Time use diary design for our times - an overview, presenting a Click-and-Drag Diary Instrument (CaDDI) for online application

Oriel Sullivan[1], Jonathan Gershuny[2], Almudena Sevilla[2], Pierre Walthery[2] and Marga Vega-Rapun[2]

1. Corresponding author: Centre for Time Use Research, University College London, 18 Woburn Square, London, WC1H 0NR, o.sullivan@ucl.ac.uk

2. University College London

Abstract

The recent global pandemic, involving restrictions on movement, social distancing and the displacement of many work activities to the home, has created an upsurge of interest in changes in the distribution and sequencing of our daily activities. Time use diary data is recognised as the leading source of evidence on this topic. The purpose of this paper is to provide a timely overview of the current *state-of-the-art* in respect of the designs of time use surveys with a view to online/smartphone deployment. It has three parts: firstly, we briefly summarise the main reasons for using diaries to collect time use information (as opposed to survey questions), and we sketch out the long tradition of time-use research from which these designs emerged. We then outline the main methods currently deployed to collect time use data, with the focus on online and smartphone app instruments. Finally, we present a detailed example of a specific kind of online diary design, the Click-and-Drag Diary Instrument (CaDDI), that may be of particular interest in respect of the sudden demand for new data on time use as it is both user-friendly to complete and capable of timely adaptation and deployment.

1. A brief introduction to time use diaries; why we need them, and how we got here

Everything we do, we do in time. Just as in physics and spatial navigation, so in social science, public health and the study of environmental sustainability, the measurement of activities in real time is of central importance. The best measurement technique for this type of data is the time use diary: the collection of the continuous stream of daily activities, with reported start/finish times, from which researchers can estimate both durations and sequences. Time use diary data is by now

recognised as the 'gold standard' for the collection of information about people's use of time (Cornwell, Gershuny and Sullivan, 2019; Gershuny et al, 2019). Questionnaire approaches based on recall (asking how much time a respondent spent in a particular activity over the past week, for example) are of limited use for this purpose, since respondents are in general unaware of totals of time devoted to specific activities, and are rarely asked about their activity sequences. In order to point to the main considerations involved in designing a time use diary survey, it is, however, first necessary to consider this alternative in more detail, as it still represents the most commonly used standard 'time-use' add-on to many major nationally-representative surveys.

Time use survey questions are usually framed in two different ways: 1) an estimate of the frequency with which one undertook a particular activity over a given reference period – for example, the past week or month (as used, for example, in the Millennium Cohort Study and the Avon Longitudinal Study of Parents and Children); and 2) an estimate of how much time one spent in a given activity over a given reference period (for example in the U.S. Panel Study of Income Dynamics, the U.K. British Household Panel Study/Understanding Society and the Australian Household Income and Labour Dynamics survey to look at housework time). Such measures are widely used, but all involve assumptions about how accurately we remember our time; methodological work comparing diary responses with questionnaire responses shows that the latter are far less accurate. It has been found that men tend to overestimate their housework time, while women may underestimate theirs (Kan and Pudney, 2008; Schultz and Grunow, 2012). Similarly, men who work longer hours tend to overestimate their working time, while part-time employed women tend to underestimate theirs (Walthery and Gershuny, 2019). The question "how many hours did you spend in your job last week?" or "how many hours did you spend doing general housework" tends to unreliability partly due to a failure of recall; we do not, as part of our normal routines, undertake the various mental processes that would be necessary to answer this sort of question accurately. Guesses are then subject to normative bias; we are likely to be influenced by a desire to *represent ourselves* in particular ways by exaggerating or minimising the time we devote to particular activities. These two sources of error, respectively, recall and normative bias, are known to distort the responses that people give to these sorts of questions (Juster and Stafford, 1985).

Time use diary research has a long history, stretching back to its origins in the late 1800s, and current best practice in diary design is the outcome of this long tradition (for a fuller description of the history see Cornwell, Gershuny and Sullivan, 2019). The modern history begins 60 years ago when media broadcasters – including the BBC - played a role in deploying large samples of diarists to estimate the daily habits of radio listeners and television viewers, to use as a guide to programming through the day and the week, and also to provide a basis for estimating audience sizes to guide the pricing of advertisements (Converse and Robinson, 1974). By the early 1960s large diary-based time use studies were underway in many countries including Czechoslovakia, France, Hungary, Poland, Japan, and the UK. This extensive pre-history meant that by the time of the first properly designed, *ex-ante* (pre-fieldwork) harmonised cross-national time use study, funded in the mid-1960s by UNESCO (Szalai, 1972), there was already a considerable international convergence of research practice. The 12-country dataset that emerged from the Szalai study, one of the first cross-national comparative studies on any subject available to social scientists, popularised a design of time use diary surveys that continues, with variations, to the present time.

The next substantial exercise in *ex-ante* harmonised cross-national comparative time diary collection, the Harmonised European Time Use Survey (HETUS), organised by Eurostat (Gershuny, 1995, Eurostat, 2009) has collected two tranches (1999-2006 and 2009-2015) of nationally representative data for all the larger EU countries. The American Time Use Study (ATUS), run by the US Bureau of Labor Statistics, departs from the basic Szalai protocol, in particular by collecting only a single activity category per timeslot. But it has been collected continuously from 2003, with annual releases of data, and is the largest source of time diary data collected anywhere. The Multinational Time Use Study (MTUS) archive, assembled, harmonized and disseminated by the ESRC Centre for Time Use Research (CTUR) at UCL is by far the largest available collection of comparative and historical time-use materials, with 1.5M days from 85 surveys in 26 countries, all harmonised *ex post,* most of the data freely downloadable for use by academic researchers (www.timeuse.org/mtus; see Fisher and Gershuny, 2016).

