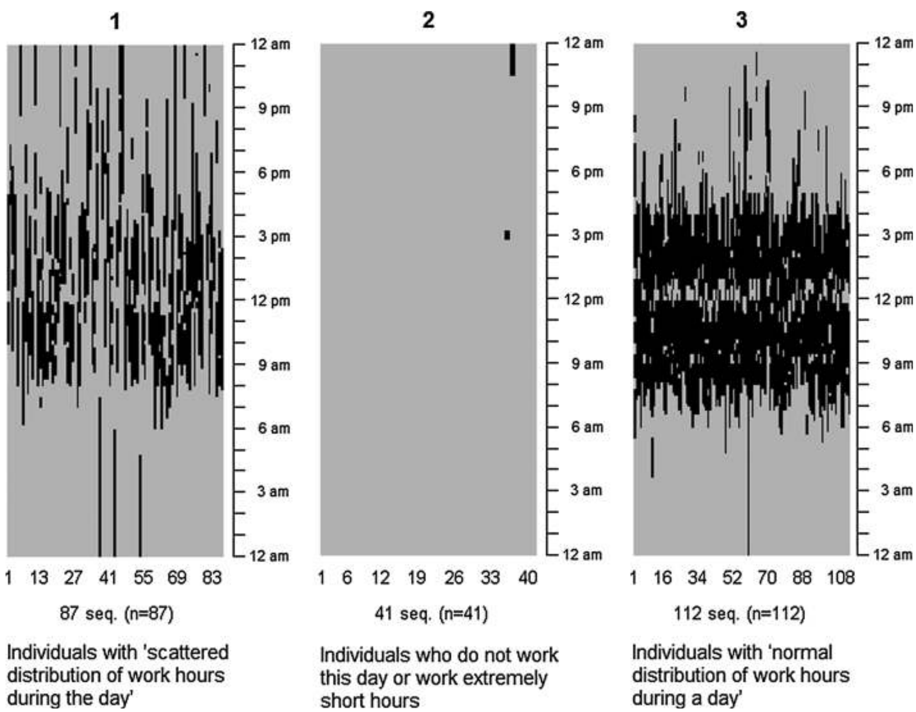


Fig. 4 Sequences of the three clusters

Table 2 Gender distribution across the clusters with standardized residuals in parentheses

Cluster	1	2	3	Total
Female	54 (2.53)	28 (2.40)	41 (−4.25)	123
Male	33 (−2.53)	13 (−2.40)	71 (4.25)	117
Total	87	41	112	240

paid work activities are carried out, and then uses clustering to generate subgroups for further analysis.

There are differences in the logic and assumptions underlying these methods, and in their views of what time use is.

6.1 Differences in Logic

Aggregated analysis is generally a macro-oriented approach used to identify the effect of background variables; it entails an underlying assumption that activities can be isolated from their context. Another assumption is that time use can be predicted from background variables independent of their context.

The logic of aggregated analysis (levels I and II) singles out one activity as the unit of analysis. This limit may be inherent to the type of statistical method used; regression analysis requires one or more outcome variables and a set of predictors. Increasing the number of outcome variables drastically increases the complexity of the model and quickly becomes problematic.

Using a level III approach entails a holistic perspective in which the sequence of everyday activities is as important as the time spent on various activities. In accordance with the time-geography approach, a level III analysis leads to questions of how the myriad activities carried out during a day fit together, and whether explanations for why activities are performed can be found in their context. Hence, the individual and his or her full activity sequence over the day is the unit of analysis.

During a day, an individual may perform 20 different activities spread over 50 time slots, indicating that some activities occur several times while others occur only once (Ellegård 2006). Individuals do not carry out their activities in chunks, but on scattered occasions throughout the day (cf. Fig. 1, left). There is value in taking this into consideration because, while aggregated time spent on a specific activity may indicate its importance, using the pattern of the occurrences of an activity may help indicate how the activity fits into the day.

Using the typology of time use presented by Ås (1978), the various activities carried out during a day have different priorities. Necessary time will affect the proportion of free time, while contracted time will structure the day in ways the individual is unable to change due to authority constraints. How much time is spent on various activities during a day arguably depends more on the individual's context than on the activity performed. The various time-geographic constraints limit the individual and how large a proportion of the day the individual can commit to contracted and necessary time.

When a basic socioeconomic category is used for comparison in the aggregated approach, the basic socioeconomic category is used to divide the empirical material. Categorization via clusters, on the other hand, is based on the empirical material regardless of how the individual fits into socioeconomic categories. In essence, in aggregated analysis the categories into which an individual falls are more important than what he or she is doing during the measured time period, while in the integrated time-geography and analysis of sequences approach, the reverse is the case.