2. Time use survey design – considerations

There are several initial considerations to take into account when designing a time use diary survey:

- Mode of collection (paper, online, smartphone).
- Number of activity categories ('full' = own-word, or 'light' = pre-coded activity list diary)
- Diary information fields (main activity only, or additional information like secondary activities, who co-present with, location/travel mode, enjoyment etc.)
- Timeslot length (user-reported start/finish times, or defined timeslots e.g. 10 minutes, 15 minutes etc.)
- Number of diary days collected (single day, weekday and weekend day, other)

Below we outline the main design alternatives currently in use, focussing first on the above considerations in relation to traditional pen-and-paper-based diaries, and then discussing new methodologies designed for deployment online or as smartphone applications.

2.1 Paper-based time use diaries

Time use diaries have traditionally been pen-and-paper based, in the form of a small booklet left behind by an interviewer for respondents to complete on a designated day or days, or completed in retrospect ('day-before interview') by an interviewer during an arranged call-back interview. This has been the standard method of collection, and all nationally-representative time use diary surveys included in the MTUS archive were collected in this way (including the most recent nationally-representative UK 2014-15 Time Use Diary Survey – UKTUS 2015). In respect of the number of activity categories recorded both options ('full' and 'light') are available for paper diaries.

Full diaries

In 'full' diaries, respondents write in their own words what they are doing, and, post -survey, coders code up their responses into typically up to 300 categories of different activities (which may then of course be amalgamated into smaller clusters of activities). These full diaries are the gold standard for large-scale nationally representative surveys, such as the UKTUS 2015 and the rest of the Harmonised European Time Use Surveys (HETUS). Figure 1 shows an example of this type of diary – that used in the UKTUS 2015 (Gershuny and Sullivan, 2017). The diary has rows representing successive 10-minute timeslots, and separate columns in which respondents record: "what were you doing?" (primary or main activity); "were you doing anything else at the same time" (secondary activity); "where were you?" (location/model of travel); and "were you alone or with somebody you know?" (co-presence). The two activity columns are each coded into over 250 distinct activity categories. An innovation of this particular survey was the addition of two columns recording whether the respondent was using an electronic device (smartphone/tablet/computer), and how much she/he enjoyed each 10-minute timeslot.

The level of granularity afforded by using 10-minute timeslots strikes a good balance in terms of reducing respondents' burden (in terms of having to remember exact start and finish times), while enabling them to complete a full record of their activities (it also facilitates the process of subsequent transposition into a data file). Activities that last longer than 10 minutes can be recorded with a line drawn across the relevant time slots – as in the example shown in Figure 1. The obvious ambiguity here lies in how respondents will record activities lasting *less* than 10 minutes; will they ignore them, record them as secondary activities or record them as lasting the full 10 minutes? This ambiguity necessitates a trade-off between the complexity and length of the diary (if timeslots lasted only one minute, for example), and accuracy of record. The general judgement is that 10-minute timeslots are optimum, and timeslots longer than 10 minutes are considered less reliable because it increases the chances that respondents will have to choose (in some way that is not accessible to the researcher) between different activities that they have done during that time.

The UKTUS 2015 comprised a two-day diary, collecting information for a randomly sampled weekday and a weekend day from each respondent. The two-day sampling design reduces cost and respondent burden in comparison to a week-long diary, but it ensures the collection of information for the types of days of the week that are most different in terms of activities – weekdays and weekend days – and so increasing the reliability of the data. This is the design used for the HETUS; the American Time Use Survey, by contrast, relies on a single day diary per respondent (thereby losing the option to distinguish weekdays from weekend days for the same respondent).

Light diaries

So-called 'light' diaries are designed to lower both respondent and coder burden and include a restricted menu of activities from which respondents may select, rendering it, in its paper form, less detailed than the full diary. Figure 2 shows the light diary used in the Understanding Society Innovation Panel 7 survey. The diary is formatted into a day's sequence of timeslots across the page, and respondents indicate by marking on the diary (with a tick or continuous line) which

Figure 1. Completed 'full' diary example: The UK time use diary 2015

Figure 2: Completed 'light' diary example from the Understanding Society Innovation Panel 7

precoded activities they were doing at what times. The aim is to restrict the size of the diary and make it simpler to complete, so respondents can choose from a limited set of activities (generally between 30 to 40 activities). This diary format, developed by the CTUR, was used in the Understanding Society Innovation Panel diary in 2013, and in the Millennium Cohort diary add-on of 2014 where pen-and-paper administration was compared with both online and smartphone app-based instrumentation in a mixed mode experiment among young people (see Chatzitheochari et al, 2018).

In an era when life is inexorably moving online, and in which online surveys and smartphone apps have been increasingly prominent in producing rapid (if not always accurate) results, attention has switched more recently to considerations of how it might be possible to collect time use diary data of good quality in a digital format.

2.2 New device-based instruments to collect time diary data

Attempts to collect time use data using apps and online devices are a relatively recent development. An advantage of internet or app-based techniques is that they are able to overcome one of the restrictions of the light diary format by providing the possibility of using 'unfolding' (sequentially nested) lists of activity with levels of detail about activities potentially rivalling those of full own-words time use diaries.

In terms of design there are currently three main approaches, that vary in terms of the completeness of their collection strategies. The 'point-estimate' approach, developed mainly for collecting information on how people are feeling at particular times of the day, relies on the sampling of a few activities through a designated day. This permits calculation of the average time spent in different daily activities across the sample, but not crucial information on activity durations or sequence information (for example, the duration of leisure activities, and what activity interrupts them, by gender; Gershuny, 2004). The other two approaches (the survey-like 'modular' approach and the light-diary-like 'click-and-drag' approach) follow the diary method, collecting the full sequence of activities across the day; necessary if one wants to analyse the timing or sequencing of activities. We now describe each of these in turn, using examples.

Point-estimate approach

This approach, often referred to as the Experience Sampling Method (ESM) has been used to collect information on the subjective experience of activities. Respondents are alerted (sampled) by smart devices at random points during the day and asked to complete a series of questions about what they are doing and how they are feeling. The American Time Use Survey (ATUS) used a variant of this method to collect information on 'mood' in its well-being module (fielded from 2010 to 2013), in which respondents were asked to recall how they were feeling at 3 randomly-selected points of the day during the interviewer-collected 'day-before' ATUS diary. This technique was promoted as a means of collecting time use information by Kahneman and Krueger in their 'Day Reconstruction Method' (Kahneman et al. 2004). A prominent UK example, collecting big data from a non-random volunteer survey, is the 'Mappiness' project which relies on a smartphone app to collect feelings of subjective affect (including 'happiness'), together with co-presence, location and activity (Bryson and MacKerron, 2017; see the website at https://www.mappinessapp.com/).

The obvious disadvantage of this approach in respect of the full potential of time use data analysis is that only a limited range of activities per day are sampled and identified. Although populations distributions of time spent in different activities may be estimated in this way, there is no option for analysing episode durations (for example, the experience of longer versus shorter periods of leisure) or activity sequences (such as, for example, the enjoyment of a particular activity when it is preceded or succeeded by another activity).

Survey-like 'modular' approach (e.g. Modular Online Time Use Survey - MOTUS)

This method has been developed by the TOR research group at Vrije Universiteit Brussel (e.g. Minnen et al, 2014; for a recent online example designed for collecting information in the current Covid-19 crisis see https://www.everydaylife.eu/). The design involves respondents initially selecting the start and end time of their first main activity of the day, and then the activity itself from drop-down menus. This is followed by the collection of further information for that activity period, such as secondary activities, who the activity was done with, and location information. And so on through each main activity of the day. Figure 3 illustrates in the left hand screen the time log information (taken from the app version of the instrument) for main ('primary') and any secondary activities done at the same time, and the collection of the context information for the same main activity episode in the right hand screen.

Figure 3: Diary example using the 'modular' approach (MOTUS)

Figure 4 illustrates the final main activity timeline for the day. MOTUS is available in both online and smartphone app modes, and Eurostat is considering implementing this approach for the

online version of the HETUS, while the UK Office of National Statistics are developing a version to trial as an online approach to time use diary surveys.

Figure 4: Timeline for diary day (MOTUS)

The Click-and-Drag Diary Instrument (CaDDI)

The 'click-and-drag' approach is a direct development of the light diary format, designed for online use. The approach was developed by the CTUR and implemented, in collaboration with Trajectory Partnership, in a 9-country time diary survey designed to collect cross-country comparative information on the enjoyment of activities (Trajectory Partnership, 2016). Respondents use a click-and-drag tool, initially dragging a pointer across a horizontal timeline bar (marked up in timeslots across the hours of the day) to create a record of the length of time they spent doing each main activity. Activities are identified using drop-down menus and are shown on the timeline bar in different colours. The screen is filled in the same way with successive rows of information showing, for example: secondary activities; who the respondent was with at the time; where they were; and how they were feeling at the time, so that the total picture represents in visual form a day's worth of time use. Figure 5 shows a screenshot of the completed diary.

This alternative to the modular model is intuitive to complete, and may be less costly in terms of repetitiveness for respondents, avoiding the burden of having to enter each main activity time-log, followed by iterated lists of drop-down menus to complete the remaining diary fields for each main activity episode. This design also facilitates a data structure familiar from the analysis of sequential life-course data – in which a change in any one of the fields identifies a new 'episode' (i.e. a point in time at which the situation changes – the location, perhaps, or who the respondent is with at the time), permitting greater flexibility in analysis. The substantive implications of these two approaches to data structure are illustrated in the final section of this article.

We describe the CaDDI instrument in more detail in the next section, including a link to a demonstration video illustrating its completion. We are currently in the process of designing a matching smartphone app-based instrument to accompany the online version.

3. Online time use diary surveys for rapid deployment: A 'click-and-drag' example

The recent global pandemic has created an upsurge in interest in the ways in which people are using their time under conditions of lockdown and social distancing. The requirement is for a diary instrument with an online format that can be rapidly administered, and in which respondent burden is not too onerous.