6.2 Difference in Methods

Although the difference between the two approaches may appear to be mainly in their focus, there is also an underlying methodological difference. They differ in what is regarded as important: Is it the activities themselves or the activities in the contexts in which they are carried out that are important? Is the order of the occurrence of activities important, or is it the aggregated time used?

The two approaches are based on two different perspectives in this regard. From the aggregated perspective, how, when, and how much of an activity an individual does is seen as rooted in background variables. The socioeconomic groupings to which the individuals belong are regarded as more important than when they do an activity. In contrast, when using a time-geographic perspective and applying a sequence analytical approach, the focus is instead on the overall pattern of activities.

Regression modeling and survival analysis are based on the assumption that aggregates are essential, and factors such as background variables and the distributions of aggregated probabilities among transitions are fundamental to the analysis. In contrast, sequence analysis treats the order of activities during the day as the core and then deploys background variables in exploring the emergent patterns. Both methods are concerned with what individuals do, but differ in their view of why individuals do what they do. From a level II perspective, what characterizes an individual socioeconomically is more important than what he or she does, while level III analysis essentially turns this perspective around, and treats what individuals do as more important than the socioeconomic characteristics ascribed to them.

The aggregated and the time-geographic approaches differ in their assumptions. Regression modeling in level II is based on probability distributions. Such methods are generally well explored and their strengths and weaknesses are fairly well established. The characteristics of time-use data generally give rise to problems. Often many individuals included in a study manifest low or no occurrence of the studied activity. This can be handled by breaking the sample into groups better suited to the assumptions made by regression modeling or by using methods that have relaxed assumptions.

Using a level III analysis from a time-geographic perspective combined with sequence analysis involves two methods, optimal matching and clustering. Both these methods have the weakness that they lack a basis in probability distributions on which to base interpretations and validation. The results of optimal matching depend on the costs of insertion and deletion (indel) and of substitution. The value of indel cannot be determined a priori, but must be found through referring to earlier research, theory, or the choice of the researcher. Substitution costs can be calculated from the sample or set by the researcher.

The second step is clustering. There are multiple approaches to determining the number of clusters to extract, but none that is based strictly on probability distributions. The researcher must make interpretations and the final decision about the clusters. Different clustering methods generate different results. The method used in this example is Ward's method, which is an agglomerative hierarchical method that requires less optimization than do other clustering methods. In this paper, Ward's method was used mainly for demonstration rather than explorative purposes.

Applying a level III analysis requires that more decisions be made along the way. While the study may benefit from the greater interactivity with the material, the method may reduce the validity of the results due to its increased fragility. It can be argued that sequence analysis trades some strengths of the aggregated analysis to take the context of activities into account. The value of this depends on the research question asked and the theoretical framework applied. While the methods used in the level III approach require more care than do traditional methods, they also yield another layer of results.

6.3 Different Views of Time

A more subtle difference between the two approaches concerns their views of time. I would argue that an aggregated method perceives time as a capital good, something an individual can use and budget. As with a normal household budget, individuals must spend some of their capital (time) on things such as sleep and work. From a time-geographic perspective, time is perceived as a frame within which each individual conducts the activities of his or her various projects. This frame limits the number of projects and also structures when they can be carried out (coupling constraints).

Both perspectives are valid. On one hand, daily life is often interrupted and is structured around planned and unplanned events. On the other hand, daily life does have consistency, routines are followed, and individuals usually have long-term projects in hand, such as raising a child or learning a skill. In both cases, the whole sequence of activities performed over a day helps us understand and analyze the contexts of everyday life.

7 Final Comments

Applying a level III analysis and basing it on a time-geographic theoretical framework that takes account of the consequences of analyzing sequences of rather than aggregated activities adds another layer to our understanding and analysis of what, for how long, and when activities are carried out. The individual's sequence of activities during a day depends on multiple factors. External factors such as coordinating with others (coupling and authority constraints) and social factors such as income, gender, age, education, and health (capacity constraints) influence what individuals do and how their everyday lives are arranged. Internally, how individuals view their life, ideas, and dreams influences how they arrange their time. All levels of analysis are arguably important when trying to understand what influences how individuals use their time, though they do yield different perspectives and understandings of time use.

The level III analysis with the time-geography theoretical framework presented here uses sequence analysis that treats individuals as analytical units, whereas in level I and II analyses the analytical unit is the activities. In the time-geographic approach, individuals are primarily grouped either with other individuals who act in a similar way or with individuals in their households, whereas in the aggregated approach they are primarily grouped with other individuals in the same socioeconomic categories. How data are treated, what questions are asked, and what analytical methods are used all influence not only the results, but also our perspective when analyzing how individuals live their lives.

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