The CTUR 9-Country Click-and-Drag Diary Instrument (CaDDI) was originally designed for deployment among an international online market research panel covering 9 different countries. The initial aim was to fill the gap in national comparative data on the enjoyment of different activities (the UKTUS 2015 was among the first national-level time use diary survey to include a field asking respondents how much they were enjoying their time throughout the day). Nine nationally comparative populations in Europe and the USA were covered: UK; USA; France; Germany; Netherlands; Sweden; Finland; Italy and Spain. The data was collected between November 2015 and May 2016 using quotas on socio-demographic factors such as age, gender, education and employment, with a minimum number of respondents guaranteed according to nationally representative quotas. Each country provided over 1,000 'diary days' of data, with a total sample of more than 10,000 days of data across the 9 countries, based on interviews with 6,000 respondents, most of whom completed 2 diary days. By using the same instrument and an identical visual demonstration video in all countries, the 9-country data is uniquely well-placed for international comparisons. An article by the CTUR team based on this data combines location and 'who were you with at the time' information to identify baseline (pre-lockdown) prevalence of 'risky' behaviours likely to be associated with transmission of the Covid-19 virus in different countries (Gershuny et al, under review).

Respondents completed a 10-minute recruitment/profiling survey including the standard range of socio-economic and demographic questions, and then completed two diaries, one for a weekend day and one for a weekday. The 'click-and-drag' diary approach proved effective. Instructions included a simple 3-minute visual online demonstration, and the average time taken to complete the diary was 15 minutes per diary day. Response quality was good, with unusually low levels of missing primary activity data (overall 6 minutes/day missing[1]).

The main advantage of CaDDI for online deployment is that it is collects the entire sequence of activities and a complete set of information fields through the whole diary day, while being intuitively easy for respondents to complete by moving across the day's timeline. The complete diary creates a visually interesting and informative picture of the day's activities for the respondent. All these features recommend it for adaptation and use in a context where timely deployment of an instrument for the collection of time use data is needed.

While we opted for a range of diary information fields for the 9-Country Study to match the specifications of the UKTUS 2015 (main activity, secondary activity, location, who with, device use and enjoyment), the design enables amendment either to include fewer fields (in which case completion time could be reduced), or to enhance, expand or amend the range and number of fields. For example, in the current Covid-19 crisis, during which the extent of social contact has

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[1] Excluding those <1% of diaries where >70% of the information was missing

become a major issue in research on transmission of the virus, the 'who you were with at the time' field could be significantly expanded to include a wider range of possible social contacts, and amended to give an indication of what kind of contact was involved (e.g. 2 metre distance only; or closer than that). Similarly, fields describing other aspects of 'affect' could be added alongside the enjoyment field, indicating levels of stress, anxiety or boredom judged relevant to the current situation. A version of the instrument (for use online and on smartphones) is currently under development for these purposes.

A completed CaDDI diary is shown in Figure 5. Note that in the completed diary the record for the entire day is displayed, in colour, allowing easy visualization across the day and permitting the identification of any gaps, errors or inconsistencies, that may then be edited. An illustration of the completion of the CaDDI follows, using screenshots (Figures 6 through 12). The demonstration file from which these screenshots were taken is available here: CaDDI demonstration video (mp4 file).

Figure 5: The completed online Click-and-Drag Diary Instrument (CaDDI)
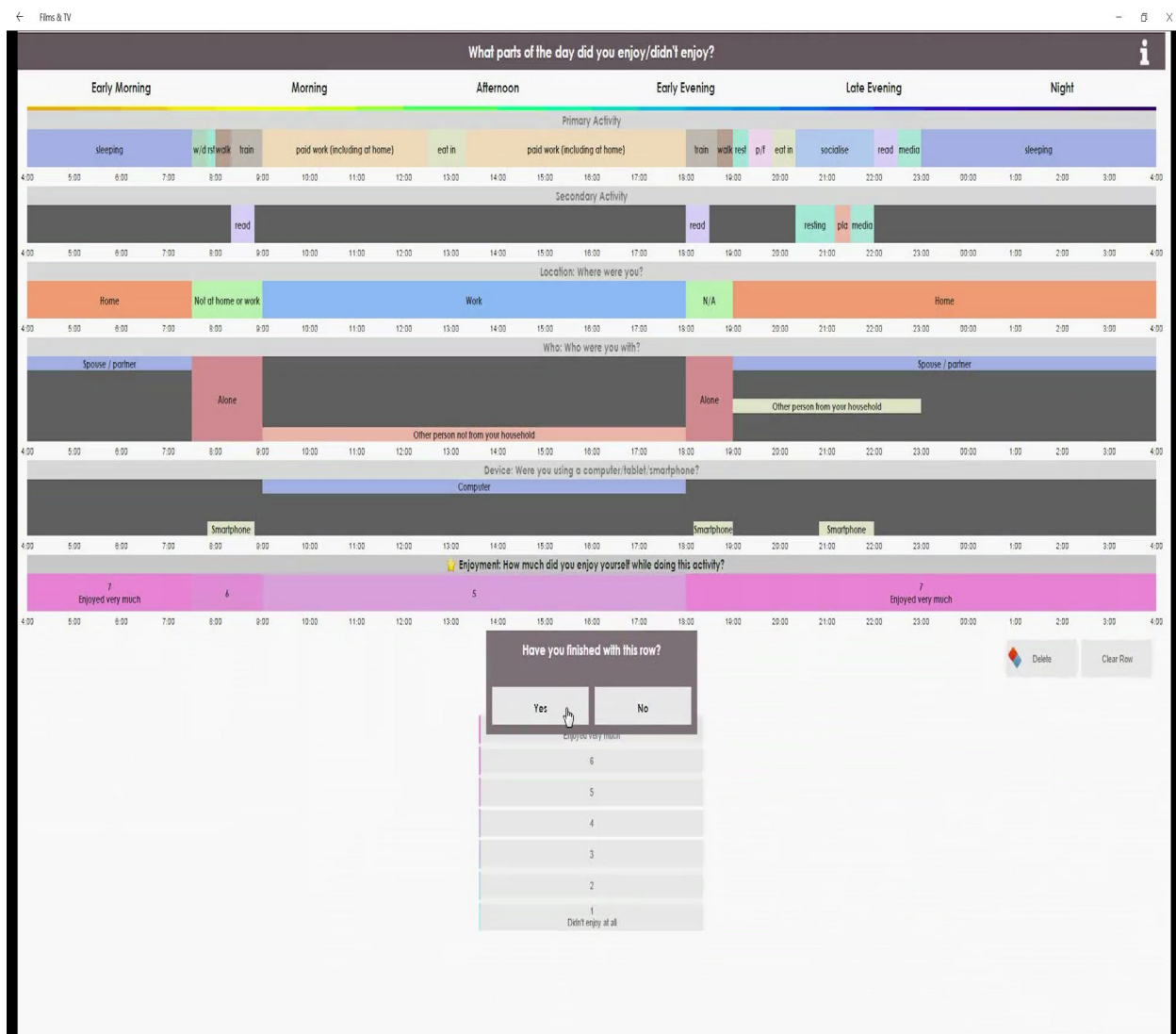
Figure 6: Filling in the main activity: initial screen view (CaDDI)
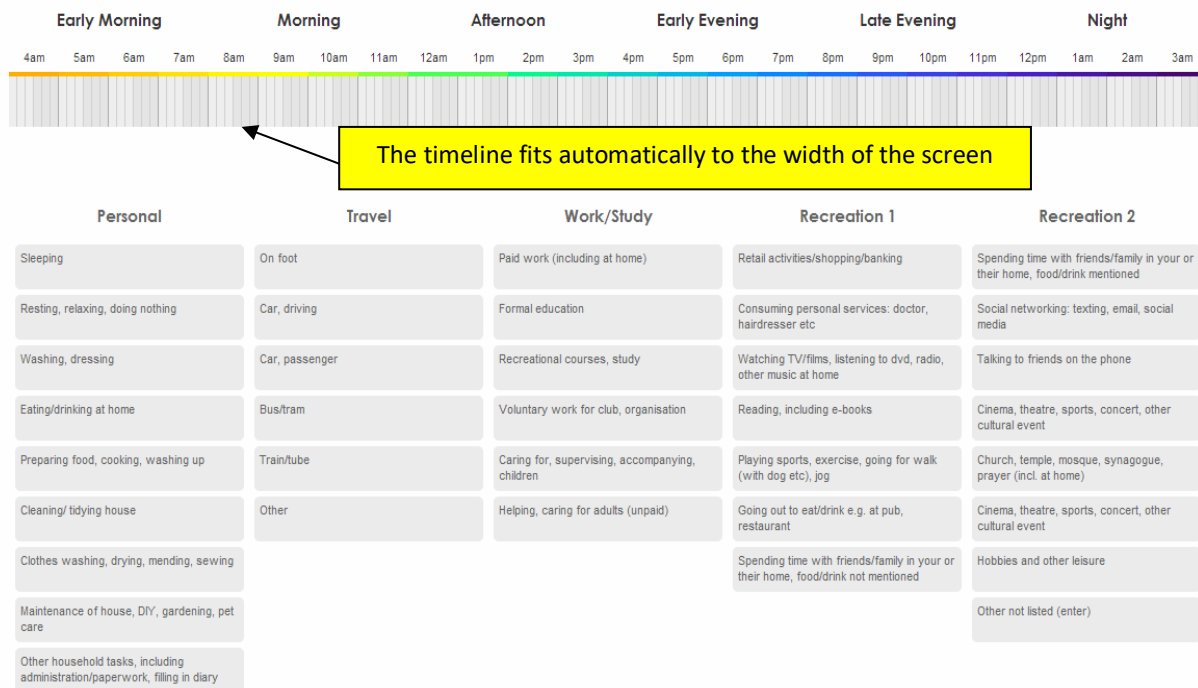
Figure 7: The respondent selects an initial activity category (CaDDI)
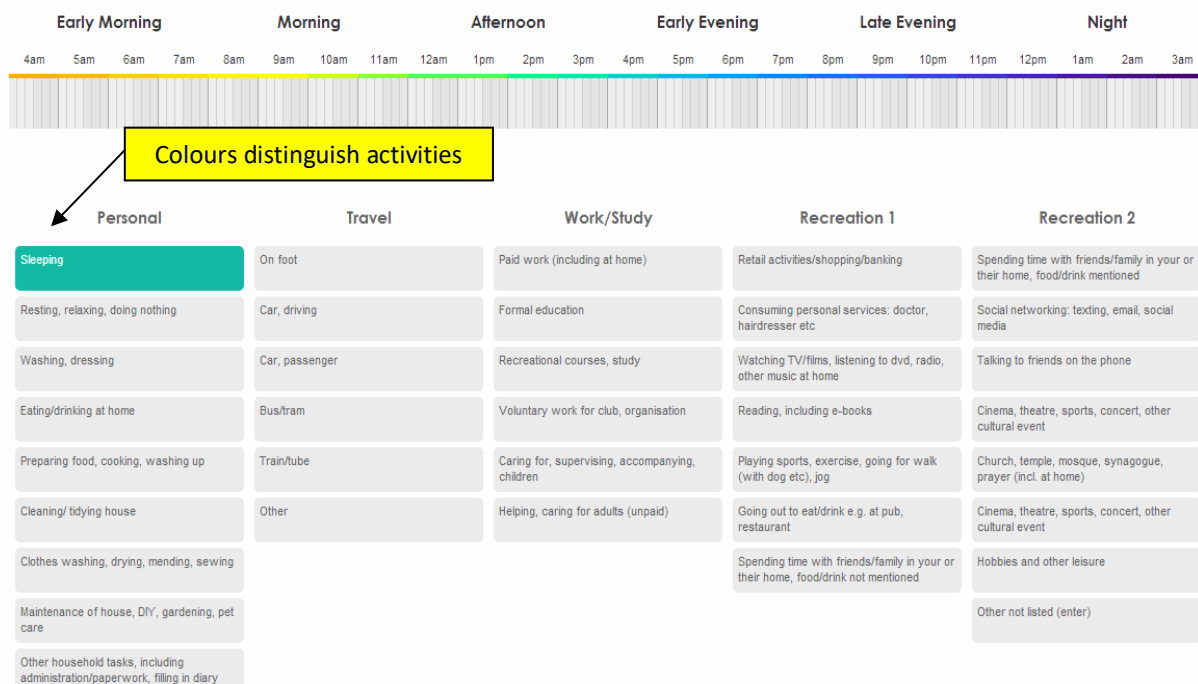
Figure 8: Clicking on the start time of the first selected activity (CaDDI)
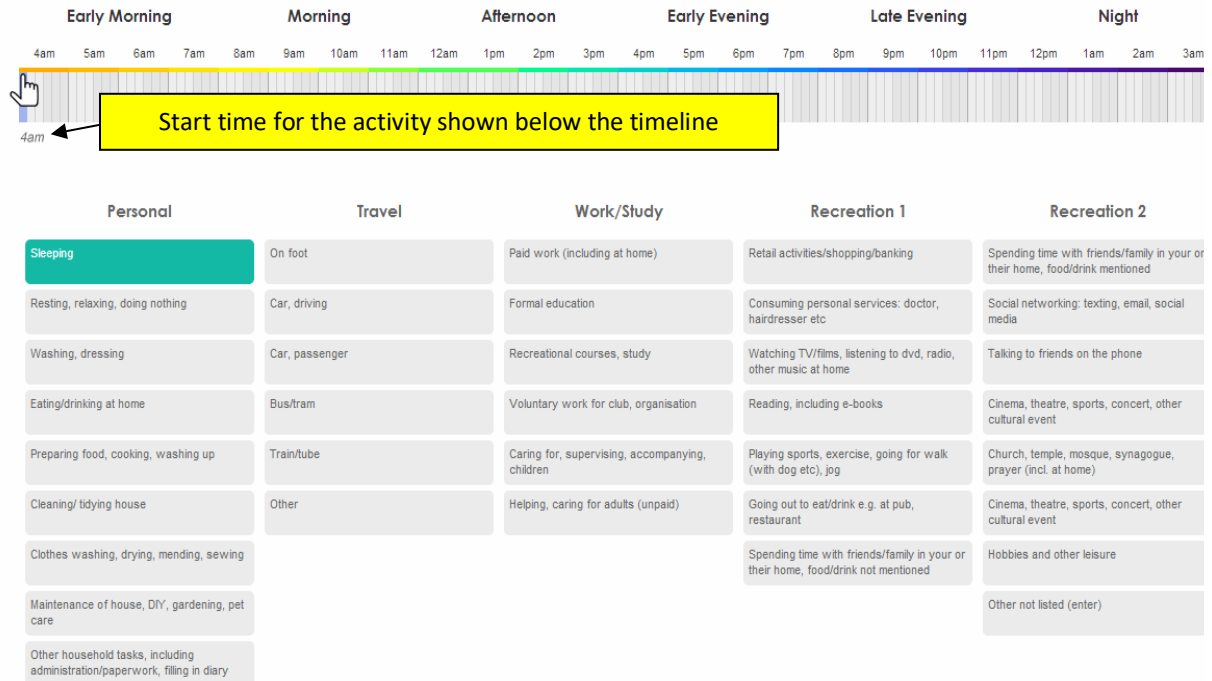
Figure 9: Dragging the cursor along the timeline to the finish time of the first activity (CaDDI)
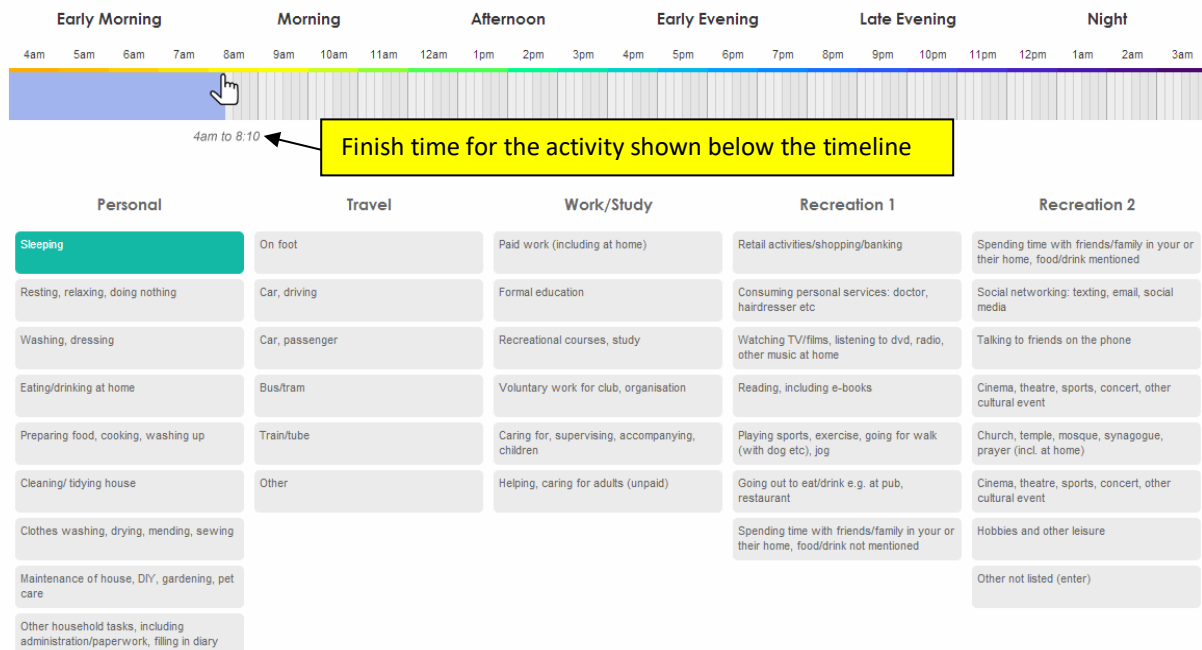
Figure 10: The respondent continues selecting and drag-dropping activities along the timeline (CaDDI)
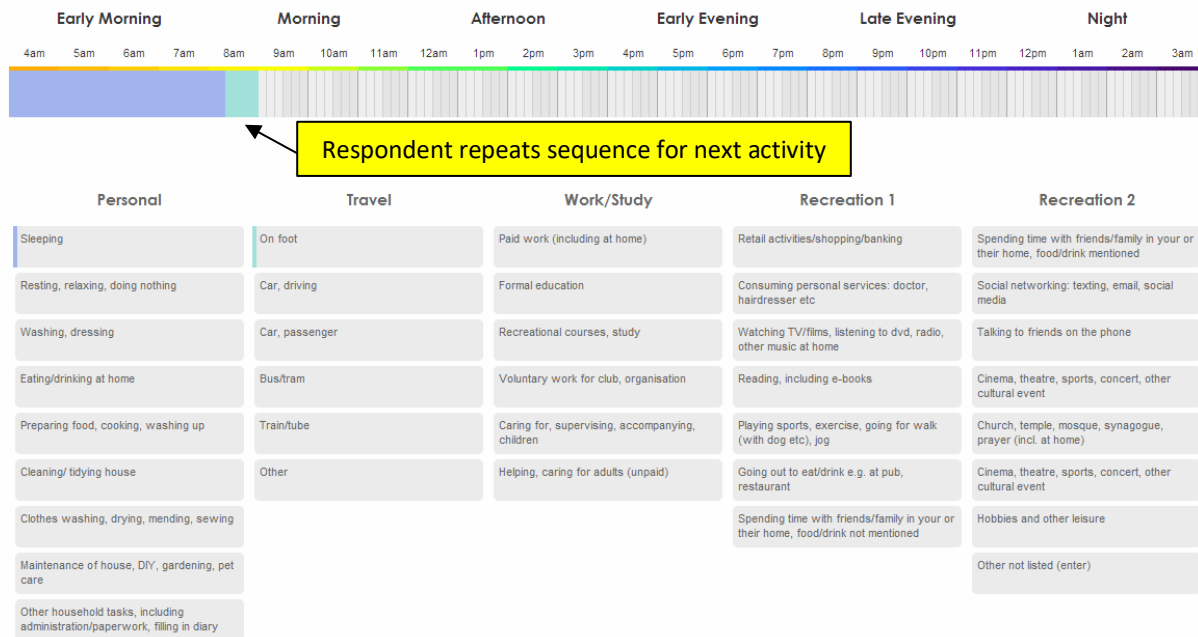
Figure 11: Completed main activity timeline (CaDDI)
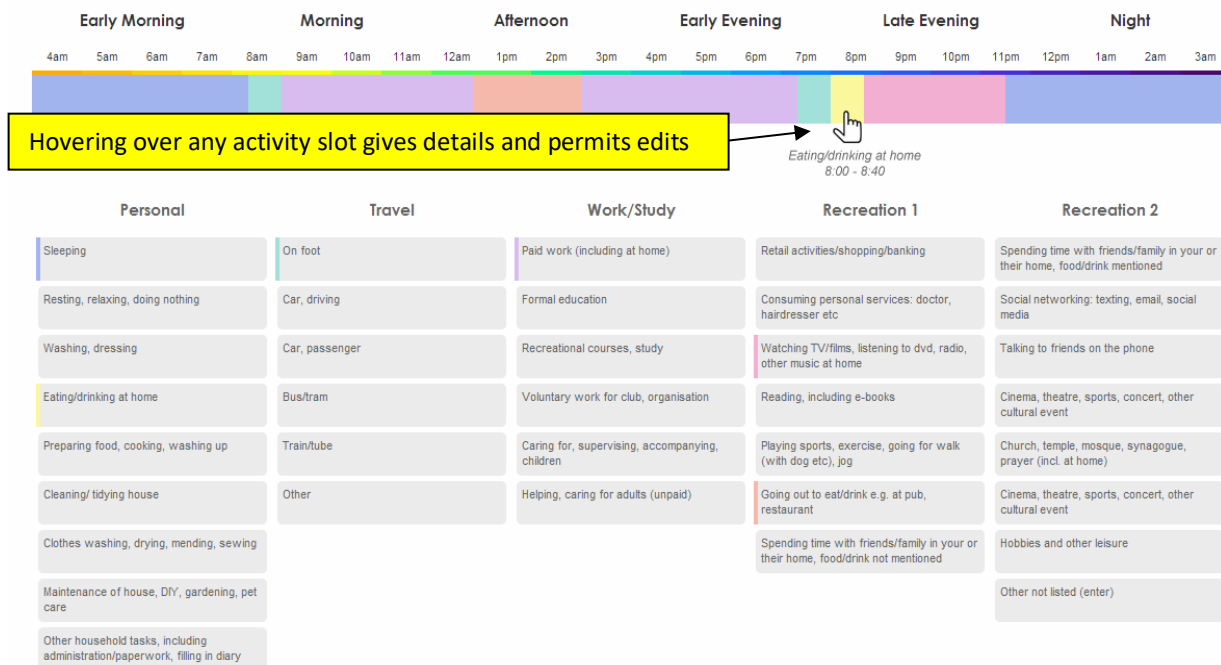
Figure 12: **A**dditional diary fields (e.g. 'who with', 'location') (CaDDI)

Figure 13: Completion of the final, enjoyment, field (CaDDI)

3.1 The online Click-and-drag diary instrument (CaDDI): some methodological observations

Analysis of the 9-Country diary data illustrates a couple of methodological points relevant to the design of an online or smartphone app diary instrument that were referred to briefly in the section above on design issues. These are:

- Independent timings for diary fields
- 'Affect' data recorded continuously throughout the day

Independent timings for diary fields

Following the methodology used in life-course analysis for longitudinal data where there are multiple fields of evidence, 'episodes' are conventionally defined as periods during which all fields remain unchanged. In contrast to some other diaries (such as those used in the ATUS and MOTUS) in which the start and finish times of the main activity serves to structure the timing of the other diary fields, the click-and-drag instrument facilitates the independent timing of each of the diary fields. When a change occurs in any one field, a new episode starts. A single main activity period may therefore form part of several episodes, during which a different secondary activity might be done, or the 'who with' field might change. Main activities can have different lengths to secondary activities, enjoyment levels can vary where the main activity is unchanged, telephones devices can be used during just part of a main or secondary activity, and so on. This flexibility not only better reflects our lived experience of time, it also accords with the accepted convention for life-course data, from which analytic techniques are directly transposable (e.g. multichannel sequence analysis; Gauthier et al 2010).

From the 9-Country Study data we can show that this difference has important implications for analysis. If, for example, we take only the duration of the main activity as defining an episode in the 9-Country Study data we find an average of 13.9[2] episodes across the survey, with some national variation—Italian respondents with average of 15.4, US respondents with an average of 12.6. But following the convention of defining episodes as periods of time in which *no* field of the diary changes, the overall mean count of daily diary episodes rises from 13.9 to 16.3 (again with USA respondents -15.0 episodes per day- at the bottom, and Italian respondents- 18.7 episodes per day- at the top).

The independence of the timing of fields has important substantive consequences. Certain activities are particularly prone to being recorded as secondary, such as snacking or watching TV. The 'using a device' field may well also feature as a secondary activity accompanying a non-screen main activity. Therefore, where episodes are defined according only to main activities this will have one of two consequences: *either* the secondary activity is recorded as lasting the duration of the main activity (e.g. a snack eaten for only 15 minutes at work is recorded as lasting the full 5-hour work episode); *or* the secondary activity is simply omitted (e.g. using a smartphone for 5 minutes is not considered worth recording during a 30-minute period where the main activity is

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[2] Excluding those 12% of diaries with fewer than 4 episodes, and/or no record of a main and secondary activity done simultaneously (an *ad hoc* definition of 'bad diaries'), the mean overall number of episodes rises to 17.5.

eating). There is no way of knowing which of these options might be adopted by respondents, and in both cases the diary record will be inaccurate, in the first case over-estimating the time spent snacking, in the second under-estimating the use of mobile devices.

Continuous recording of 'affect' fields

It has become popular to collect information on affect (either positive or negative) through the 'experience sampling method' (e.g. the 'Day Reconstruction Method' – Kahneman et al. 2004). But the continuous recording of affect fields in time use diaries, which was pioneered by Robinson for the 1985 U.S. Time Use Survey (Robinson and Godbey, 1997), has advantages from an analytic perspective. For example, it permits standardisation of enjoyment scores at the level of the individual diarist, in order to mitigate individual and cultural differences in reporting standards (we can 'normalise' each diarist's responses to produce a daily individual mean enjoyment of zero, with a standard deviation of 1). It also permits the modelling of duration effects in relation to affect. For example, in analysis of the 9-Country Study data, we were able to provide support, across certain activities, for the fundamental economic postulate of diminishing marginal utility. So, for example in the case of sleep, a positive coefficient for enjoyment across activity duration coupled with a negative duration-squared term combine to produce downward-turning modelled marginal utility curves. The enjoyment curve for sleeping across activity duration reaches its maximum level at a very plausible seven and a half hours (450 minute) duration, and turns downwards thereafter (see Gershuny, 2012).

Acknowledgements

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